UNIVERSITY OF CALIFORNIA, SAN DIEGO

Ixpantepec Nieves Mixtec Word Prosody

A dissertation submitted in partial satisfaction of the
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in

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by

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The dissertation of Lucien Serapio Carroll is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Co-Chair

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DEDICATION

To the people of Ixpantepec Nieves and Familia Indígena Unida.

EPIGRAPH

"El pueblo y partido de Icpactepec,
de la cercanía del dicho obispado [Tlacotepec],
… hablan los naturales dél la dicha lengua misteca y mexicana."
(The town and district of Ixpantepec,
nearby said diocese [Tlacotepec],
… the people from there speak the Mixtec and Mexica languages.)
—*El distrito y pueblos que tiene el obispado de Tlaxcala, con otras cosas*
(Pérez de Andrade c. 1572/1904:20)

"El pueblo de Ycpatepec
esta dos leguas de Çilacaioapa,
… es tierra fragosa y lengua misteca."
(The town of Ixpantepec
is two leagues from Silacayoapan,
… the terrain is rough and the language is Mixtec.)
—*Relaciones geográficas de la Diócesis de Tlaxcala*
(Aznar c. 1580/1905:238)

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ACKNOWLEDGEMENTS

How can I adequately thank all the people who have made this work possible? As my involvement with Mixtec research has a short history, and my own struggles with writing have quite a long history, this dissertation depends on the work and influence of many others. This dissertation owes its existence not only to those who have assisted me in the dissertation itself, but also to those who developed the collaboration between the Mixtec community and the academic community in San Diego, as well as to those who have guided and encouraged me in my development as an academic and as a linguist.

First of all, I am grateful to my Mixtec tutors— Florencia Camacena, Moisés Ortiz, Otilio Osorio, Matilde Castillo and Felicita Osorio—, who spent long hours trying to teach me to hear and understand the language and answering my many questions. Without their patient instruction and encouragement, I could never have even begun to hear the subtler phonological contrasts of Mixtec, much less produce them, however poorly I do so. The data preparation has been a collaborative effort, as each of my tutors has helped me in different ways. From all of my teachers I learned vocabulary and important phrases, and with all of them, I practiced hearing and pronouncing tones. Maestra Florencia taught me many new words and phrases and was always ready with a pop comprehension quiz, and she told me much about how things in Nieves were when she was young. Maestro Moisés taught me new words and phrases and gave insight into language use. Maestro Otilio not only taught me about vocabulary and tones, but about speaker variation, speech styles and traditional stories. His intuitions about phonological contrasts and language structure were particularly valuable. Besides teaching me vocabulary and phrases, Maestra Matilde was especially patient with teaching me to hear the tone contrasts, and she excelled at translating between Mixtec and Spanish. Finally, Maestra Felicita taught me new vocabulary and phrases and the tone changes in noun phrases. I am also indebted to the Mixtec community in San Diego, especially Familia Indígena Unida, who have welcomed me and provided social context for my learning about the language and culture. I especially wish to thank Valentina Torres, who provided essential advice and assistance,

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Finally, I owe thanks and apologies to my friends and family who put up with me at my worst. Besides friends already mentioned, this also includes Dan, Zoe, Leslie, Hope, Bethany, Gwen, Ryan, Alex, Lisa, Francis, and (especially) Rebecca. And of course my siblings, Mom and Dad, and Angie. Thanks for understanding or—when not understanding—tolerating me!

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ABSTRACT OF THE DISSERTATION

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This dissertation presents a phonological description and acoustic analysis of the word prosody of Ixpantepec Nieves Mixtec, which involves both a complex tone system and a default stress system. The analysis of Nieves Mixtec word prosody is complicated by a close association between morphological structure and prosodic structure, and by the interactions between word prosody and phonation type, which has both contrastive and non-contrastive roles in the phonology. I contextualize these systems within the phonology of Nieves Mixtec as a whole, within the literature on other Mixtec varieties, and within the literature on cross-linguistic prosodic typology.

The literature on prosodic typology indicates that stress is necessarily defined ab-

stractly, as structured prominence realized differently in each language. Descriptions of stress in other Mixtec varieties widely report default stress on the initial syllable of the canonical bimoraic root, though some descriptions suggest final stress or mobile stress. I first present phonological evidence—from distributional restrictions, phonological processes, and loanword adaptation—that Nieves Mixtec word prosody does involve a stress system, based on trochaic feet aligned to the root. I then present an acoustic study comparing stressed syllables to unstressed syllables, for ten potential acoustic correlates of stress. The results indicate that the acoustic correlates of stress in Nieves Mixtec include segmental duration, intensity and periodicity.

Building on analyses of other Mixtec tone systems, I show that the distribution of tone and the tone processes in Nieves Mixtec support an analysis in which morae may bear H, M or L tone, where M tone is underlyingly unspecified, and each morpheme may sponsor a final +H or +L floating tone. Bimoraic roots thus host up to two linked tones and one floating tone, while monomoraic clitics host just one linked tone and one floating tone, and tonal morphemes are limited to a single floating tone. I then present three studies describing the acoustic realization of tone and comparing the realization of tone in different prosodic types. The findings of these studies include a strong directional asymmetry in tonal coarticulation, increased duration at the word or phrase boundary, phonation differences among the tone categories, and F0 differences between the glottalization categories.

Chapter 1

Introduction

1.1 Aims

This dissertation provides a description and analysis of the word prosody of Ixpantepec Nieves Mixtec. We focus on word prosody in order to advance our understanding of typological issues in Nieves Mixtec. But like any work of this length, this dissertation aims to fulfill multiple goals.

One basic goal is simply to provide a first description of Nieves Mixtec phonology. The only published study to address any aspect of Nieves Mixtec phonology is the dialectological survey of Josserand (1983), which included Nieves as one of 130 Mixtec varieties.[1] The survey data from Nieves Mixtec consists only of a word list, and the analysis only deals with the diachronic development of the segmental inventory. By filling in the shortage of basic phonological description of Nieves Mixtec, this dissertation is intended to provide a stepping stone for further descriptive study of the phonology and

[1] I refer to particular Mixtec topolects as "varieties" because the granularity of a "language" is hard to define in the context of a large dialect continuum like Mixtec. In addition, since the regional and social variation in Mixtec is still poorly documented, especially in the Mixteca Baja region, I also hesitate to use "dialect" for particular Mixtec varieties. The designation of "dialect" still implies a delimited speech community, which in general is not established, as variation within municipalities (*municipios*) and between neighborhoods within towns (*pueblos*) is reported by speakers but poorly documented. Finally, because of the popular usage of "dialecto" (dialect) to refer pejoratively to any language with limited contemporary writing traditions, Mixtec speakers prefer to call the topolects "variantes" (variants/varieties) of Mixtec rather than "dialectos" of Mixtec. I adopt this usage here, except when specifically referring to ISO "language" categories.

morphosyntax of the language, as well as to assist applied work in literacy development, language maintenance, and documentation of the Mixtec cultural heritage.

A second goal is to contextualize the prosodic properties of Nieves Mixtec within the literature on other Mixtec varieties. Mixtec people self-identify as a single ethnic group, but Mixtec languages constitute a large dialect continuum, with so much variation among the regional varieties that classification based on surveys of mutual intelligibility estimate about 50 distinct Mixtec languages (Egland 1978; Lewis, Simons, & Fennig 2013). Some description of the tone systems is available for many of these varieties, including extensive description and analysis for a few varieties (e.g. R. M. Alexander 1980; Tranel 1996; Daly & Hyman 2007; McKendry 2013). Similarly, the descriptions of many varieties mention stress, and for a few varieties, the descriptions include some of the phonological and/or phonetic properties of stress (e.g. Pankratz & Pike 1967; Gerfen 1999; McKendry 2013). Contextualizing the description of Nieves Mixtec word prosody within the literature on other Mixtec varieties both enhances our understanding of Nieves Mixtec and contributes to our understanding of the commonalities and variation within Mixtec.

Finally, a third goal is to contextualize the prosody of Nieves Mixtec within the cross-linguistic literature on word prosodic typology. Mixtec languages are generally described as having both complex lexical tone systems and word-level stress (e.g. Hunter & Pike 1963; Pankratz & Pike 1967; E. V. Pike & Oram 1976; McKendry 2013), and the typological variation and acoustic properties of such languages are only beginning to be explored (Remijsen & van Heuven 2005; Pearce 2006). Studies in many other languages, including some languages of Mexico (Chávez-Peón 2008; Guion, Amith, Doty, & Shport 2010; DiCanio 2012b; Caballero & Carroll 2015), have identified distinct acoustic correlates of stress and tone. There are only a few acoustic studies of any Mixtec variety (Meacham 1991; Gerfen 1996; Gerfen & Baker 2005; Herrera Zendejas 2009; McKendry 2013; DiCanio, Amith, & García 2014; DiCanio, Zhang, Amith, Castillo García, & Whalen submitted), most of which address stress or tone but not their interaction. Moreover, though many descriptions of Mixtec mention stress, evidence is sparsely available regarding possible reanalysis of the described phenomena as effects of morphological domains, prosodic boundaries, or tone configurations. The description provided here takes advantage of previous work in prosodic typology in order to illuminate these issues and provide typologically relevant evidence.

1.2 Genetic affiliation

Mixtec languages belong to the Otomanguean stock, a very large language family spanning Meso-America. Figure 1.1 shows the genetic relationships within Otomanguean (L. Campbell 1997:158). Mixtec is grouped with Triqui and Cuicatec in the Mixtecan family, which belongs to the Eastern Otomanguean branch, along with Amuzgo, Zapotecan and Popolocan families.

Mixtec is a dialect continuum, in which distant varieties generally have low mutual intelligibility but neighboring varieties might or might not have high mutual intelligibility, depending on patterns of migration within the Mixtec region. A map of the Mixtec region is shown in Figure 1.2, with each shaded circle corresponding to one of the ISO languages. The geographic location on the scale of the whole Mixtec region is an approximate indicator of dialect relatedness, comparable to the clusterings based on mutual intelligibility (Egland 1978:25) and linguistic features (Josserand 1983:470), to the extent that these two are compatible. Mixtec varieties are distributed across the western end of the Mexican state of Oaxaca and adjacent corners of the states of Guerrero and Puebla. They are traditionally divided among three regions—Alta (Highland), Baja (Lowland), and Costa (Coastal)—while Kaufman (2006) groups them into a different three "language areas"—Northern, Central, and Southern—and Josserand (1983) groups the Mixtec varieties into a dozen "dialect areas" based on structural similarities. In the map in Figure 1.2, one representative variety from each dialect area is labeled.

The traditional divisions of the Mixtec region—Alta, Baja, and Costa—are also indicated in the map in Figure 1.2. Note, however, that these are primarily geographical designations, and they poorly reflect similarities and differences in phonological systems.

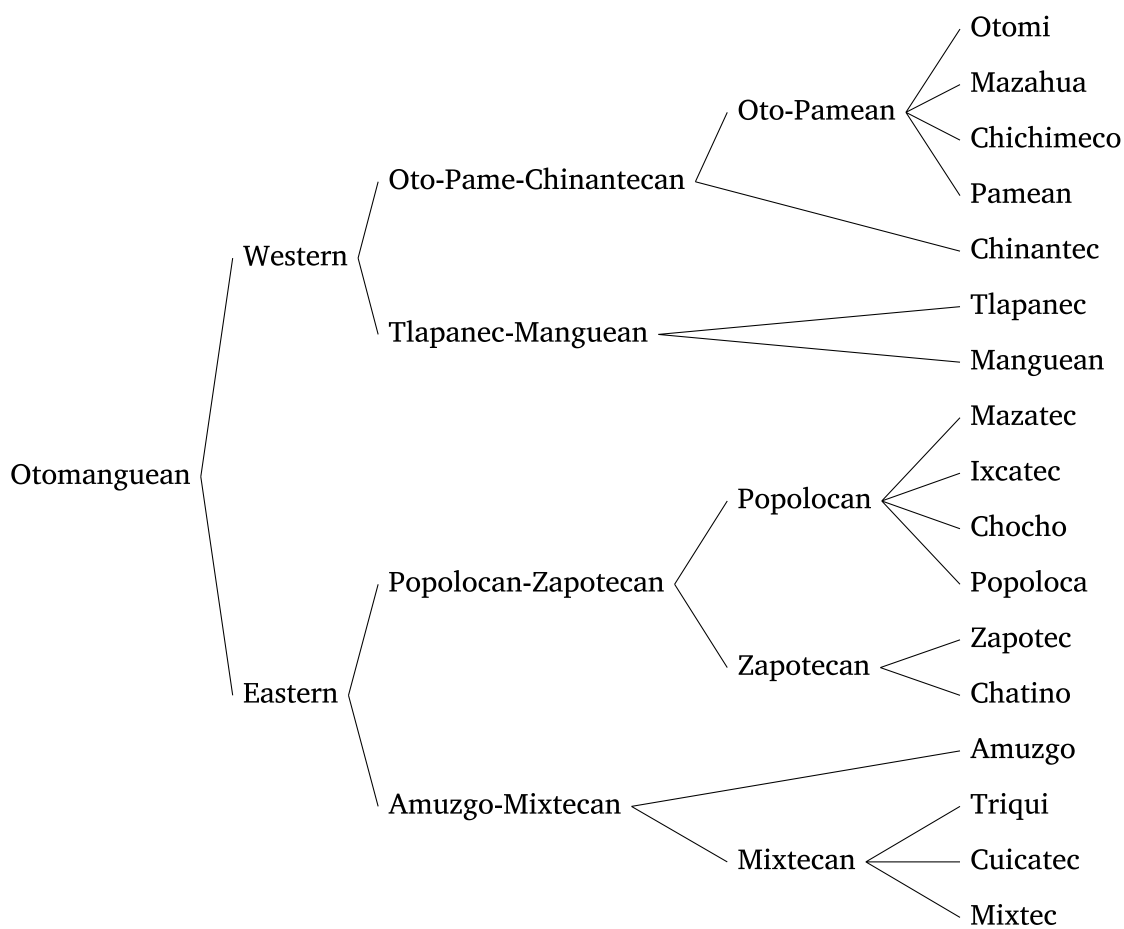


Figure 1.1: The Otomanguean stock, in families according to L. Campbell (1997)

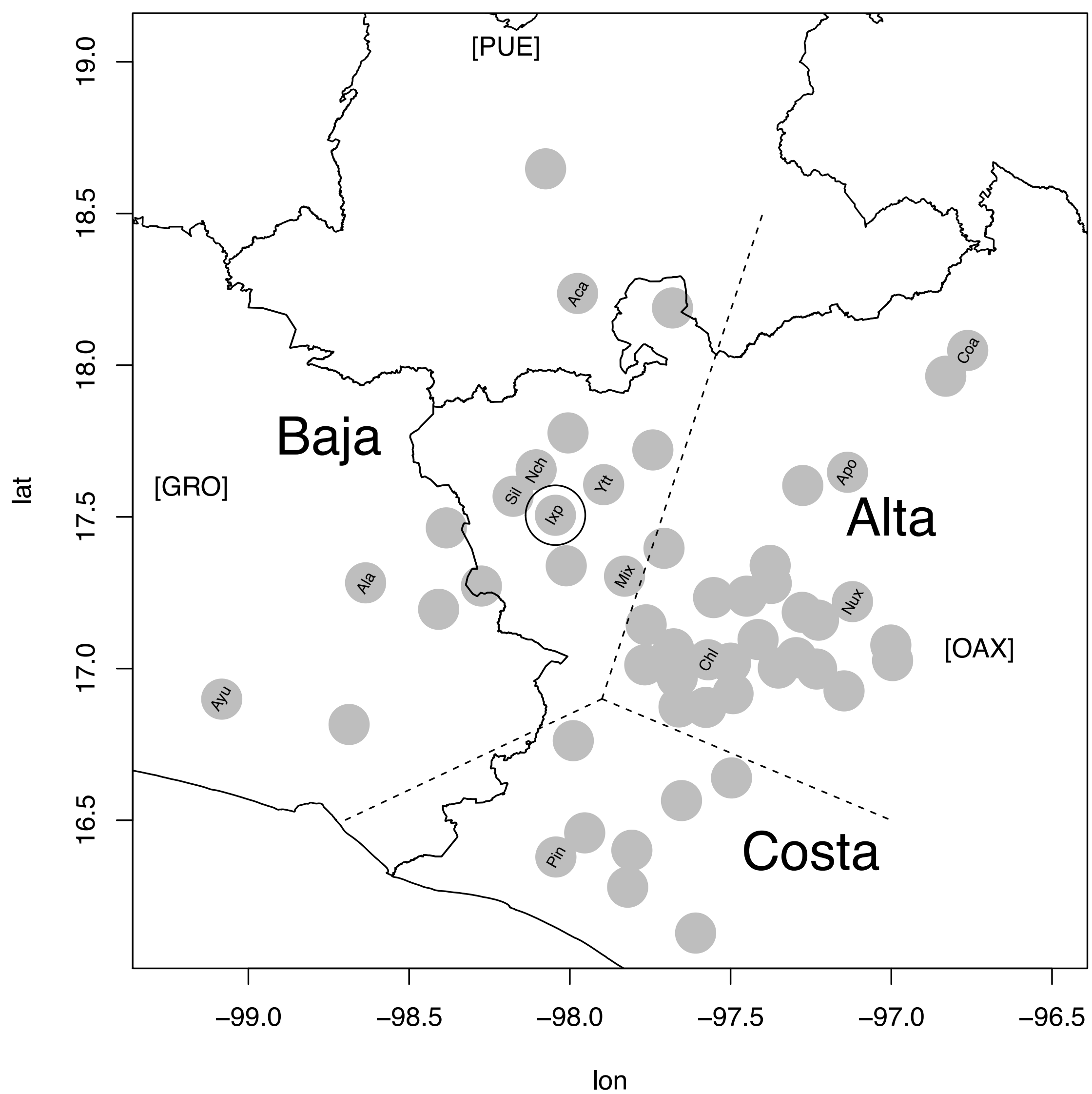


Figure 1.2: The location of Ixpantepec Nieves (IXP) and of other Mixtec varieties. Except for Ixpantepec Nieves and San Jorge Nuchita (NCH), each gray circle represents the central location of one ISO language.

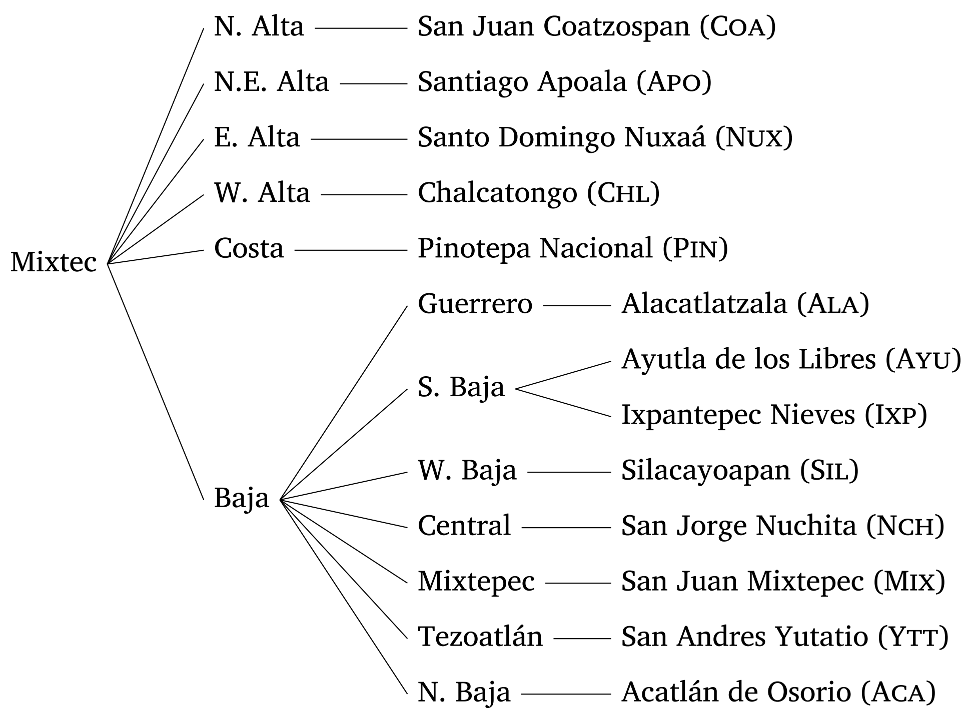


Figure 1.3: Mixtec dialect groups, showing selected varieties (Josserand 1983:470)

According to the comparative study performed by Josserand (1983), the Costa varieties do share phonological and lexical features, but the Baja region is set apart primarily by lexical innovations rather than phonological properties, and neither lexical nor phonological properties align with the Alta region as a whole. For comparison between the geographical locations and the clustering based on linguistic features, the varieties highlighted in the map are shown in Figure 1.3 within the dialect groups proposed by Josserand (1983:470). This dialect grouping is not entirely compatible with the dialect clusterings based on mutual intelligibility that form the basis of the ISO language categories for Mixtec, especially in the region around Ixpantepec Nieves. The mutual intelligibility survey that formed the basis of the ISO language codes in Mexico (Egland 1978) indicated a dialect grouping approximately co-extensive with the district of Silacayoapam, which contains the municipality of Ixpantepec Nieves. This dialect grouping is realized as Silacayoapan Mixtec (mks) in the ISO language categories (Lewis et al. 2013). However, Josserand (1983) found significant structural differences within this region, and the dialect areas she suggested place the towns of Silacayoapam district within three separate groups. The ISO category of Silacayoapan Mixtec (mks) includes some varieties from the Southern Baja dialect area, including Ixpantepec Nieves, as well as all the varieties of Western Baja and some of the varieties of Central Baja. Because of our focus on Ixpantepec Nieves and because Josserand (1983) divides Silacayoapam varieties across three dialect groups, I treat them as three separate categories. For other varieties, I depend on ISO categories but use abbreviations that are more mnemonic, approximating the abbreviations used by Josserand (1983). Appendix A provides a table showing correspondences between the abbreviations used in this work and the abbreviations used by Josserand and the ISO standard.

1.3 Previous documentation

Little previous research has described the Mixtec of Ixpantepec Nieves, but a few studies have addressed some aspects. The dialectological survey of Josserand (1983) includes Nieves Mixtec as one of 130 Mixtec varieties. The primary data consists only of word lists, and the analysis deals primarily with segmental phonology. Lexical differences are only briefly discussed, and the tones are not transcribed. Other aspects of Nieves Mixtec that have been addressed include narrative structure (Villas-Boas 2010) and relative clauses (Caponigro, Torrence, & Cisneros 2013). In addition, Perry (2009) interviewed people in Nieves as part of an ethnographic study of language shift. More broadly within Silacayoapam district, there are a few other towns included in the dialectological survey (Josserand 1983), and for one town, San Jerónimo Progreso, there is a phonological sketch (North & Shields 1977), an analysis of referent tracking in discourse (North 1987) and a syntactic sketch (Shields 1988). There is also a literacy primer that includes some short stories (North & Morales B. 2011).

On the other hand, there is much work describing other Mixtec varieties. Phonological descriptive work in some form is available for about a dozen Mixtec varieties. Aspects of these descriptions relevant to the stress system of Nieves Mixtec are reviewed in §4.2 and aspects relevant to the tone system are reviewed in §6.4. However, there are only a few phonetic and acoustic studies of any Mixtec variety. The acoustic studies that are relevant to Mixtec stress are reviewed in §5.1 and those that are relevant to Mixtec tone are reviewed in §7.1. Syntactic descriptions are also available for about a dozen Mixtec varieties. The syntax of Nieves Mixtec is beyond the scope of this dissertation, and I refer the interested reader to the syntactic descriptions of structurally similar varieties—those of Silacayoapan (SIL, Shields 1988), San Andrés Yutatio (YTT, Williams 2007), and Chalcatongo (CHL, Macaulay 1996).

1.4 Sociolinguistic status

The total number of speakers of all Mixtec languages is almost half a million in Mexico (INEGI 2010), with an additional estimated 50,000–100,000 Mixtec speakers in California (Kresge 2007). A multi-generational pattern of migration out of the Mixteca region has led to the establishment of transnational communities, with a third of Mixtecos living in diaspora communities in northern Mexico and the United States (Velasco Ortiz 2005), while still maintaining close ties to their heritage communities. In these diaspora communities as well as in the Mixtec homelands, Mixtec people are increasingly interacting with speakers of other varieties as well as generally shifting away from Mixtec language use (Cornelius et al 2009).

Within the district of Silacayoapam, Ixpantepec Nieves is the strongest holdout of Mixtec language use, with reportedly 76% of the 1100 residents over the age of 5 able to speak the language, whereas the percentage of Mixtec speakers is lower in the other municipalities of Silacayoapam (CDI-PNUD 2010). In Ixpantepec Nieves, a few of the oldest speakers are monolingual in Mixtec and many adults both there and in diaspora communities are bilingual in Mixtec and Spanish or trilingual adding English. However, Mixtec is used little in educational or community events and language use is contracting. With few exceptions, the youth have ceased to use the language. In addition, speakers report that changing cultural practices have interrupted the transmission of associated

Table 1.1: Language consultants

Name	Initials
Florencia Camacena	FC
Moisés Ortiz	MO
Otilio Osorio	OO
Matilde Castillo	MC
Felicita Osorio	FO

genres of discourse. These changing cultural practices include migrant farmwork instead of subsistence farming, buying tortillas instead of making them together in the home, and buying manufactured clothing rather than making them within the community. Mastery of these genres is now only found among the oldest generation. Speakers are also well aware of phonological and lexical differences between the language as spoken by the generation of bilingual adults and the language as spoken by the monolingual elders. Many native words have been replaced by new loanwords in the speech of the bilingual generation, and as discussed in §4.5, new loanwords show less segmental and prosodic adaptation than the more conventional loanwords found in the speech of the elders.

1.5 Data collection and presentation

The data presented in this dissertation was recorded in San Diego, California, as part of a larger collaboration and exchange with the Mixtec community in San Diego, via the organization Familia Indígena Unida. Some of the data presented here was elicited and recorded as part of field methods classes at UCSD in 2012 and 2013, some of it prior to my involvement. The remainder of the data was recorded in one-on-one tutoring sessions between September 2012 and October 2014, either on campus at UCSD or in office space provided by the community center where Familia Indígena Unida runs their programs.

The names of language consultants who tutored me are shown in Table 1.1. All consultants requested to be acknowledged by name. They were all born in Ixpantepec Nieves and spent their childhood there, but their histories of migration differ considerably. One consultant (MO) has lived his whole life in Nieves, and he was visiting San Diego during the time our sessions were recorded. At the other end of the spectrum, one consultant (MC) has lived in San Diego for over 20 years, since her early 20s. All consultants speak both Mixtec and Spanish. The oldest speaker (FC) has Mixtec language dominance, while the other speakers have approximately balanced native fluency in Mixtec and Spanish, and some of them (e.g. OO) have basic proficiency in English.

Throughout the dissertation, data is presented with three transcription tiers plus morpheme glosses and a translation, as in (1.1).

(1.1)	tóo tóo	ndáka̲ tu̲’un ún
	[to˥(ˈto˥o˧)	(ˌ^{n}da˥ka˨)(ˈtṵ̃˩ũ˧)]
	/tóo–tóo	´\\$^{n}$dàkà–tù^{ʔ}u$_{n}$ = ú$_{n}$/
	moment–moment	IPFV\REP:request–word = 2S.FAM
	‘you are constantly asking questions’	

<OO MIN0892>

The first tier reflects the practical orthography endorsed by the Academy of the Mixtec Language (Ve’e Tu’un Savi). Tones are marked according to their lexical surface form, with high tone marked with an acute accent (<á>) and low tone marked with an underscore (<a̲>). Mid tones and floating tones are unmarked. The second tier represents broad phonetic transcription, reflecting some post-lexical phonological processes in addition to any processes of the lexical phonology. Tones are indicated using iconic Chao tone letters (Chao 1930), ranging from a high target ([˥]) to a low target ([˩]). Glottalization and nasalization are marked for each segment. The third tier represents the underlying morphophonemic form. High and low tones are indicated with the conventional acute (/á/ high) and grave (/à/ low) accents, with mid tones left unmarked. Glottalization is marked once per morpheme as a superscript on the initial vowel, and nasalization is indicated per morpheme, either implicitly by the presence of nasal consonants or else explicitly by a subscript <n>. The fourth tier shows the corresponding morpheme glosses. A full table of gloss abbreviations is provided in Appendix B. Finally, for multi-morphemic utterances as in (1.1), a translation is provided, followed by a data citation code, which indicates the speaker (OO) and the audio file (MIN0892). Data citation codes are also provided when variation is discussed.

1.6 Overview

The remainder of the dissertation is organized as follows. Chapter 2 provides a cross-linguistic summary of the literature on word prosody. I discuss the core concepts of stress and tone systems, and how these systems may interact phonologically. Then I review studies of the acoustic correlates of stress and tone categories in other languages. In chapter 3, I describe the basic phonological properties of Ixpantepec Nieves Mixtec, apart from prosody. I describe the phoneme inventory, phonotactics, and phonological properties of morphemes. Chapter 4 provides a phonological description of the stress system. I review descriptions of stress in other Mixtec varieties, and then I show that distributional restrictions and a few phonological processes in Nieves Mixtec support my proposal of fixed stress on the first syllable of the canonical bimoraic root. Finally, I describe prosodic patterns in loanword adaptation, which support basing the analysis of stress on metrical structure, specifically on moraic trochees. In chapter 5, I present an acoustic study of stress, comparing the acoustic properties of stressed syllables to those of pre-tonic and post-tonic syllables. The findings indicate that the acoustic correlates of stress include the segmental durations and vowel height primarily, and properties of the intensity spectrum secondarily. Chapter 6 provides a phonological description of the tone system. First, I describe the inventory of tone patterns, some tone processes in content words, and some tone processes in functional morphemes. Then I review descriptions of tone in a few other Mixtec varieties and compare these to the tone system of Nieves Mixtec. In Chapter 7, I present three acoustic studies of tone, comparing the realization of tone in stems of different phonological classes. Tone realization in disyllabic stems is contrasted with that of monosyllabic stems, and tone realization in plain stems is contrasted with that of glottalized stems. Finally, Chapter 8 summarizes the dissertation and outlines directions of future research.

Chapter 2

Word prosodic typology

2.1 Introduction

This chapter provides a cross-linguistic review of literature that characterizes the phonological and phonetic typology of word prosody, which substantiates the assumptions made in this dissertation. The phonological typology of word prosody is addressed in section §2.2, focusing on stress and tone as phonological systems and their interaction. Section §2.3 provides an overview of the literature on the acoustic correlates of stress and tone categories.

2.2 Defining stress and tone

In this dissertation, our primary concern is prosodic phenomena within the domain of the phonological word, in particular the systems of stress and tone. A preliminary requirement in such an investigation is a careful elaboration of what is meant by the terms *stress* and *tone*. Since we are focused on the word domain, both *stress* and *tone* are used without modification here to refer to properties of word prosodic systems. But these concepts extend into phrasal prosody, so when necessary I will refer to *word* stress and *lexical* tone to distinguish them from the properties of phrasal prosodic systems. Both terms are defined in relation to the prosodic systems, and prosodic systems more readily lend themselves to comparison to prototypes rather than to categorical definitions (Hyman 2009), though defining criteria are nonetheless helpful.

2.2.1 Stress systems

A *stress language* may be defined as:

(2.1) a. "a language with word-level metrical structure, e.g. English" (Hyman 2009: 215), or

b. one in which prominence is obligatory ("every lexical word has *at least* one syllable marked for the highest degree of prominence") and cumulative ("*at most* one syllable" is thus marked) (Hyman 2006:213).

To illustrate the prototype suggested in (2.1a), the role of lexical stress in English is exemplified by the different stress patterns found in nouns and verbs, which include noun-verb pairs such as those in (2.2, 2.3).

	a.	b.	c.
(2.2)	permit [ˈpɚmɪt] 'authorization'	attribute [ˈʔætɹəˌbjut] 'property'	interchanges [ˈʔɪntɚˌʧeɪnʤəz)] 'junctions'
(2.3)	permit [pɚˈmɪt] 'allow'	attribute [əˈtɹɪbjut] 'ascribe'	interchanges [ˌʔɪntɚˈʧeɪnʤəz] 'swaps around'

In each of these pairs, the single primary stress (ˈ) falls on the initial syllable in the nouns (2.2) and on a later syllable in the verbs (2.3). In addition, (2.2b) differs from (2.3b) in that (2.2b) has one syllable with secondary stress (ˌ), having less prominence than the primary stress syllable but more than the unstressed syllable, while (2.3b) has no syllable with secondary stress. In the contrast between (2.2c) and (2.3c), the first and third syllables in both words bear stress, and they differ in the sequencing of secondary stress before or after primary stress.

First, the definitions in (2.1) are notable in that neither restricts the phonetic realization of stress. Attempts to identify a cross-linguistic phonetic definition of stress, as reviewed in §2.3, have found an assortment of acoustic measures that are each associated with stress in some languages, but none of which are associated with stress in all stress systems studied. Instead, each language that displays a stress system does so by a confluence of phonological and phonetic factors suggesting structured syllable prominence. Second, both definitions assume theoretical machinery that is closely associated with stress: either metrical structure (Liberman & Prince 1977), that is, the organization of syllables into feet and feet into larger domains, or a scale of syllable prominence (Prince 1983). These concepts are integrated in the later versions of metrical stress theory (e.g. Hayes 1995) which use bracketed grids, such as those shown in (2.4).

```
(2.4)  a.                               b. ( .          X   )
          (X              . )              (X       . ) (X   )
          (X  . )  (X     . )              (X   . ) (X) (X  . )
          ˈin ter ˌchan ges                ˌfra ter ˌni ˈza tion
```

The paired parentheses indicate groupings of syllables into prosodic domains such as feet and phonological words, while the columns of ‘X’s indicate relative syllable prominence, both in general across the word and—in the cases of an ‘X’ and a period on the same row—direct dominance within a domain. At each level, within each domain, just one syllable is promoted to prominence at that level, and that syllable is said to be the *head* of that domain. Each stressed syllable is at minimum the head of a foot, and the primary stressed syllable is the head of the word. The prominence projects up from the syllable, in that only syllables bearing prominence at one level are eligible for prominence at the next higher level.

2.2.2 Tone systems

In contrast, a *tone language* may be defined as:

(2.5) a. “a language with word-level pitch features, e.g. Mandarin” (Hyman 2009: 215), or

b. a language “in which an indication of pitch enters into the lexical realization of at least some morphemes” (Hyman 2001:1368).

To elaborate on the suggested prototype of Mandarin tone, consider the words in (2.6, 2.7), with phonetic transcriptions[1] according to how they are pronounced in Beijing Standard Mandarin phrase-finally (Xu 1997).

(2.6)	a. 妈 [ma˥] /má/ 'mother'	b. 麻 [ma˧˥] /mǎ/ 'hemp'	c. 马 [ma˨˩˦] /mà/ 'horse'	d. 骂 [ma˥˩] /mâ/ 'scold'

(2.7)	a. 八 [pa˥] /pá/ 'eight'	b. 拔 [pa˧˥] /pǎ/ 'pull'	c. 把 [pa˨˩˦] /pà/ 'hold'	d. 爸 [pa˥˩] /pâ/ 'father'

As indicated, the four words in (2.6) minimally contrast in tone only, and so do the four words in (2.7).

The tonal contrast is specified in the underlying form of each word, and the contrast is realized primarily by differences in pitch contour. But as discussed below in §2.3, the realization of Mandarin tones is not limited to differences in pitch contour (Xu 1997; van Santen & Shih 2000). Unlike the stress minimal pairs in English, which depend on having multiple syllables to support the contrast between more prominent versus less prominent syllables, the tonal contrast in Mandarin can be realized on single syllables. However, in natural Mandarin speech, the perception of tone category on a particular syllable is still strongly influenced by the tone and prominence of neighboring syllables (Xu 1994; Kochanski, Shih, & Jing 2003).

The hedge in (2.5b) that tone must be relevant for "at least some morphemes" but not all, is important even for a prototypical tone language like Beijing Standard Mandarin. In Beijing Standard Mandarin, some morphemes are not lexically specified for tone, and they acquire their pitch from phonological default assignment and phonetic processes (Y. Chen & Xu 2006). Examples of this sort are shown in (2.8).

[1] The phonetic transcriptions of tone use iconic Chao tone letters (Chao 1930), which provide an abstraction of the pitch contour joined to a staff for scale. The phonemic tone marks used here and following are the standard IPA diacritics: /á/ high tone, /ā/ mid tone, /à/ low tone, /ǎ/ rising tone, and /â/ falling tone.

(2.8)	a. 妈妈	b. 爸爸	c. 八吗	d. 骂吧
	[ma˥ma˧]	[pa˥˩ba˩]	[pa˥ma˧]	[ma˥˩ba˩]
	/má–ma/	/pâ–pa/	/pá = ma/	/mâ = pa/
	mom–RED	dad–RED	eight = Q	scold = DUB
	‘mother’	‘father’	‘eight?’	‘go on, scold’

As a consequence of the lexicalized reduplication in the kinship terms in (2.8a–b), the second syllables of these words have default tone (Packard 1998)—a short tone distinct from the four lexical tones, with pitch heavily dependent on the previous tone. Mandarin reduplicated words tend to have default tone on their second element, and among reduplicated kinship terms the generalization is exceptionless. The final clitics in (2.8c–d) have default tones because they are grammatical particles (Chao 1968:795). In many analyses of Mandarin prosody (e.g. Packard 1998; Duanmu 1999), these morphemes have default tones because they are unstressed.

2.2.3 Stress and tone contrasted

An illuminating comparison between tone systems and stress systems is provided by Hyman (2009:216):

(2.9)
a. Form: Stress is necessarily structural, as stress is the result of labeling strong versus weak elements within a hierarchy of prosodic domains, while tone is necessarily featural, since tones are phonemic values, more comparable to segmental features.

b. Function: Stress necessarily aids in parsing word units, as there is exactly one primary stress per word, while tone prototypically differentiates between lexical items.

c. System: Stress is necessarily syntagmatic, since stress is defined relative to surrounding structure, while tone is primarily paradigmatic, as tone is defined relative to a set of alternatives.

d. Bearer: Stress is necessarily borne by syllables, while the tone-bearing unit (TBU) is prototypically the mora.

e. Level: Stress is necessarily a property of the output level of the lexical phonology, and might or might not be found in underlying representations of a particular language, while tone is prototypically a property of both underlying representations and surface forms.

f. Domain: Stress is obligatory in the domain of the phonological word, while tone is prototypically found on each morpheme, though it may be more restricted.

In other words, besides the defining criteria of obligatoriness and cumulativity from (2.1b), there are several other necessary phonological properties of a stress system. On the other hand, the comparable phonological properties for tone systems are merely prototypical, with the exception of (2.9a) featural form. This notably contrasts with the situation for phonetic properties (§2.3), where tone systems are necessarily realized via pitch, but stress systems have a set of merely prototypical phonetic effects.

Stress and tone are thus logically independent, since the stress system has no necessary phonetic correlate that would conflict with the pitch specification of tone, and the paradigmatic featural specification of tone does not conflict with syntagmatic stress. Similarly, the absence of one system in a language does not imply the presence or absence of the other (see Table 2.1, adapted from Hyman (2006)). Just as there are toneless stress languages like English (or Turkish or Finnish) and stressless tone languages (like Yoruba or Skou), there are languages with both stress and tone systems like Mandarin (or Maˈya or Swedish), and languages with no apparent stress or tone systems (like Bella Coola or French).[2]

[2]Hyman (2006) provides more examples of each category, but for some of these languages, there is disagreement in the literature about the categorization, particularly for the [–tone, –stress] category. For example, French has phrase-final lengthening that is sometimes described in terms of metrical structure and stress (Banel & Bacri 1994). Hyman also places Bengali and Tamazight in the [–tone, –stress] category, but both Bengali (ud Dowla Khan 2014) and Tamazight (Faizi 2001) have been described as having word-level metrical structure.

Table 2.1: Co-occurrence of stress and tone systems (Hyman 2006:237)

	+stress	–stress
+tone	Maˈya, Swedish	Yoruba, Skou
–tone	Turkish, Finnish	Bella Coola, French

2.2.4 Phonological interaction of stress and tone

Though stress systems and tone systems are logically independent, they can be phonologically dependent, such that one system partially or fully determines the surface form of the other system. As discussed in depth in §4.2, previous studies of Mixtec languages have described different phonological dependencies between stress and tone systems, such as stress shift due to tone configuration (e.g. Ayutla Mixtec (Pankratz & Pike 1967)) and a larger tonal inventory licensed on stressed syllables (Yoloxochitl Mixtec (DiCanio et al. 2014)).

Among languages with both stress and tone systems, there is a wide variety of interaction phenomena. Some of these phenomena reported in the literature (e.g. de Lacy 2002; J. Zhang 2002; Pearce 2006; Hyman 2006) are listed in (2.10–2.12).

(2.10) Stress-sensitive tone

a. Association of tone to heads, e.g. Chizigula (Kenstowicz & Kisseberth 1990) and Lamba (L. S. Bickmore 1995)

b. Tonal deletion on non-heads, e.g. Shanghai Wu Chinese (Duanmu 1999)

c. Tonal contrast reduction on non-heads, e.g. Wuyi Wu Chinese (Fu 1984)

In Chizigula (Kenstowicz & Kisseberth 1990), a high tone surfaces on the stressed penultimate syllable of a word if any morpheme in the word is specified for high tone. In Lamba (L. S. Bickmore 1995), the first stressable morpheme and every other syllable up to the beginning of the root is stressed. If any morpheme in the word is specified for high tone, all the stressed syllables bear high tone. In Shanghai Wu Chinese (Duanmu 1999), all morphemes are mono-syllabic and have a lexical tone specification. The initial syllable of the word is stressed, and only the tone of that morpheme is realized. All non-initial syllables lose their underlying tones, and the tone of the initial syllable spreads over the word. In Wuyi Wu Chinese (Fu 1984; J. Zhang 2007), all morphemes are similarly monosyllabic and have a lexical tone specification, but the final syllable of the word is stressed. An inventory of six tonal contours is supported in word-final plain (i.e. non-glottalized) syllables, but these are replaced with two level tones (high and low) in non-final plain syllables.

(2.11) Foot-sensitive tone

a. Spreading of tone within feet, e.g. Kera (Pearce 2006)

b. Association of tone patterns with certain foot types, e.g. Bole (Newman 1972)

In Kera (Pearce 2006), low tone spreads regressively from the stressed syllable to the preceding unstressed syllable, only if they are parsed into the same iambic foot.[3] In Bole (Newman 1972), disyllabic verbs that fit an iambic foot have H.H tone, but disyllabic verbs with an initial heavy syllable (involving either a trochee or a monosyllabic iamb) have L.H tone.

(2.12) Tone-sensitive stress

a. Placement of stress on the leftmost/rightmost/only high tone, e.g. Lithuanian (Blevins 1993)

b. Preference for metrical structure with footed non-head low tone, e.g. Ayutla Mixtec (Pankratz & Pike 1967)

In Lithuanian (Blevins 1993), stress falls on the first high tone syllable. If there is no lexical high tone, one is inserted on the initial syllable. In Ayutla Mixtec (Pankratz & Pike 1967; de Lacy 2002), stress is described as trochaic and conditioned by tone alone. The

[3] I refer to Kera metrical prominence as "stress" for consistency with the rest of the discussion, but Pearce (2006) specifically declines to call it "stress". Pearce argues that Kera shows phonological and acoustic evidence of word-level prosodic structure—metrical feet with a distinction between heads and non-heads within feet—, but she finds no evidence of word-level culminative prominence. Informally, Kera exhibits secondary stress but not primary stress. The Kera metrical prominence thus falls outside the definition of stress used by Pearce. However, the metrical prominence of Kera in other ways resembles a stress system, and primary stress does not have a consistent cross-linguistic phonetic correlate. Evidence of word-level stress might be revealed by further studies of Kera phrasal prosody and intonation.

stress generally prefers rightmost H tones, but it will select a H.L foot over an earlier H.H foot. (See §4.2 for further discussion.)

It is worth noting that the presence or absence of one of the interaction types in (2.10–2.12) does not imply the presence or absence of the other phenomena. Neo-Štokavian Serbo-Croatian (Zec 1999) has both tone-sensitive stress and stress-sensitive tone. In this language, input tones together with syllable weight determine foot structure and stress, and then these determine the placement of tone in the output. Kera (Pearce 2006) demonstrates both stress-sensitive tone and foot-sensitive tone, in that tones preferentially associate to heads, and low tone spreads within the foot, while high tone avoids placement or spreading onto an unstressed syllable.

Finally, it must be noted that in many of these cases, the categorization of a phenomenon as being an interaction between systems of lexical tone and word stress is highly subject to interpretation. For example, de Lacy (2002) cites Hixkaryana primary stress as an example of tone-dependent stress, but Hayes (1995) considers the described phenomena to be intonational tones and phrasal boundary effects. Similarly, the example of Shanghai Wu tone patterns (2.10b) is frequently used as an example of unstressed tone deletion and head-dominant tone spreading, especially in contrast to head-final Chinese systems like those of Wuyi Wu (2.10c), Beijing Standard Mandarin (N. Zhang 1997), or Southern Min (M. Y. Chen 1987). However, there is considerable disagreement in the literature about what prosodic domains are involved. According to the analysis of Duanmu (1990; 1993; 1999), most of the tone change effects are the result of word-level metrical structure. In his analysis, Chinese dialects with abundant tone spreading, like Shanghai Wu, only have light syllables, which leads to disyllabic feet and spreading from stressed syllables onto unstressed syllables. In contrast, dialects with minimal tone spreading, like Beijing Standard Mandarin, only have heavy syllables—except in the case of default-toned morphemes as in (2.8)—, which leads to monosyllabic feet and more tonal stability. However, Bao (2003; 2004) argues that Chinese tone processes are not based on the metrical structure of words but rather based on phrasal prosody. In his analysis, the dominance of initial or final syllables does reflect the prominence of prosodic heads, but these are heads of phrases rather than of words. A third approach is taken by J. Zhang (2002; 2007), who acknowledges that both word stress and phrasal stress may contribute asymmetries to the tonal processes, but he focuses primarily on the role of rime duration in affecting tonal stability. In his account, if word stress or phrasal prosody has any effect, it is only through its effect on duration, and boundary effects like pre-pausal final lengthening have a greater role than prominence effects.

2.3 Acoustics of stress and tone

This section provides a review of acoustic studies of stress and tone in the world's languages. The reviewed literature demonstrates that stress and tone have prototypical acoustic properties, beyond tone's necessary association with F0, and yet no single acoustic property is diagnostic of one or the other. The acoustic properties recruited to realize tone and stress are also used for other phonological categories, such as those of phrasal prosody (especially phrasal stress) and phonation type, which acts as a prosodic property in some languages (Dilley, Shattuck-Hufnagel, & Ostendorf 1996; Ní Chasaide & Gobl 2004; Garellek 2014) but is widespread as a segmental feature (Gordon & Ladefoged 2001). This thesis is focused on the word-level stress and lexical tone, but Nieves Mixtec does show evidence of phonologically contrastive glottalization (discussed in §4.4.2 and §7.5), and it is assumed here that there are some effects of phrasal prosody in Nieves Mixtec. These factors must be taken into consideration in interpreting the acoustic results.

The acoustic properties discussed in this section are: vowel duration, vowel intensity, vowel quality, consonant duration, mid-band spectral tilt, low-band spectral tilt, periodicity and fundamental frequency. The findings are summarized in Table 2.2, showing languages in which the listed acoustic properties have been found to be associated with the phonological categories of interest here. These are not all the acoustic properties that have been considered as correlates of these phonological categories, nor is this an exhaustive inventory of the languages that have been investigated. But these are the acoustic properties which are considered in the studies of stress and tone in Nieves Mixtec reported in Chapters 4 and 5, and the studies reviewed here are sufficient to demonstrate the cross-linguistic trends and exceptions. Each acoustic property is discussed in sequence, beginning with the properties that are most associated with stress and ending with the properties that are most associated with tone.

2.3.1 Vowel Duration

The most widely reported acoustic correlate of stress is vowel duration, and it was also one of the earliest acoustic correlates recognized. Fry (1955) observed that the vowel durations in British English disyllabic noun/verb stress minimal pairs, such as ˈ*permit* ‘license’ and *per*ˈ*mit* ‘allow’ or ˈ*digest* ‘compilation’ and *di*ˈ*gest* ‘absorb’, were on average longer in the stressed syllable. In addition, in synthesized tokens that were manipulated to have larger or smaller ratios between the two vowel durations, the duration ratios strongly influenced whether the token was perceived as the noun or the verb.

An association between vowel duration and stress is also reported for many other languages. These include other non-tone languages like Dutch (Sluijter & van Heuven 1996b), Spanish (Ortega-Llebaria & Prieto 2007), Greek (Arvaniti 1994), Amman Arabic (de Jong & Zawaydeh 2002), Menominee (Milligan 2005), Tongan (Garellek & White 2015), and conservative varieties of Balsas Nahuatl (Guion et al. 2010). An association between vowel duration and stress is also reported in tone languages such as Chickasaw (Gordon 2004), Raramuri (Caballero & Carroll 2015), Pirahã (Everett 1998), MaˈYa (Remijsen 2002), Curaçao Papiamentu (Remijsen & van Heuven 2005), and in one variety of Balsas Nahuatl (Oapan) that has innovated a tone system (Guion et al. 2010).

Previous work on Otomanguean languages have also found longer durations in stressed vowels. In Quiaviní Zapotec (Chávez-Peón 2008), where the stress falls on the word-final syllable, the stressed vowel—at least in syllables without a moraic ‘fortis’ coda—is more than twice as long as unstressed vowels. In Itunyoso Triqui (DiCanio 2010), where the stress is on the word-final syllable, final vowels are about 50% longer than penultimate vowels. In Coatzospan Mixtec (Gerfen 1996:200–208), where the stress in non-compound words falls on the initial syllable of the bimoraic root, the initial vowels of

Table 2.2: Acoustic properties correlated with the phonological categories of interest

Acoustic Property	Phonological System			
	Phrasal Stress	Word Stress	Tone	Phonation
Vowel Duration	English, Dutch, Nahuatl, Mixtec	English, Dutch, Greek, Spanish, Tongan, Arabic, Menominee, Nahuatl, Raramuri, Pirahã, Chickasaw, Papiamentu, Maˈya, Zapotec, Triqui, Mixtec	Mandarin, Mixtec	Hmong, Mixtec
Vowel Intensity	English, Dutch, Swedish, Spanish	Spanish, Berber, Quechua, Tongan, Pirahã, Chickasaw, Papiamentu, Mixtec, Zapotec	Mandarin, Maˈya	Mazatec
Consonant Duration	English, Dutch	Dutch, English, Raramuri, Pirahã, Greek, Triqui	Mandarin	Korean
Vowel Quality	English	English, Arabic, Maˈya, Tongan, Papiamentu	Shuijingping Hmong, Fuzhou	Western Cham
Mid-band spec tilt	English, Swedish	Dutch, Spanish, Nahuatl	Triqui	Yi, Gujarati, Mazatec, Triqui
Low-band spec tilt		Tongan, Nahuatl	Mandarin, Vietnamese, Hmong	Korean, Yi, Gujarati, Mazatec, Zapotec, Hmong, Triqui
Periodicity		Tongan	Mazatec	Mazatec, Yi, Zapotec, Hmong
Fundamental Frequency	English, Swedish, Quechua, Spanish, Berber	Nahuatl, Quechua, Menominee, Tongan, Creek, Chickasaw	Papiamentu, Maˈya, Creek, Chickasaw, Mandarin, Kyungsang Korean, Triqui, Zapotec, Gujarati, Mazatec	Korean, English, Arabic, Triqui, Western Cham

two disyllabic verbs were found to have longer duration than the final vowels. Similarly in Santo Domingo Nuxaa Mixtec (McKendry 2013:231–234), stress in non-compound words falls on the initial syllable of the bimoraic root, and the initial vowels of 11 disyllabic nouns were found to have longer duration than the final vowels, independent of vowel quality and tone. These two studies of Mixtec stress are discussed in more detail in §5.1.

Many studies of stress acoustics do not adequately distinguish word stress from phrasal stress, and in some languages nearly every syllable that bears word stress also bears phrasal stress, making the two inextricable (Garellek & White 2015). However, studies that have successfully distinguished word stress from phrasal stress have often found effects of phrasal stress on vowel duration, instead of or in addition to the word stress effect. Fry (1955; 1958) does not make clear what utterance frames were used in his production experiments, but in his perception experiments, the target words were put in utterance-final position, and in an English declarative utterances with default information structure, the last lexical word bears 'nuclear stress', the most prominent (phrasal) stress in the intonation phrase (Pierrehumbert & Hirschberg 1990). At least as early as Klatt (1976:1219), it was recognized that English vowel duration differences attributable to word stress alone were inconsistent compared to the effects of phrasal stress and phonological vowel quality reduction. Sluijter and van Heuven (1996a) measured the durations of whole syllables rather than the vowels, but their results may be considered reflective of vowel durations, as most of the variation in syllable duration in English is localized to the vowel (Klatt 1976). They found that in American English stressed syllables were about 20% longer than unstressed syllables, and both stressed and unstressed syllables in words that bore phrasal stress were about 20% longer still. In contrast, N. Campbell and Beckman (1997) found a strong interaction between the effects on duration of word stress, phrasal stress and intonation, also in American English. Among syllables that bore an intonational high boundary tone and no phrasal stress, the durations of syllables with word stress were longer than unstressed syllables, but among syllables that bore an intonational low boundary tone, no such contrast was found between unstressed syllables and syllables bearing word stress. Furthermore, in words that bore phrasal stress, the stressed syllables had even longer durations, while unstressed syllables did not have increased duration. Also in American English, Cho and Keating (2009) compared syllables bearing primary word stress with syllables bearing secondary stress and found that vowels under primary word stress had only slightly (c. 5%) longer duration than vowels bearing secondary stress, but under the combination of primary stress and phrasal stress, the vowel duration was considerably longer (c. 15%) than the secondary stressed vowels.

Similar effects of phrase stress are reported for a few other languages. For Dutch as in English, Sluijter and van Heuven (1996b) found independent effects of word stress and phrase stress on duration, though the effects of word stress were between 20% and 50% depending on condition, while the effects of phrasal stress were much smaller. In Balsas Nahuatl (Guion et al. 2010), two conservative dialects that do not have tone contrasts were found to have longer vowel durations in stressed vowels than in unstressed vowels. However, an interaction was found between the effect of stress and the effect of position in the utterance, suggesting that phrasal prosody plays a key role. In both dialects, the duration difference due to stress was statistically significant in utterance-final position but not in utterance-medial position. On the other hand, no effect of utterance position was found in two other dialects that have innovated a tone system. In one tone-innovating dialect, no effect on duration due to either stress or position was found. In the other tone-innovating dialect, stressed vowels had longer duration than unstressed vowels independent of position, and no statistically significant effect was found for position in the utterance. In Santo Domingo Nuxaá Mixtec (McKendry 2013:234–247), the stressed (initial) vowel of a simple disyllabic noun was found to have longer duration than the post-tonic (second) vowel in three different focus conditions, but the duration difference was small when there was contrastive focus on the verb. This study is discussed in detail in §5.1.

Furthermore, vowel length is known to be affected by many other factors, including phonation and tone.[4] In White Hmong, creaky voice vowels have shorter duration

[4] Extending "phonation type" to the contrast between voiced and unvoiced, the phonation of neighboring segments can be relevant. In English, vowels have longer duration when the following consonant is voiced, especially phrase-finally (Klatt 1976; de Jong 2004).

and shorter duration vowels have a higher probably of being identified with the creaky tone category (Garellek, Keating, Esposito, & Kreiman 2013). Similarly in Coatzospan Mixtec (Gerfen & Baker 2005), creaky voice vowels tend to have shorter duration than modal voice vowels. In Mandarin, vowels that bear rising and dipping contour tones have longer duration than vowels that bear level and falling tones (van Santen & Shih 2000). Similar relationships between vowel duration and tone contour are reported for Yoloxochitl Mixtec (DiCanio, Amith, & Castillo Garcia 2012), where longer vowel durations are found with particularly complex tone contours.

2.3.2 Vowel Intensity

From the earliest discussions of the phonetics of stress (e.g. Sweet 1890:44), stress was associated with the perception of loudness, which was attributed to the amplitude of the sound wave. And in fact, many studies have found an association between stress and intensity, which is the mean (RMS) amplitude of the sound wave. Fry (1955) observed that vowel intensity, like duration, was greater in the stressed syllables of English stress minimal pairs, though the intensity differences between stressed and unstressed vowels were not as consistent as the differences found for duration. In addition, manipulation of intensity in recorded tokens did shift hearers' perception of the token as a noun or a verb, but the effect was weaker than the effect found for duration. An association between stress and intensity is also reported for Spanish (Ortega-Llebaria & Prieto 2007), Quechua (Hintz 2006), Pirahã (Everett 1998), Chickasaw (Gordon 2004), Berber (Gordon & Nafi 2012) and Curaçao Papiamentu (Remijsen & van Heuven 2005).

A couple of previous acoustic studies of Otomanguean languages have also found a correlation between vowel intensity and stress. In Quiaviní Zapotec (Chávez-Peón 2008), the intensity of stressed modal vowels was found to be greater than pre-tonic modal vowels, though no statistically significant difference was found for breathy vowels.[5] In Santo

[5] The experimental design might have contributed to the lack of an effect among breathy vowels. Among modal vowels, the stressed and unstressed vowels were in the same words, so the utterance contexts were closely matched. For the breathy vowels, the unstressed vowels were in different words and utterances than the stressed vowels.

Domingo Nuxaá Mixtec (McKendry 2013), the intensity of stressed vowels was found to be greater than the post-tonic vowels, independent of vowel quality and tone.

Studies that have distinguished between word stress and phrasal stress have often found that vowel intensity is more associated with phrasal stress than with word stress. In American English (Sluijter & van Heuven 1996a), increase in intensity due to stress is statistically significant, but the increase due to stress alone is small (1–3 dB). Both unstressed and stressed syllables had increased intensity under focus, with stressed syllables increasing more. Similarly, Cho and Keating (2009) found that in trisyllabic nonce words with either primary or secondary stress on the initial syllable, primary stress alone (without phrasal stress) did not increase intensity beyond the level found for syllables bearing secondary stress in words without phrasal stress. But in words that do bear phrasal stress, syllables bearing the main stress of the word had considerably higher intensity than secondary stress syllables, even while the intensity of secondary stress syllables also increased. In Dutch (Sluijter & van Heuven 1996b), the intensity difference between stressed and unstressed vowels was mostly limited to the focused condition. There was almost no intensity difference when not under focus, while the combination of word stress and contrastive focus resulted in a large increase in intensity.

A few studies have found intensity to be associated with other phonological categories, including tone and phonation. In Maˈya (Remijsen 2002), higher tones tend to have higher intensity. In Mandarin (Jongman, Yue, Moore, & Sereno 2006), the falling tone has the highest intensity and the low dipping tone has the lowest intensity. In Santo Domingo Nuxaá Mixtec (McKendry 2013), higher tones have somewhat higher intensity than lower tones, though the trend was not found to be statistically significant. Non-modal phonation typically has lower intensity than modal phonation (Gordon & Ladefoged 2001). In Mazatec (Keating, Esposito, Garellek, ud Dowla Khan, & Kuang 2011), intensity (called “energy” there) is associated with a vowel phonation contrast. In Coatzospan Mixtec (Gerfen & Baker 2005), a descent in intensity is associated with creaky vowels.

2.3.3 Consonant Duration

Fry (1955) did not find statistically significant differences in consonant duration associated with stress, but later studies in English have found small but reliable lengthening of the durations of onsets[6] in stressed syllables (e.g. Oller 1973; Greenberg et al. 2003; Cho & Keating 2009). Cho and Keating (2009) considered the durations of /t/ and /n/ in initial position of nonce words, and found that the closure durations of both consonants were on average longer in primary stressed syllables than in secondary stressed syllables. A similar study in Dutch (Cho & McQueen 2005) considered the durations of /t/, /d/, /s/ and /z/ in the initial position of real names and found that the durations of all four consonants were longer in stressed position than in unstressed position. In Greek (Arvaniti 1994), the durations of onsets in two stress minimal triplets showed lengthening in syllables bearing primary stress. In Pirahã (Everett 1998), the durations of onsets in two stress near-minimal pairs showed lengthening in stressed syllables. In Raramuri (Caballero & Carroll 2015), the durations of onsets in five stress near-minimal pairs showed lengthening in stressed syllables. Finally, in Itunyoso Triqui (DiCanio 2010), consonant durations in a large sample of words showed longer onset durations in stressed syllables than in pre-tonic syllables. However, consonant duration is often more strongly influenced by phrasal prosody, especially by proximity to a phrasal boundary but also by phrasal stress. These effects are particularly well documented in English (Keating, Cho, Fougeron, & Hsu 2003; Cho & Keating 2009), but have also been shown for Dutch (Cho & McQueen 2005), German (Kuzla, Cho, & Ernestus 2007), French (Fougeron 2001), Japanese (Onaka 2003) and Korean (Cho & Keating 2001).

[6] A few studies have also reported lengthening in codas in English, as well as other languages, but the reported effects are difficult to interpret. Greenberg, Carvey, Hitchcock, and Chang (2003) shows a small but reliable effect of coda lengthening in English, but the contrast there is between ‘heavy’ stress and ’none’, conflating word stress and phrasal stress. There are also reported lengthening effects of fortis consonants in Zapotec, but phonetic studies of Zapotec consonants (Chávez-Peón 2008; 2010; Arellanes 2009) do not make comparisons of consonant duration in relation to stress. van Santen and Shih (2000) show longer coda durations in Mandarin, but it is unclear what kind of stress they are assuming.

2.3.4 Vowel Quality

Phonological interactions between vowel quality and stress are well known, either as sonority-driven stress or stress-based vowel reduction (Kenstowicz 1996; Crosswhite 2000). The phonological interactions themselves produce correlations between vowel quality and stress, and comparable phonetic effects are also known. Unstressed vowels have been found to be more centralized in English (Lindblom 1963; Cho & Keating 2009), Dutch (van Bergem 1993), and Curaçao Papiamentu (Remijsen & van Heuven 2005). In Bulgarian (Pettersson & Wood 1987; Wood & Pettersson 1988), non-high vowels are raised in unstressed positions, while high vowels are not substantially affected. In Amman Arabic (de Jong & Zawaydeh 2002), for the one vowel quality /a/ examined, unstressed vowels had a lower first formant (F1), consistent with either raising or centralization of unstressed vowels. Similarly in Maˈya (Remijsen 2002), the one vowel quality /a/ considered was found to have lower F1 in unstressed than stressed position, consistent with either raising or centralization of unstressed vowels.

However, vowel quality effects are also found associated with phrasal stress, tone and phonation. In both English (Cho & Keating 2009) and Dutch (van Bergem 1993) the vowel qualities are more peripheral in syllables that bear phrase stress compared to syllables that have word stress but not phrase stress. In Standard Mandarin (Tsay & Sawusch 1994; Hoole & Hu 2004), non-front vowels show a gradient association between higher tone and less front vowel qualities. In Fuzhou (Tsay & Sawusch 1994; Jiang-King 1995), vowels undergo a categorical vowel quality raising conditioned by a tone raising process. In Shuijingping Hmong (Mortensen 2006), tone processes raise the vowel quality of one tone class and lower the vowel quality of another tone class. And in Cham, a register contrast based primarily on phonation type is associated with small vowel height differences (Edmondson & Gregerson 1993; Brunelle 2009a)

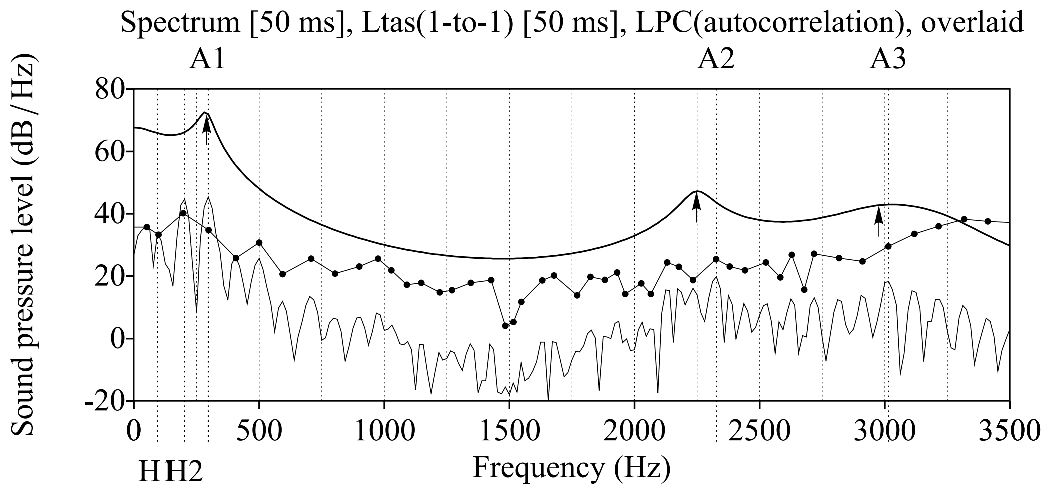


Figure 2.1: Vowel spectrum of [i], showing the first two harmonics (H1, H2) and the harmonics closest to F1, F2 and F3 (A1, A2 and A3, respectively). The spectra shown are the LPC (top), the estimated glottal source spectrum (middle) and the LTAS (bottom).

2.3.5 Mid-band Spectral Tilt

As raw intensity was found to be an unreliable acoustic correlate of the perceived loudness of a vowel, other measures more consistently associated with perceived loudness were sought. It was found that the acoustic spectrum around the vowel formants (between 500 Hz and 5000 Hz) do have increased intensity in effortful speech, while overall intensity is more affected by the energy at lower frequencies (Glave & Rietveld 1975). Perceptions of loudness in speech are also more influenced by the mid-range frequencies. On that basis, Sluijter and van Heuven (1996b) proposed several acoustic measures of mid-range intensity normalized against the intensity of the fundamental frequency (F0), such as H1-A2, the decrease in amplitude from the first harmonic (H1)—equivalent to F0—and A2, which is the harmonic closest to the second formant (F2). A sample vowel spectrum with labeled formants and harmonics is shown in Figure 2.1. These measures are called spectral tilts because they are based on the slope of the decrease in amplitude between particular harmonics. Sluijter and van Heuven (1996b) show that these measures are better associated with stress in Dutch, while overall intensity is associated with phrasal stress. Similar results were found for American English (Sluijter & van Heuven 1996a). However, N. Campbell and Beckman (1997) have contrary findings in American English. They find that spectral tilt is associated with nuclear stress (i.e. phrasal stress), and that spectral tilt does not distinguish unstressed syllables from syllables that bear word stress but not phrase stress. The difference in results might be due to differences in the unstressed syllables. Sluijter and van Heuven (1996a) used mono-morphemic words that had fully unstressed syllables, but in order to prevent vowel reduction (vowel quality centralization), the "unstressed" syllables in the N. Campbell and Beckman (1997) study bear secondary stress, as initial members in hyphenated surnames: ˌBadd-ˈEllis, ˌBeede-ˈEllis, ˌBoode-ˈEllis. An association between mid-band spectral tilt and word stress has also been reported in Balsas Nahuatl (Guion et al. 2010) and Spanish (Ortega-Llebaria & Prieto 2007).

One drawback of spectral tilt measures is that the amplitudes of the harmonics are heavily influenced by the filtering effect of the oral (and nasal) cavity resonances. Each vowel formant raises the amplitudes of harmonics near the formant frequency and reduces the amplitudes of harmonics further away from the formant frequency (Iseli & Alwan 2004). As a result, measured spectral tilts are sensitive to changes in vowel quality, especially for high vowels. The inverse filtering function to remove the filtering effect of the vowel formants can be calculated (Iseli & Alwan 2004; Iseli, Shue, & Alwan 2007), but the correction calculation is itself highly sensitive to errors in identifying formant frequencies. The segmented line in Figure 2.1 represents the approximated glottal spectrum, along which "corrected" spectral tilt measures are found.[7]

However, spectral tilt effects are not limited to word stress nor to stress more generally. An association between mid-band spectral tilt and phrasal stress has been reported in English (N. Campbell & Beckman 1997) and Swedish (Heldner 2003). Spectral tilt differences associated with vowel phonation contrasts are reported in Yi, Gujarati and

[7] Corrected spectral tilt measures are conventionally marked with an asterisk (e.g. H1*-A2*) or a subscript "c" (e.g. $H1_c$-$A2_c$) to distinguish them from uncorrected measures. All the spectral tilt measures used in this thesis are corrected, so there is no need to distinguish between corrected and uncorrected measures.

Mazatec (Keating et al. 2011), in language-particular interactions with tone. In Itunyoso Triqui (DiCanio 2012a), lower H1-A3 spectral tilt values are associated with higher tones, and tones with coda breathy phonation have a rising-falling H1-A3 contour.

2.3.6 Low-band Spectral Tilt

The amplitude difference between the first two harmonics (H1-H2) is linked to open quotient (OQ), the portion of the glottal cycle in which the glottis is open (Klatt & Klatt 1990; Henrich, d'Allesandro, & Doval 2001). The acoustic parameter H1-H2 is a widely reported correlate of phonation type, such as in Kyungsang Korean (Kenstowicz & Park 2006), Yi (Keating et al. 2011; Kuang 2013), Gujarati (Esposito 2010a; Keating et al. 2011), Mazatec (Garellek & Keating 2011; Keating et al. 2011), White Hmong (Keating et al. 2011; Garellek et al. 2013), Quiaviní Zapotec (Chávez-Peón 2010), and Itunyoso Triqui (DiCanio 2012a). Since in many tone languages, phonation type is a secondary marker of tone category, H1-H2 is also widely reported as an acoustic correlate of tone category. Examples include Mandarin (Lee 2009; Kuang 2013), Itunyoso Triqui (DiCanio 2012a), Vietnamese (Brunelle 2009b), White Hmong (Garellek et al. 2013), Black Miao (Kuang 2013), and Green Mong (Andruski & Ratliff 2000; Andruski 2006). But H1-H2 is also reported as a correlate of stress in some languages. Such languages include Tongan (Garellek & White 2015) and Balsas Nahuatl (Guion et al. 2010). Guion et al. (2010) did not use corrected (inverse filtered) spectral tilt measures, so it is conceivable that the H1-H2 differences they found in Balsas Nahuatl reflect vowel quality differences rather than voice quality differences. But in the case of Tongan (Garellek & White 2015), stress-related differences were found for the corrected H1-H2 measure, which should be independent of vowel quality.

2.3.7 Periodicity

Several related acoustic measures deal with speech signal noise, where the absence of such noise is periodicity. These include: jitter, the frequency modulation of the cycle in the time domain (Wendahl 1966); shimmer, the amplitude modulation of the cycle in the time domain (Wendahl 1966); the harmonics-to-noise ratio (HNR), which treats noise as additive in the frequency domain (Boersma 1993); and cepstral peak prominence (CPP), which treats noise as additive in the domain of frequencies-of-frequencies (Heman-Ackah, Michael, & Goding 2002). These measures have most often been reported as correlates of phonation contrasts, but they have also been associated with tone and stress contrasts. Modal voice is characterized by low signal noise, so in typical modal voice, jitter and shimmer are low while HNR and CPP are high. An association between phonation type and one or more of these measures of periodicity has been reported in Yi (Keating et al. 2011; Kuang 2013), Quiavini Zapotec (Chávez-Peón 2010), White Hmong (Keating et al. 2011; Garellek et al. 2013), and Mazatec (Garellek & Keating 2011; Keating et al. 2011). In Mazatec, an interaction of tone and phonation on CPP was found. Within H tone vowels, modal voice vowels had higher CPP than breathy or laryngealized vowels, but within M tone vowels, CPP did not distinguish among phonation types, and within L tone vowels, CPP did not distinguish between modal voice and laryngealized vowels, while breathy vowels had lower CPP. Finally, CPP was found to distinguish stressed from unstressed vowels in Tongan (Garellek & White 2015).

2.3.8 Fundamental Frequency

Since fundamental frequency (F0) is the primary acoustic correlate of perceived pitch, tonal contrasts are necessarily correlated with differences in F0, though the encoding of tone as F0 can involve F0 contours on single vowels and from one vowel to the next, besides the overall F0 height. Studies of individual languages have quantified these effects in Papiamentu (Remijsen & van Heuven 2005) Maˈya (Remijsen 2002), Creek (Martin & Johnson 2002), Chickasaw (Gordon 2004), Mandarin (Xu 1997), Kyungsang Korean (Kenstowicz & Park 2006), Itunyoso Triqui (DiCanio 2012a), Quiaviní Zapotec (Chávez-Peón 2010), and Mazatec (Garellek & Keating 2011), among many others. J. A. Alexander (2010) compares the F0 heights and slopes of monosyllabic words in isolation, in languages of different tone densities: Cantonese, Mandarin, Thai, Yoruba, and Igbo. The analysis found that level tone systems were approximately optimally dispersed within the single dimension of F0 height, while contour tone systems were approximately optimally dispersed within the two dimensional space of F0 onset and F0 offset.

Correlations between F0 and phonation type are also widely reported. The close association between F0 and phonation (including consonant voicing), such as F0 differences associated with consonant voicing in English and Yoruba, and glottal stops and fricatives in Arabic, led Hombert, Ohala, and Ewan (1979) to propose that F0 differences like these are the original basis of tone systems. A correlation between F0 and phonation type has been reported in other non-tonal languages, such as Seoul Korean (Silva 2006; Cho, Jun, & Ladefoged 2002), and Cham (Edmondson & Gregerson 1993; Brunelle 2009a), as well as in other tonal languages, such as Kyungsang Korean (Kenstowicz & Park 2006) and Itunyoso Triqui (DiCanio 2012a).

High F0 and F0 movements were formerly considered a primary correlate of stress even in prototypical non-tonal stress languages like English, and such correlations between F0 and stress have been reported for a few non-tonal languages, such as Quechua (Hintz 2006), Nahuatl (Guion et al. 2010), and Tongan (Garellek & White 2015). However, when effects of word stress were distinguished from effects of phrase stress in English, it was recognized that these F0 features were intonational tones associated with phrase stress (N. Campbell & Beckman 1997). Similar F0 features of phrase stress have also been established for Spanish (Prieto, van Santen, & Hirschberg 1995; Ortega-Llebaria & Prieto 2007), Swedish (Heldner 2003), Quechua (Hintz 2006), and Berber (Gordon & Nafi 2012), among many others. But a correlation between F0 and stress can also arise via the interaction between stress and tone. In privative tone languages with tone restricted to stressed syllables, such as Creek (Martin & Johnson 2002) and Chickasaw (Gordon 2004), there is a resulting correlation between F0 and stress. Furthermore, studies in some high-density tone languages, such as Thai (Potisuk, Gandour, & Harper 1996) and Mandarin (Xu 1999; Kochanski et al. 2003), have reported a correlation between stress and expanded F0 range or more pronounced F0 movements.

2.4 Summary

This chapter surveyed the literature on word prosody, in both its phonological and acoustic properties. The literature shows that stress systems are well-defined phonologically, but the acoustic encoding of stress varies from language to language. In contrast, tone systems are less well-defined phonologically, but the acoustic encoding of tone is more consistent across languages, in that all tone systems must use fundamental frequency, by definition.

The key properties of stress systems are that each word has one syllable that is the most prominent syllable in the word. This metrical prominence may be realized acoustically via some combination of longer segmental durations, greater vowel intensity, more sonorant vowel qualities, shallower spectral tilt, greater periodicity, higher fundamental frequency, or larger frequency range, among other properties. An important complication is that many of these acoustic properties are associated with phrasal stress rather than (or in addition to) word stress. Because syllables that bear phrasal stress are a subset of syllables that bear word stress, it can be difficult—if not impossible—to distinguish these effects.

The key property of tone systems is that at least some morphemes are underlyingly specified for a contrast that is realized primarily via fundamental frequency. However, tone systems still differ in how they use fundamental frequency to encode tone contrasts and how other acoustic properties also play a role. In particular, acoustic properties typical of phonation contrasts—such as spectral tilt and periodicity—are often found to be associated with tone contrasts. In addition, tone systems may manifest many of the phonological and acoustic properties typical of stress systems.

Chapter 3

General phonology

3.1 Introduction

This chapter provides a general view of the phonology of Ixpantepec Nieves Mixtec, establishing the context for the discussion of the prosodic aspects of the language and the complex tonal processes it displays, which will be described in detail in the following chapters. As much as possible, I will postpone issues of tone and prosody to those chapters, though as will become apparent, several basic phonological properties are closely entangled with issues of prosody.

A general phonological description of Nieves Mixtec is necessary because only one previous study has described any aspects of the phonology. The dialectological survey of Josserand (1983) included Nieves as one of 130 Mixtec varieties, but the primary data consists only of word lists, and the analysis only deals with segmental phonology, and only from a diachronic perspective. Other aspects of Nieves Mixtec that have been addressed include narrative structure (Villas-Boas 2010) and relative clauses (Caponigro et al. 2013). In addition, Perry (2009) interviewed people in Nieves as part of an ethnographic study of language shift. However, none of these studies discuss the phonological structure. On the other hand, the phonologies of several closely related Mixtec varieties have been described. These include Silacayoapan (SIL) Mixtec (North & Shields 1977) and Metlatónoc (MET) Mixtec (Overholt 1961). And the pedagogical grammar of San Andrés Yutatio (YTT) Mixtec (Williams 2007) focuses on morphosyntax but includes some description of the segmental inventory and tonal processes. This chapter focuses on the segmental phonological contrasts and distributions of Nieves Mixtec, discussing other varieties only when relevant to particular analytical questions. The stress and tone systems of other Mixtec varieties are compared with those of Nieves Mixtec in Chapters 4 and 6.

The organization of this chapter is as follows. The following section (§3.2) introduces the basics of the phoneme inventory. Then, several phonotactic contraints and morphemic properties, which raise representational issues for the phoneme inventory, are dealt with in section §3.3. Finally, the morphophonology of verb roots is described in section §3.4.

3.2 Phoneme inventory

This section provides a basic description of the segmental phonology, discussing the segment inventory and major allophonic processes. The analysis is based on a corpus that contains 503 bimoraic roots. The canonical root in native vocabulary is bimoraic, either disyllabic with short vowels (CVCV) or monosyllabic with a long vowel (CVV). The initial consonant is optional, but root-initial vowel hiatus is generally broken by glottal stop epenthesis (see §3.3.2). In roots without a medial consonant, the vowels must be identical, that is, forming a long vowel.[1] No consonant clusters are permitted. There are no apparent tone-segment co-occurrence restrictions, so we will postpone discussion of tone to chapter 6, and take advantage of segmental minimal pairs to demonstrate the segmental inventory. I will describe the consonant inventory first, and then describe the vowel inventory.

[1] As discussed in §3.3.4, there are a few exceptions in glottalized morphemes.

Table 3.1: Consonants in the phonemic inventory of Nieves Mixtec

		labial	coronal			dorsal	
			apico-alveolar	lamino-alveolar	post-alveolar		labzd
voiceless	stop		t	t^{j}	tʃ	k	k^{w}
	cont		s		ʃ	x	
voiced	stop	(^{m}b)	^{n}d	^{n}d^{j}		($^{\text{ŋ}}$g)	
	cont	v	l		ʒ		
	nasal	m	n		ɲ		

3.2.1 Consonants

Table 3.1 shows the 18 consonants in the phonemic inventory of Nieves Mixtec. There are many coronal phonemes and a few of these consonants are among the most common in the lexicon. The coronals /s/, /ʒ/ and /n/ each appear in over 70 words in the sample of 503 roots. But even more common than these consonants is /k/, which appears in 118 roots in the sample. The prenasalized stops /^{m}b/ and /$^{\text{ŋ}}$g/ may be considered marginal phonemes, as they each only appear in a couple of roots in the corpus. Other underrepresented consonants are /m/, /^{n}d/, /l/, /ɲ/ and /k^{w}/, each appearing in less than 30 roots in the corpus. The contrasts along nasalization and minor coronal place are severely limited by phonotactic constraints which are described in section §3.3. Here I simply focus on the justifications for phonemic status and the phonetic properties.

There are five consonants in the voiceless plosives series: /t/, /t^{j}/, /ʧ/, /k/, and /k^{w}/. They are voiceless with some aspiration in prosodically strong positions (e.g. phrase-initially or in open-class roots, see §4.3), but they can lenite to phonetically voiced allophones (t→[d, ð], t^{j}→ [ɾ], k→[g, ɣ]) in prosodically weak positions (e.g. in clitics).[2] The place contrasts among the coronals can be demonstrated by the minimal pairs shown

[2]Comparable lenition of the other voiceless stops (/ʧ/ and /k^{w}/) has not been noted, though neither of these appear in clitics.

in (3.1–3.3).[3]

(3.1)	a.	táá [ta˥a˥] /táá/ ‘sir’	b.	tya̲a [tʲa˩a˧] /tʲàa/ ‘man’	c.	chaa [tʃa˧a˧] /tʃaa/ ‘hello’ (F)

(3.2)	a.	sata̲ [sa˧ta˩˧] /satà´/ ‘back’	b.	satya [sa˧tʲa˧] /satʲa/ ‘scratch’ (RE)	c.	tyutyu [tʲu˧tʲu˧] /tʲutʲu/ ‘paper’	d.	chuchu [tʃu˧tʃu˧] /tʃutʃu/ ‘bathe’ (RE)
(3.3)	a.	tani [tã˧nĩ˧] /tani/ ‘crumble’	b.	tyani [tʲã˧nĩ˧] /tʲani/ ‘between’	c.	tyiin [tʲĩ˧ĩ˧] /tʲii$_{n}$/ ‘grab’	d.	chíín [tʃĩ˥ĩ˥] /tʃíí$_{n}$ˋ/ ‘fingernail’

The contrast is supported in initial position as shown in (3.1, 3.3) as well as in morpheme medial position as in (3.2). The contrast is supported before oral vowels as in (3.1, 3.2) as well as before nasal vowels as in (3.3). All three coronal plosives are licensed before /a/ and /ã/, but before each of the other vowels, either /t/ or /tʲ/ is not permitted. These distributional restrictions are discussed in §3.3.5.

The contrast between /k/ and /kʷ/ is demonstrated by the minimal pairs in (3.4–3.6).

(3.4)	a.	kíi̲ [ki˦i˩] /kî/ ‘quick’	b.	kuíi̲ [kʷi˦i˩] /kʷî/ ‘green’
(3.5)	a.	ka̲chi̲ [ka˧tʃi˩˧] /kàtʃì´/ ‘guilt’	b.	kua̲chi [kʷa˩tʃi˧] /kʷàtʃi/ ‘cotton’

[3]See §1.5 for description of transcription conventions. In the phonetic transcriptions, I am marking nasal vowels with the IPA standard tilde, while in phonemic transcriptions, nasal specification is marked per morpheme, either implicitly by the presence of nasal consonants or by a subscript <n> on the last nasal vowel. Phonetic tone markings are iconic tone letters, representing idealized phonetic targets of pitch contours. Phonemic tone markings use conventional tone accents (high tone [á], low tone [à], and mid tone [ā]), except that mid tone is generally left unmarked. Glossing follows conventional use, except as noted in Appendix B.

(3.6) a. nda̱ka̱
[^{n}da˧ka˩]
/^{n}dàkà/
‘ask’

b. nda̱kua̱
[^{n}da˧k^{w}a˩]
/^{n}dàk^{w}à/
‘pus’

The contrast is supported in both root-initial position, as in (3.4, 3.5), and in root-medial position, as in (3.6). However, the syllable /k^{w}a/ in positions other than root initial (i.e. unstressed positions, as described in §4.3) can be realized in casual speech as [ko] as in (3.7), while syllables phonologically specified as /ko/ as in (3.8) do not alternate.

(3.7) a. xikua̱
[ʃi˧k^{w}a˩˨] ∼ [ʃi˧ko˩]
/ʃik^{w}à´/
‘eyebrows’
<MC MIN0296>

b. kua̱nana
[k^{w}a˩nã˧na˧] ∼ [ko˩nã˧nã˧]
/k^{w}à–nana/
MOT–go_up
‘go up’

<OO MIN0980>

(3.8) a. xíko̱
[ʃi˧ko˩] cf *[ʃi˧k^{w}a˩]
/ʃikò/
‘smell’
<MC MIN0338>

b. kojíkó na
[ko˧xi˥ko˥nã˥˩] cf *[k^{w}a˧...]
/ko–xíkó = na`/
IR–tall = 3P
‘they may be tall’

<OO MIN0344>

The offglide of /k^{w}/ is treated as a secondary articulation rather than the second member of a consonant cluster because its distribution is quite restricted. The phone [w] does not occur as an independent onset and it does not occur with any other consonant.

There are three phonemes in the voiceless fricative series: /s/, /ʃ/, /x/. The phoneme /x/ can also be realized as [h] without velar contact. The following minimal pairs in (3.9, 3.10) demonstrate the contrasts.

(3.9) a. sa̱a̱
[sa˧a˩]
/sàà/
‘arrive’

b. xa̱a
[ʃa˩a˧]
/ʃàa/
‘chin’

c. ja̱á
[xa˩a˥]
/xàá/
‘later’

(3.10)	a.	kisi [ki˧si˧] /kisi/ ‘come’	b.	kíxi [ki˥ʃi˧] /kíʃi/ ‘doing’ (IPFV)	c.	ki̲ji [ki˩xi˧] /kìxi/ ‘pot’

As shown, the contrasts are supported in both initial positions as in (3.9) and in medial positions as in (3.10). The contrasts between the fricatives and plosives in initial position are shown by comparison of (3.9) with (3.11).

(3.11)	a.	táá [ta˥a˥] /táá/ ‘sir’	b.	chaa [ʧa˧a˧] /ʧaa/ ‘hello’ (F)	c.	kaa̲ [ka˧a˩] /kaà/ ‘sit’

The contrasts in medial position are shown by comparison of (3.12) with (3.13).

(3.12)	a.	ndyita [^{n}d^{j}i˧ta˧] /^{n}d^{j}ita/ ‘stand’ (PL)	b.	ndyi̲chí [^{n}d^{j}i˩ʧi˥] /^{n}d^{j}ìʧí/ ‘greenbean’	c.	kaka [ka˧ka˧] /kaka/ ‘walk’ (IR)

(3.13)	a.	ndyi̲sa̲ [^{n}d^{j}i˧sa˩] /^{n}d^{j}ìsà/ ‘truth’	b.	ndyixi [^{n}d^{j}i˧ʃi˧] /^{n}d^{j}iʃi/ ‘liquor’	c.	kaja [ka˧xa˧] /kaxa/ ‘do’ (IR)

There are four phonemes in the prenasalized series (/^{m}b/, /^{n}d/, /^{n}d^{j}/, and /^{ŋ}g/), though /^{m}b/ and /^{ŋ}g/ are sufficiently rare that they may be considered to be marginal phonemes. Only a few words with these sounds are attested, several of which are loanwords. Among the attested words with /^{m}b/, all of which are shown in (3.14), it is found only in initial position.

(3.14)	a.	mbali ∼ mbáa̲ [^{m}ba˧li˧] ∼ [^{m}ba˥a˩] /^{m}bali/ ∼ /^{m}báà/ ‘child’s godfather’ (<Sp. compadre) <OO MIN0018>	b.	mbúrró /^{m}bu˥ro˥/ /^{m}búróˋ/ ‘donkey’ (<Sp. burro)	c.	mbó’ló [^{m}bo˥ʔlo˥] /^{m}bó^{ʔ}lóˋ/ ‘bunch’ (<Sp. boludo?)

Among the attested words with /^{ŋ}g/, shown in (3.15), it is found only in medial position.

(3.15)	a. inga	b. língá	c. nunga
	[i˧^{ŋ}ga˧]	[li˥^{ŋ}ga˥]	[nu˧^{ŋ}ga˧]
	/i^{ŋ}ga/	/lí^{ŋ}gá/	/nu^{ŋ}ga/
	'other'	'swinging'	'later'

On the other hand, the coronal prenasalized stops are quite frequent, though their distribution is restricted (see §3.3 for discussion). The minor place contrast is only supported before /a/, shown in (3.16, 3.17).

(3.16)	a. nda̱a̱	b. ndyaa
	[^{n}da˧a˩]	[^{n}d^{j}a˧a˧]
	/^{n}dàà/	/^{n}d^{j}aa/
	'straight'	'watch over'

(3.17)	a. nda'yi	b. ndya'yi̱
	[^{n}da˧ʔʒi˧]	[^{n}d^{j}a˧ʔʒi˩]
	/^{n}da^{ʔ}ʒi/	/^{n}d^{j}a^{ʔ}ʒì/
	'shout'	'mud'

The contrasts between the prenasalized stops and the voiceless stops are shown by comparison of (3.16) with (3.18) below.

(3.18)	a. táá	b. tya̱a
	[ta˥a˥]	[t^{j}a˩a˧]
	/táá/	/t^{j}àa/
	'sir'	'man'

The contrast is harder to demonstrate in medial position, because the prenasalized coronals are not particularly common there. However, near-minimal pairs involving comparable vocalic environments are available, such as /^{n}d, ^{n}d^{j}/ in (3.19) in comparison to /t, t^{j}/ in (3.20).

(3.19)	a. landyi	b. kuéndá	c. lu̱ndyu̱
	[la˧^{n}d^{j}i˧]	[k^{w}e˥^{n}da˥]	[lu˧^{n}d^{j}u˩]
	/la^{n}d^{j}i\`/	/k^{w}é^{n}dá\`/	/lù^{n}d^{j}ù/
	'navel'	'property'	'stump'

(3.20)	a. ndyatyí	b. sata̱	c. ju̱tyu̱
	[^{n}d^{j}a˧t^{j}i˧]	[sa˧ta˩]	[xu˧t^{j}u˩]
	/^{n}d^{j}at^{j}í/	/satà´/	/xùt^{j}ù/
	'wait'	'back'	'priest'

Unless there is some long-range voicing interaction between the initial and medial consonants, as there is for labial place (described in §3.3.6), the evidence indicates there is no loss of contrast in medial position. The contrast is also maintained even outside the root, where the voiceless series may surface as voiced. For example, though the voiceless stop /t/ may become voiced [d] in an enclitic as in (3.21a), it is not confusable with the prenasalized stop (3.21b).

(3.21) a. kúnákaa̱ tó
[ku˥na˥ka˧a˩do˧]
/´\ku–na–kaà = tó/
IPFV\INCH–REP–sit = 3.WD
'it (wooden) is sitting'

< OO MIN0047:3:11.7 >

b. kúnákaa̱ ndó
[ku˥na˥ka˧a˩^{n}do˧]
/´\ku–na–kaà = ^{n}dó/
IPFV\INCH–REP–sit = 2P
'you all are sitting'

The voiceless stop /tʲ/ frequently appears as a voiced tap [ɾ] in function words and enclitics, as in (3.22a), positions where /^{n}dʲ/ is also lenited somewhat as in (3.22b).

(3.22) a. ni̱ ke'en rí kua̱'an rí
[nĩ˨kḛ̃˧ḛ̃˧ɾi˥ kʷã̰˩ã̰˧ɾi˥]
/nì = keˀe$_{n}$ = tʲí kʷàˀa$_{n}$ = tʲí/
PFV = take = 3.ZO go = 3.ZO
'it (dog) took off'

< OO MIN0353:0:34.7 >

b. ke'en ndyi̱ kua̱'an ndyi̱
[kḛ̃˥ḛ̃˦^{n}dʲi˩ kʷã̰˩ã̰˨^{n}dʲi˩]
/´\keˀe$_{n}$ = ^{n}dʲì kʷàˀa$_{n}$ = ^{n}dʲì/
IPFV\take = 1P.EX go = 1P.EX
'we would set out'

< MC MIN0148:1:30. >

Even though the paired consonants in (3.22) have preceding nasal vowels and following oral vowels, the voicing of [tʲ] in (3.22a) does not lead to neutralization. The prenasalized stops are consistent in having both nasal and oral components, though the nasal component can be difficult to perceive in utterance-initial positions, and the oral portion can be quite short elsewhere.

There are three phonemes in the voiced continuant series: /v/, /l/, and /ʒ/. The /l/ is consistently an approximant while the others are usually fricatives, though /ʒ/ may be realized as a glide [j], and the otherwise labiodental /v/ may be realized as bilabial [β] or [β̞]. The words in (3.23, 3.24) show the contrasts among the voiced continuants.

(3.23)	a.	va̱a̱ [va˧a˨˩] /vàà´/ ‘below’	b.	laa [la˧a˧] /laa/ ‘bird’	c.	yaa [ʒa˧a˧] /ʒaa/ ‘music’
(3.24)	a.	válí [va˥li˥] /válí`/ ‘little’ (PL)	b.	láyí [la˥ʒi˥] /láʒí`/ ‘male’	c.	yavi̱ [ʒa˧vi˨˩] /ʒavì´/ ‘agave’

The place contrast is evidenced in both initial (3.23, 3.24) and medial position (3.24). The voicing contrast is shown by comparison of (3.23) to the voiceless fricatives in (3.23), and the manner contrast is shown by comparison with the prenasalized voiced stops in (3.25).

(3.25)	a.	mbáa̱ [ᵐba˥a˩] /ᵐbáà/ ‘child’s godfather’	b.	nda̱a̱ [ⁿda˧a˩] /ⁿdàà/ ‘straight’	c.	ndyaa [ⁿdʲa˧a˧] /ⁿdʲaa/ ‘watch over’

Finally, there are three phonemes in the nasal series: /m/, /n/, and /ɲ/. Like /ʒ/, /ɲ/ may realized as a glide ([j̃]) in unstressed syllables, while the others are consistently stops. The distribution of the nasals is limited by palatal (§3.3.5) and labial (§3.3.6) phonotactics, but the place contrast can be shown before /ã/, as in (3.26, 3.27).

(3.26)	a.	má’a̱n [mã˥ʔã˩] /máˀà/ ‘raccoon’	b.	na’an [nã˧ʔã˧] /naˀa/ ‘early’	c.	ña’a̱n [ɲã˧ʔa˨˩] /ɲaˀà´/ ‘woman’
(3.27)	a.	nama̱ [nã˧mã˨˩] /namà´/ ‘earth wall’	b.	náná [nã˥nã˥] /náná/ ‘mother’	c.	náñá [nã˥ɲã˥] /náɲá`/ ‘chayote’

As shown, the nasals contrast in both initial position as in (3.26) and in medial position as in (3.27). However, the phonotactics of nasality (discussed §3.3.3) are so limiting that the nasal series is not strictly contrastive with either the prenasalized stops or the voiced continuants. With very few exceptions, the nasal consonants co-occur with nasal vowels and the other voiced consonants co-occur only with oral vowels.

Conventionalized loanwords from Spanish show adaptation to the phoneme inventory and phonotactics of Nieves Mixtec, but novel loanwords are readily adopted with minimal segmental adaptation. (Though see §4.5.1 for discussion of prosodic adaptation). As a result, the consonants of Mexican Spanish occupy a marginal status within the language. These include voiceless labial stops as in (3.28) and fricatives as in (3.29).

(3.28)

a. páñí
[pã˥ɲĩ˥]
/páɲí`/
'shawl'
(<Sp. paño)

b. píndo̲
[pi˥^{n}do˩]
/pí^{n}dò/
'speckled'
(<Sp. pinto)

c. Kupala
[ku˧pa˥la˥]
/kupálá`/
'(San Juan) Copala'

(3.29)

a. kafée̲
[ka˧fe˥e˩]
/kaféè/
'coffee'
(<Sp. café)

b. teléfo̲no̲
[te˧le˥fõ˧nõ˩]
/teléfònò/
'telephone'
(<Sp. teléfono)

Also included are plain voiced stops as in (3.30).

(3.30)

a. Benjamíi̲n
[bẽ˧xã˧mĩ˥ĩ˩n]
/benhamíîn/
'Benjamin'

b. Davíi̲d
[da˧βi˥i˩ð]
/daβíîd/
'David'

Taps are found even in stressed positions, as in (3.31).

(3.31)

a. aparátó ~ pirátó
[a˧pa˧ˈɾa˥to˥] ~ [pi˧ˈɾa˥to˥]
/apaɾátó`/ ~ /piɾátó`/
'device'
<MC MIN0148, MIN0643>

b. María
[ma˧ˈɾi˥ja˥]
/maɾíjá/
'Maria'

Finally, the alveolar trill is found in loanwords from Spanish, such those in (3.32), as well as in two animal names shown in (3.33).

(3.32)

a. réjá
[re˥xa˥]
/réxá`/
'grill'
(<Sp. reja)

b. ránchó
[ra˥ntʃo˥]
/rántʃó`/
'ranch'
(<Sp. rancho)

(3.33)

a. chirí'í
[tʃi˧ri˥ʔi˥]
/tʃirí^{ʔ}í/
'bat'

b. chiráka̲
[tʃi˧ra˥ka˩]
/tʃirákà/
'woodpecker'

The /ʧi/ syllable appears as the initial syllable in several animal names, but it is less common than /tʲi–/ and /ⁿdʲi–/, semi-productive prefixes also associated with animals. This suggests that these /ʧi/ words in (3.33) are also loanwords, but drawn from another Mixtec variety, perhaps the variety of Tecomaxtlahuaca (affiliated with Santiago Juxtlahuaca (JUX)), located just 25 km south of Ixpantepec Nieves. The word for ‘animal’ and the names of three specific animals are shown in (3.34).

(3.34) Ixpantepec Nieves

a. kityi̲	b. tyijí’ma̲	c. tyikui̲ín	d. yi̲i
[ki˧tʲi˧˩]	[tʲi˧xi˥ʔma˧˩]	[tʲi˥kʷĩ˩ĩ˥]	[ʒi˩i˧]
/kitʲì´/	/tʲi´–xiˀmà´/	/tʲi´–kʷìí$_{n}$/	/ʒìi/
‘animal’	ZO–tail	ZO–kʷii$_{n}$	‘coati’
	‘scorpion’	‘mosquito’	

Animal names commonly have the /tʲi–/ animal class prefix as in (3.34b, c), corresponding to the second syllable of /kitʲì´/ ‘animal’ (3.34a), though many animal names have no such marking, as in (3.34d). The Proto-Mixtec reconstructed forms (Josserand 1983), shown in (3.35), have /tɨ/ in these words.[4]

(3.35) Proto-Mixtec

a. *kitɨˀ	b. *tɨ luˀweˀ$_{n}$	c. *tɨ kʷejiˀ$_{n}$	d. *jɨjɨ
‘animal’	‘scorpion’	‘mosquito’	‘coati’

The comparative data from contemporary varieties (Josserand 1983) show divergence from that source. Many varieties maintain a stop, but in some varieties, the stop has changed to an affricate, as in (3.36), or to a fricative as in (3.37).

(3.36) Guadalupe Portezuelo (GUA)

a. kitsi	b. tsidi’ma	c. tsiyii
[kit͡si]	[t͡siðiʔma]	[t͡sijii]
‘animal’	‘scorpion’	‘coati’

(3.37) Xayacatlan del Bravo (ACA)

a. kisi	b. sidu’ma	c. sikuiin	d. si’ii
[kisi]	[siðuʔma]	[sikʷĩĩ]	[siʔii]
‘animal’	‘scorpion’	‘mosquito’	‘coati’

Some varieties maintain a stop in the prefix but affricate the medial consonant, as in

[4] Josserand (1983) does not provide tone information for reconstructed forms and only rarely for recorded contemporary forms.

(3.38).

(3.38) Apoala (APO)

	a.	b.	c.	d.
	kichi	ndidu’ma	tikuañu	tiyiyi
	[kiʧi]	[^{n}diðũʔmã]	[tikʷãɲũ]	[tiʒiʒi]
	‘animal’	‘scorpion’	‘mosquito’	‘coati’

And in Tecomaxtlahuaca, shown in (3.39), the stop is maintained root-medially, but it is affricated in the prefix.

(3.39) Tecomaxtlahuaca (JUX)

	a.	b.	c.	d.
	kityi	chisu’ma	chikuani	yii
	[kitʲi]	[ʧisuʔma]	[ʧikʷãnĩ]	[ʒii]
	‘animal’	‘scorpion’	‘mosquito’	‘coati’

The forms for ‘animal’ in Nieves (3.34a) and Tecomaxtlahuaca (3.39a) are the same, but for the Nieves words with /tʲi–/ animal class prefix (3.34b, c), the cognate forms in Tecomaxtlahuaca (3.39b, c) have /ʧi–/. Thus, the /ʧi/ initial syllables in the animal names in (3.33a, b), in combination with the rare /r/ phoneme there, suggest that those are loanwords from Tecomaxtlahuaca.

In addition to the lamino-alveolar stops in Table 3.1, there are also a few attested onsets with palatal off-glides that might be considered either a single segment or a cluster. There is not much evidence of their status, but I treat them as surface-level palatalization derived from /i/ at the lexical level. The attested examples are shown in (3.40, 3.41).

(3.40)	a.	b.	c.
	kusiá’a̱n	kia̱’a	tyimia’an
	[ku˧sʲã˥ʔã˩]	[kʲa˩ʔa˧]	[tʲi˧mʲã˥ʔã˩]
	/kusíˀà$_n$/	/kìˀa/	/tʲi´–miˀà/
	IR:eat.meal	x.sibling	ZO–devil
	‘will eat a meal’	‘cross-sex sibling’	‘devil’

(3.41)	a.	b.	c.	d.
	u̱su̱	ku̱su̱	kia̱	sia̱a̱n
	[u˧sʲu˩]	[ku˧sʲu˩]	[kʲa˩]	[sʲã˧ã˩]
	/ùsiù/	/kùsì/	/kià/	/siàà$_n$/
	‘ten’	IR:eat.bread	COP.3.N	PROX.2
		‘will eat bread’	‘it is’	‘here by you’

As shown, this palatalization is attested on [s] (3.40a, 3.41a, b, d), [k] (3.40b, 3.41c), and [m] (3.40c). Despite the similarity of resulting palatalization, the examples above represent three different derivation paths. The three [Cʲaʔa] words (3.40) reflect a process that makes morphemes conform with the phonotactic preference for identical vowel qualities in adjacent vowels (described in §3.3.4), here forming a glottalized long vowel. Variation is observed in the case of [kʲa˦ʔa˩] (3.40b), which may also be pronounced as [ki˦ʔa˩] (3.42a). This variation is paralleled in one other word where the onset is palatalized underlyingly (3.42b).

(3.42)
a. kia̲'a ~ ki̲'a
[kʲa˩ʔa˨] ~ [ki˩ʔa˨]
/kìˀa/
x.sibling
'cross-sex sibling'
<OO, MC>

b. xá'á ~ xí'á
[ʃã˥ʔã˥] ~ [ʃĩ˥ʔã˥]
/ʃíˀá$_n$/
'hawk'
<OO, MC>

This variation follows a historical process characteristic of bisyllabic morphemes with medial /v/ < */w/ or /ʒ/ < */j/ (Josserand 1983), which often lose the medial consonant and then fuse into one syllable, as discussed in §3.3.4. Variation has not been observed with [tʲi˧mʲã˥ʔã˩] (3.40c), [ku˧sʲã˥ʔã˩] (3.40a) or its realis form [si˧sʲã˥ʔã˩]. But the [sʲu] words (3.41a, b) are also variable, alternately produced without palatalization, as shown in (3.43).

(3.43)
a. u̲su̲
[u˨sʲu˩] ~ [u˨su˩]
/ùsiù/
'ten'
<OO, MC>

b. kusi ~ kusu
[ku˧si˧ ~ ku˧sʲu˧ ~ ku˧su˧]
/kusi/
IR:eat.bread
'will eat bread'
<OO, MC>

It is not the case that this is simply variable palatalization in the context of /u/, comparable to the laminal/palatalized articulation observed on stops (described in §3.3.5). There are comparable words with underlying /u/, such as those shown in (3.44) where no palatalization is observed in /su/ syllables.

(3.44)
a. kúsú
[ku˥su˥] cf *[ku˥sʲu˥]
/kúsú/
'white'
<OO, MC>

b. ndyu̲sú
[^{n}dʲu˩su˦] cf *[^{n}dʲu˩sʲu˦]
/^{n}dʲùsú/
'chicken'
<OO, MC>

As in (3.42), the variation in (3.43) suggests influence of the preference for identical vowels within a morpheme, but in (3.43) it is achieved by spreading the vowel quality rightward rather than leftward as it was in (3.42). Though [u˧si˩] is not accepted as a pronunciation of [u˧sʲu˩] 'ten' (3.43a) in Nieves, the final vowel is [i] in several neighboring varieties (Josserand 1983), including that of Silacayoapan, as well as being the final vowel in Josserand's reconstructed form.

Finally, the form [kʲa˩] is also variable. The other attested forms reflect fusion and reduction of the copula /kuu/ and the generic class clitic /=ɲà/ (3.45).

(3.45) kia̠ ~ kuu ña̠
[kʲa˩] ~ [kʲa˩a˩] ~ [ku˧a˩] ~ [ku˧jã˩] ~ [ku˧u˧ɲã˩]
kià ~ kuu=ɲà
COP.3.N ~ COP=3.N
'it is'

<OO, FC>

This suggests that the palatal off-glide derives from the palatal onset of the clitic, by denasalization.

In sum, Nieves Mixtec has a relatively small consonant inventory, with five voiceless stops, three voiceless fricatives, four voiced prenasalized stops, four voiced continuants, and three nasals. However, many of these contrasts are contextually limited, and the nasals are not strictly contrastive with the other voiced consonants within native vocabulary. These restrictions are discussed in section §3.3.

3.2.2 Vowels

Though the vowel system of Nieves Mixtec has just five vowel qualities, there are a total of 17 vowel phonemes (shown in Table 2) when contrasts in nasalization and quantity are included. Glottalization (discussed in §3.3.2) is considered a prosodic property of the morpheme, realized in the vowel but not a property of the vowel. The full variety of contrasts is supported only in the root.

Because the canonical root is strictly bimoraic, and because there is a strong preference for identical vowels even in CVCV roots, there are a couple of plausible alternative

Table 3.2: Vowels in the phonemic inventory of Nieves Mixtec

	oral			nasal		
	front	central	back	front	central	back
+high	ii		uu	ĩĩ		ũũ
	i		u	ĩ		ũ
−high	ee	aa	oo	ẽẽ	ãã	
	e	a	o		ã	

analyses besides the one assumed here, the lexical specification of vowel length. The arguments for and against these analyses are essentially prosodic, depending on stress-dependent alternations and the distribution of underlying tone, and so this discussion is deferred to the next chapter (§4.4.1).

The contrast in height is demonstrated by the following minimal pairs. The contrast is easily demonstrated in long vowels, both plain (3.46, 3.47) and glottalized (3.48, 3.49).

(3.46) a. vií
[vi˧i˦]
/vií/
'clean'

b. ve̱e
[ve˩e˨]
/vèe/
'heavy'

(3.47) a. kuu
[ku˧u˧]
/kuu/
COP

b. koo
[ko˧o˧]
/koo/
IR.EXIST

(3.48) a. ndyi̱'i̱
[^{n}dʲi˨ʔi˩]
/^{n}dʲìˀì/
'finish'

b. ndye'e
[^{n}dʲe˧ʔe˧]
/^{n}dʲeˀe/
'see'

(3.49) a. yu'u̱
[ʒu˧ʔu˩˧]
/ʒuˀù´/
'mouth'

b. yo'o̱
[ʒo˧ʔo˩˧]
/ʒoˀò´/
'rope'

However, the short vowels with /e/ and /o/ qualities have limited distribution. The only single-vowel minimal pairs or near-minimal pairs involve loan words, such as those shown in (3.50–3.53).

(3.50) a. sáko
[sa˥ko˦]
/sáko/
'opossum'
< Nah. [tɬɑkʷɑːtsin]

b. sáku
[sa˥ku˦]
/´\saku/
IPFV\RE:cry
'crying'

(3.51) a. návélá
[nã˥ve˥la˥]
/ná–vélá`/
3F.FRM–grandma
'grandma' < Sp. [aˈβwela]

b. vílá
[vi˥la˥]
/vílá/
'soft'

(3.52) a. léka̱
[le˥ka˩]
/lékà/
'bag'
< Sp. [taˈleɣa]

b. ndyi̱ka
[ⁿdʲi˩ka˨]
/ⁿdʲìka/
'wall'

(3.53) a. che̱lo̱
[tʃe˨lo˩]
/tʃèlò/
'calf'
< Sp. [beˈsero]

b. ilo
[i˧lo˧]
/ilo`/
'rabbit'

On the other hand, the loanwords in these pairs (3.50a, 3.51a, 3.52a, 3.53a) show major prosodic and segmental changes, suggesting that they are old loanwords, integrated into the native phonology.

The best evidence of a height contrast in short vowels is a few bisyllabic words that have identical vowels, such as those in (3.54–3.55).

(3.54) a. chílí
[tʃi˥li˥]
/tʃílí/
'lizard'

b. chéle
[tʃe˥le˦]
/tʃéle/
'rooster'

(3.55) a. yoko̱
[ʒo˧ko˨˩]
/ʒokò/
'hive'

b. yuku̱
[ʒu˧ku˨˩]
/ʒukù´/
'mountain'

These examples demonstrate there is a contrast in at least one position within the root.

The shortage of minimal pairs suggests an analysis in which the vowel height in one position is dependent on the height of the other vowel, but there is no clear evidence as to which vowel position is dominant.

Finally, there is a height contrast in long nasal front vowels, demonstrated by the minimal pairs in (3.56, 3.57).

(3.56)	a.	kuíi̲n [kʷĩ˦ĩ˩] /kʷîî$_n$/ 'thin'	b.	kueen [kʷẽ˧ẽ˧] /kʷee$_n$/ IR:buy 'will buy'
(3.57)	a.	ni'i [nĩ˧ʔĩ˧] /niˀi/ 'find'	b.	ne'e [nẽ˧ʔẽ˧] /neˀe/ 'carry'

In contrast, there is no evidence of a height contrast in short nasal front vowels, nor within nasal back vowels, long or short. The phonetic height of nasal back vowels varies by phonological context and speaker. In general, the vowel quality of nasal back vowels is higher when it is a long vowel, as in (3.58), or when both syllables of a disyllabic root have nasal back vowels, as in (3.59).

(3.58)	a.	nuu̲ [nũ˧ũ˩˧] /nuù´/ face	b.	tu̲ún [tũ˩ũ˦] /tùú$_n$/ black	c.	ñu'u [ɲũ˧ʔũ˧] /ɲuˀu/ drag	d.	ku̲'u̲n [kũ˨ʔũ˩] /kùˀù$_n$/ IR:go
(3.59)	a.	ñu̲ñu̲ [ɲũ˨ɲũ˩] /ɲùɲù/ honey	b.	ku̲ñu [kũ˩ɲũ˨] /kùɲu/ meat	c.	ñunu̲ [ɲũ˧nũ˩˧] /ɲunù´/ net	d.	kunu [kũ˧nũ˧] /kunu/ IR:run

When only the first syllable of a disyllabic root has a nasal back vowel, the vowel tends to be higher before /n/, as in (3.60), and lower before /m/, as in (3.61).

(3.60)	a. kuni	b. nu̲ni̲	c. kuna	d. núná
	[kũ˧nĩ˧]	[nũ˧nĩ˩˧]	[kũ˧nã˧]	[nũ˥nã˥]
	/kuni/	/nùnì´/	/kuna/	/núná`/
	yesterday	corn	IR:open	STAT:open

(3.61)	a. ko̲mi̲	b. to̲mi	c. no̲mi̲	d. noma̲
	[kõ˧mĩ˩˧]	[tõ˩mĩ˧]	[nõ˧mĩ˩]	[nõ˧mã˩]
	/kùmì´/	/tùmi/	/nùmì/	/numà/
	‘four’	‘feather’	‘hurry’	‘bush’

When only the second syllable has a nasal back vowel, the vowel tends to be lower, as in (3.62).

(3.62)	a. ni̲no	b. chiño	c. sa̲no	d. ká’no
	[nĩ˩nõ˧]	[ʧĩ˧ɲõ˧]	[sã˩nõ˧]	[kã˥ʔnõ˦]
	/nìnu/	/ʧiɲu/	/sànu/	/káˀnu/
	above	work	daughter.law	big.SG

For some speakers, the height variation across phonological contexts is quite pronounced, while for other speakers the height variation is more subtle.

Within the non-high vowels, contrasts in backness are also easily demonstrated for the long oral vowels, whether plain as in (3.63, 3.64) or glottalized as in (3.65, 3.66).

(3.63)	a. ve̲e	b. va̲a̲
	[ve˩e˧]	[va˧a˩˧]
	/vèe/	/vàà´/
	‘heavy’	‘below’

(3.64)	a. ka̲a	b. ko̲o̲
	[ka˩a˧]	[ko˧o˩˧]
	/kàa/	/kòò´/
	‘metal’	‘snake’

(3.65)	a. kué’é	b. kuá’á
	[kʷe˥ʔe˥]	[kʷa˥ʔa˥]
	/kʷéˀé/	/kʷáˀá/
	‘crazy’	‘red’

(3.66) a. ya’a̱
[ʒa˧ʔa˩˧]
/ʒa^{ʔ}à´/
‘chile’

b. yo’o̱
[ʒo˧ʔo˩˧]
/ʒo^{ʔ}ò´/
‘rope’

For the non-high short vowels, there are a few minimal pairs as in (3.67–3.69).

(3.67) a. chéle
[tʃe˥le˧]
/tʃéle/
‘rooster’

b. che̱’la
[tʃe˩ʔla˧]
/tʃè^{ʔ}la/
‘dragonfly’

(3.68) a. tóto̱
[to˥to˩]
/tótò/
‘pavement’

b. táto̱
[ta˥to˩]
/tátò/
‘bailiff’

(3.69) a. ndyiko
[^{n}d^{j}i˧ko˧]
/^{n}d^{j}iko/
‘follow’

b. ndyi̱ka
[^{n}d^{j}i˩ka˧]
/^{n}d^{j}ìka/
‘wall’

There are also near-minimal pairs with two identical short vowels as in (3.70–3.72).

(3.70) a. e̱ve̱
[ʔe˧ve˩]
/èvè/
‘two’

b. ndava
[^{n}da˧va˧]
/^{n}dava/
‘jump’

(3.71) a. kata
[ka˧ta˧]
/kata/
‘will sing’

b. koto
[ko˧to˧]
/koto/
‘will look’

(3.72) a. jaka
[xa˧ka˧]
/xaka/
‘mix’

b. jo̱ko̱
[xo˧ko˩˧]
/xòkò´/
‘shoulder’

Between the nasal long vowels /ẽẽ/ and /ãã/, minimal pairs can demonstrate the contrast in both plain roots as in (3.73, 3.74) and in glottalized roots as in (3.75, 3.76).

(3.73) a. kueen
[kʷẽ˧ẽ˧]
/kʷee$_n$/
'will buy'

b. kuáán
[kʷã˥ã˥]
/kʷáá$_n$/
'yellow'

(3.74) a. me̱e
[mẽ˩ẽ˧]
/mèe/
PRO.EMPH

b. ma̱a
[mã˩ã˧]
/màa/
'linen'

(3.75) a. ke'en
[kẽ˧ʔẽ˧]
/keˀe$_n$/
'will give'

b. ka'an
[kã˧ʔã˧]
/kaˀa$_n$/
'think'

(3.76) a. ne'e
[nẽ˧ʔẽ˧]
/neˀe/
'carry'

b. na'a
[nã˧ʔã˧]
/naˀa/
'early'

In sum, Nieves Mixtec has a standard set of five oral vowels, crossed with nasalization and contrastive length. However, among the nasal vowels, short vowels are only found with the three peripheral vowel qualities, and long vowels are found with these three vowel qualities plus /ẽẽ/.

3.3 Morpheme features and phonotactics

This section describes the canonical morphemes and their phonotactics. Several analytical issues are introduced regarding the phonological representation of features which are strongly associated to morphemes rather than purely phonological units: glottalization, nasalization, and vowel quality. In doing so, the static distributions of consonant co-occurrence and vowel co-occurrence are also examined. Finally, phonotactic restrictions on palatal and labial features in consonant-vowel sequences are described and examined.

3.3.1 The canonical root

Across Mixtec languages, the minimal open-class word is bimoraic, corresponding to the canonical bare root, while affixes and clitics are typically monomoraic. The bimoraic morpheme, dubbed a 'tonemic couplet' (K. L. Pike 1948), plays a prominent role in both the prosody and the tonal phonology. Though there is robust evidence for the couplet, there is little evidence that would disambiguate the internal prosodic structure of the couplet. Early definitions of the couplet in other Mixtec dialects (K. L. Pike 1948; Hunter & Pike 1963; Pankratz & Pike 1967) described it as a disyllabic unit, but the development of moraic theory (Hyman 1985) leads naturally to the analysis that the couplet is bimoraic and not necessarily disyllabic (Gerfen 1999; McKendry 2013). The couplet is clearly binary, in that every couplet—maximally CVCV (or glottalized CVˀCV) and minimally VV (or glottalized VˀV)—has two vocalic positions. This regular correspondence suggests an analysis in which each vowel position is a mora and only vowels can be moraic. Here I assume that the couplet corresponds to a bimoraic foot, which may be either monosyllabic or disyllabic. The prosodic structure and phonological role of the couplet are discussed further in Chapter 4.

The inventory of canonical roots can be classified into four template shapes, according to whether the root is glottalized and whether there is a root-medial consonant.

(3.77) a. (C)VCV: b. (C)VV:

u̠ni̠	ni̠no	iin	ñuu
[ʔũ˨nĩ˩]	[nĩ˩nõ˨]	[ʔĩ˧ĩ˧]	[ɲũ˧ũ˧]
/ùnì/	/nìnu/	/ii$_{\text{n}}$/	/ɲuu/
'three'	'up'	'one'	'town'

(3.78) a. (C)VˀCV: b. (C)VˀV:

i'ní	ni'ma̠	u̠'u̠n	ñu'u̠
[ʔĩ˧ʔnĩ˥]	[ɲĩ˧ʔmã˩˨]	[ʔũ˨ʔũ˩]	[ɲũ˧ʔũ˩]
/iˀní`/	/ɲiˀmà´/	/ùˀù$_{\text{n}}$/	/ɲuˀù/
'hot'	'smoke'	'five'	'earth'

The roots with medial consonants (3.77a, 3.78a) are disyllabic. I consider the roots without medial consonants (3.77b, 3.78b) monosyllabic, except in a few cases, discussed in

§3.3.4, where a CV^{ʔ}V root has non-identical vowels, in which case it is disyllabic.

3.3.2 Glottalization

Though glottalization is often realized as a segmental stop [ʔ] after the first vowel position of the couplet, it is better understood as a prosodic feature of the morpheme. Early descriptions of other Mixtec varieties did treat it as a consonant segment (K. L. Pike 1948; Hunter & Pike 1963; E. V. Pike & Cowan 1967; Pankratz & Pike 1967; North & Shields 1977). Later descriptions generally took it to be a property of the vowel or initial syllable (Bradley 1970; Josserand 1983), and distributionally it is characteristic of the morpheme (Macaulay & Salmons 1995).

Only roots may be glottalized—no glottalization can appear in affixes and clitics, which are monomoraic. In addition, glottalization is lexically restricted to morphemes that either have no medial consonant or have a voiced medial consonant. As noted already, contrastive glottalization is restricted to associate to the first vowel of the root, but besides a segmental stop, it may be realized as localized creaky voice or creaky voice throughout the vowel, depending on prosodic conditions. In some cases, a glottalized morpheme may be realized without any apparent glottalization. If glottalization occupied a segmental slot, this would significantly complicate the specification of possible syllables, creating the only possible coda or the only possible consonant cluster. Moreover, unlike consonants, the glottalization is transparent to nasal harmony (discussed in §3.3.3) and nearly transparent to vowel harmony (discussed in §3.3.4). For these reasons, I consider contrastive glottalization to be lexically specified as associated to the morpheme as a whole, but prosodically conditioned to associate to the initial vowel.

On the other hand, there is also epenthetic (non-contrastive) glottalization which fills an empty onset position root-initially and at word boundaries. As shown above in (3.77, 3.78), the initial consonant position of the root is optionally empty, but a glottal stop is regularly inserted in this position, both utterance initially and utterance internally, as in (3.79).

(3.79) a. o̲ko̲ u̲su̲ iin
[ʔo˨ko˩ ʔu˨su˩ ʔĩ˧ĩ˧]
/òkò ùsù ii$_{n}$/
twenty ten one
'thirty one'

<MC MIN0005:11:28.0>

b. yuku̲ íi īin yito̲
[ʒu˧ku˩ ʔi˧i˥ ʔĩ˧ĩ˧ ʒi˧to˩˨]
/ʒukù´ ´\ii ii$_{n}$ ʒitò´/
mountain IPFV\EXIST one tree
'There is a tree on the mountain'

< MC MIN0379:6:37.2 >

Besides targeting bare roots as in (3.79), the glottal epenthesis targets roots with prefixes as in (3.80) or proclitics as in (3.81).

(3.80) a. ni̲ ku'e've sa̲'a̲ i̲
[nĩ˨ku˩ʔe˧ʔve˧ sa˨ʔi˧˩]
/nì = ku–eˀve sàˀà´ = ì/
PFV = INCH–hurt foot = 1S
'I hurt my foot'

<OO MIN0315>

b. si̲'ii kuíká ndyi̲
[si˩ʔi˧i˧ kʷi˥ka˥^{n}dʲi˩]
/sì–ii kʷíká` = ^{n}dʲì/
HAB–EXIST rich = 1P.EX
'we were rich'

<FC MIN0730:3:23.2>

(3.81) a. tá iin tá iin rí
[ta˥ʔĩ˧ĩ˧ ta˥ʔĩ˧ĩ˧ɾi˥]
/tá = ii$_{n}$ tá = ii$_{n}$ = tʲí/
each = one each = one = 3.ZO
'each animal'

<OO MIN0765>

b. ilo tyi uju
[ʔi˧lo˧ tʲi˧ʔu˧hu˧]
/ilo` tʲi = uhu`/
rabbit and = deer
'rabbits and deer'

<MC MIN0338:11:58.6>

The epenthesis also targets word boundaries even if the vowel is of an affix or proclitic as in (3.82), rather than being root-initial.

(3.82) a. intya̲a̲n
[ʔĩ˧tʲã˨ã˩]
/i$_{n}$tʲàà$_{n}$/
DIV:tomorrow
'tomorrow'

<MC MIN122:10:30>

b. u̲n kúu
[ʔũ˩ku˩u˦]
/ù$_{n}$´ = ´\kuu/
NEG.IR = IPFV\POT
'cannot'[5]

<OO MIN0792>

However, no epenthesis applies before a vocalic enclitic as in (3.83).

[5] I gloss /ù$_{n}$´/ as irrealis (NEG.IR) even though its complement is not properly an irrealis root but one of a set of inflected verb forms that includes potential and imperative forms, plus some adjectives and this potential verb, regardless of aspect. The corresponding realis negation /kò´/, glossed as NEG.RE, is used with perfective and imperfective verbs, plus adjectives. The imperfective form of the potential verb is compatible with either negation marker.

(3.83)

a. ni sita i
[nĩ˩si˧təi˩]
/nì = sita = ì/
PFV = RE:sing = 1S
'I sang'

<OO MIN0086:0:20.0>

b. sísi ún
[si˥sũ˥]
/´\sisi = ú$_n$/
IPFV\RE:eat.bread = 2S.FAM
'you are eating (tortilla)'

<OO MIN0090:3:11.8>

The status of glottalization is discussed again in §4.4.2 in the context of its interaction with stress.

3.3.3 Nasalization

As observed for many other varieties of Mixtec (Marlett 1992), the overwhelming majority of morphemes (including affixes and clitics, besides roots) can be categorized as either nasal or non-nasal. In Nieves Mixtec, all the vowels in a nasal morpheme are nasal and all the vowels in a non-nasal morpheme are oral. The consonants in a bimoraic nasal morpheme can be nasal consonants (/m, n, ɲ/) or voiceless consonants (/t, tʲ, tʃ, k, kʷ, s, ʃ, x/), but in monomoraic nasal morphemes, any consonants must be nasal consonants. In non-nasal morphemes, the consonants can be oral voiced consonants (/ᵐb, ⁿd, ⁿdʲ, v, l, ʒ/) or one of the voiceless consonants listed above.

In most Mixtec varieties, voiceless consonants in nasal roots may appear either root-initially or root-medially. In some varieties, both vowels in such roots are nasal, while in other varieties, the last vowel is nasal but the initial vowel is oral. In Nieves, morphemes with a medial voiceless consonant are non-nasal, with no nasal segments, except for three known exceptions, shown in (3.84).

(3.84)

a. ajin
[ã˧xĩ˩˦]
/àxì$_n$´/
'delicious'

b. tyikajín
/tʲi˧kã˩xĩ˥/
/tʲi–kàxí$_n$/
3.RND–kaxi$_n$
'big tostada'

c. tyimája
[tʲi˧mã˥xã˩]
/tʲi´–maxà$_n$/
3.ZO-maxa$_n$
'grub'

Since all three words have /x/ in root-medial position, I hypothesize that /x/ is systematically permitted in medial position in nasal roots, unlike other voiceless consonants. The exceptionality of /x/ may be due to its possible realization as [h], as cross-linguistically, laryngeal segments are typically transparent to nasal harmony (Walker 2000:53).

There are two small sets of roots that do not fit cleanly into the outlined categories of nasal and non-nasal morphemes. The first set is composed of loanwords, such as those in (3.85, 3.86).

(3.85) a. málí
[mã˥li˥]
/málí`/
'child's godmother'
< Sp. [koˈmadɾe]

b. néle̱
[nẽ˥le˩]
/nélè/
'Daniel'
< Sp. [daˈɲel]

(3.86) a. sadóo̱n
[sa˧ðõ˧õ˩]
/sadóò$_{n}$/
'hoe'
< Sp. [asaˈðon]

b. melóo̱n
[mẽ˧lõ˧õ˩]
/melóò$_{n}$/
'melon'
< Sp. [meˈlon]

In loanwords, nasalization spreads from a nasal consonant to the following vowel as in (3.85a, b, 3.86b). But even in loanwords that are otherwise well-integrated into the language, nasalization does not spread from a nasal vowel to a following voiced consonant as in (3.85a, b, 3.86b), nor to a preceding voiced consonant as in (3.86). Nasalization also does not spread from a nasal through a consonant to the following vowel as in (3.85) nor to a preceding vowel as in (3.86a). The second set is a few words, all shown in (3.87), which have an initial nasal consonant and vowel but a voiceless medial consonant and an oral final vowel.

(3.87) a. ñu̱tyí
[ɲũ˩tʲi˧]
/ɲùtʲí/
'sand'

b. náchi̱
[nã˥tʃi˩]
/nátʃì/
'beetle'

c. núchí
[nũ˥tʃi˥]
/nútʃí
'beautiful'

They are all phonologically quite similar, with all coronal consonants and /i/ final vowel.

In Marlett's analysis, which did not include data like the words in (3.87), the distribution of nasality is taken to indicate that nasality is specified on the morpheme level. The nasal feature docks on the right boundary and then spreads leftward, with some dialectal differences in how the nasality spreads. Besides unifying the oral and nasal vowels, he unifies /^{n}d/ with /n/, /v/ with /m/, and /ʒ/ with /ɲ/. The other voiced continuant /l/ is taken to be always oral simply due to its limited distribution, while he suggests that the other prenasalized stops (/ᵐb/ and /ᵑg/ in the inventory he discusses) are best considered consonant clusters. Though this analysis has the advantage of simplifying the phoneme inventory, it runs up against a few problems in Nieves, which suggest that it is not appropriate as a synchronic analysis, though it may indeed accurately reflect the etymology of the nasal and prenasalized series.

One problem already suggested is that there are a few roots (3.87) that cannot be derived this way. A possible resolution would be to say that in Nieves Mixtec nasalization spreads across voiceless medial consonants (as attested for the Ocotopec (OCO) variety of Mixtec), but the nasal feature then delinks from the final isolated vowel, or alternatively, that in nasal roots with medial voiceless consonants, the nasality skips the final syllable and docks directly with the initial syllable. I have not been able to find cognate roots for the words in (3.87), but some of Marlett's examples of nasal words that have a voiceless medial consonant in Ocotopec Mixtec are attested in Nieves Mixtec. Several of these are shown in (3.88).[6]

(3.88) Nasal roots with voiceless medials (Josserand 1983; Marlett 1992)

	Proto-Mixtec	Ocotopec	Nieves	
a.	*ⁿdixiₙ	nĩxĩ	ⁿdʲìsì	'wing'
b.	*jɨkɨₙ	ɲĩkĩ	ʒikì	'squash'
c.	*jutuˀₙ	ɲũtũ	ʒitò´	'tree'
d.	*jesiˀₙ	ɲũxĩ	ʒasì´	'gourd'

All are found as fully oral roots in Nieves, contrary to what would be predicted by the proposed rule as applied to the same underlying morpheme nasality categories, as Marlett proposes. So though the formal device of skipping/delinking from the final vowel can produce the observed distribution of nasalization—by specifying the words in (3.87) as nasal and the words in (3.88) as non-nasal—, it apparently cannot do so from the same underlying forms as in other dialects. Skipping or delinking from the final vowel is a

[6]Proto-Mixtec reconstructions are from Josserand (1983), and the Ocotopec data is from Marlett (1992). Neither provide tone information.

plausible etymology for the exceptional words in (3.87), but that still does not explain why those words retained nasal initial consonants with oral final vowels while the words in (3.88) became fully oral.

A second problem is that Marlett's hypothesis doesn't satisfactorily account for the distribution of the other prenasalized stops, /^{m}b/ and /^{ŋ}g/, which he treats as consonant clusters. I treat all the prenasalized stops as single segments rather than consonant clusters because a cluster of a nasal stop and an oral voiced stop would itself violate the nasality phonotactics, and the prenasalized stops pattern as oral consonants in respect to the nasality phonotactics, rather than as nasal consonants or as nasal-oral clusters. The prenasalized stops co-occur with oral segments, whereas a nasal stop would be expected to co-occur with nasal segments. If the prenasalized stops were clusters of a nasal stop and an underlying voiceless stop (with surface voicing), they would still be expected to require preceding voiced segments to be nasal. Though there may be some nasalization in the latter half of a vowel that precedes a prenasalized stop, the nasalization does not extend to the preceding consonant. Furthermore, though both /^{m}b/ and /^{ŋ}g/ are distributionally restricted, they do not pattern similarly, as would be expected of consonant clusters. The /^{m}b/ is found only root-initially, while /^{ŋ}g/ is found only root-medially, and if they were consonant clusters, they would be the only ones in the language. A phonologically natural variant of Marlett's hypothesis would unify /m/ with /^{m}b/, /n/ with /^{n}d/ and /^{n}d^{j}/ with /ɲ/. This has the advantage of treating the prenasalized stops more consistently, but this runs up against similar problems. It leaves /^{ŋ}g/ as a phoneme without a nasal allophone, and fails to account for the rather different distributions of /m/ and /^{m}b/.

The nasal phonotactics are sufficiently strong to make it generally useful to consider morphemes as nasal or non-nasal, and at least within the native vocabulary, it is possible to derive segmental nasality from a morpheme-level nasal feature. However, the exceptional native vocabulary in (3.87) and the failure of vowel-to-consonant nasalization in the loanwords (3.85, 3.86) make it difficult to base the phonemic inventory on that analysis. The nasal consonants do not quite unify with comparable oral consonants, and complicated rules are required to specify which vowels are nasal in the morphemes that do not cleanly fit into the nasal and non-nasal categories.

3.3.4 Vowel quality

Vowels within the root show a preference for identical vowel quality. In CVV roots and CVˀV roots, with a few exceptions, the vowels not only share nasality but also vowel quality, such as in (3.89–3.93).

(3.89)	a.	iin [ĩ˧ĩ˧] /ii$_n$/ ‘one’	b.	si̱’i̱ [si˨ʔi˩] /sìˀì/ RE.die
(3.90)	a.	léé [le˦e˦] /léé`/ ‘baby’	b.	ve’e [ve˧ʔe˧] /veˀe/ ‘house’
(3.91)	a.	tyaan [tʲã˧ã˧] /tʲaa$_n$/ ‘forehead’	b.	sa̱’a̱ [sa˨ʔa˩˧] /sàˀà´/ ‘foot’
(3.92)	a.	ko̱o̱ [ko˧o˩˧] /kòò´/ ‘snake’	b.	yó’o [ʒo˦ʔo˧] /ʒóˀo/ PROX.1
(3.93)	a.	yu̱u̱ [ʒu˧u˩˧] /ʒùù´/ ‘stone’	b.	nu̱’u [nũ˩ʔũ˧] /nùˀu$_n$/ ‘teeth’

In plain CVV roots this generalization is exceptionless, while in glottalized CVˀV roots the overwhelming majority have identical vowels, but there are a few exceptions. In roots with a medial consonant (CVCV and CVˀCV), there is a strong trend towards identical vowels, but there are many roots that depart from that trend. Table 3.3 shows counts of vowel co-occurrence in oral and nasal CVˀV and CVCV roots, arranged in rows according

Table 3.3: Vowel co-occurrence in Nieves Mixtec roots with glottalization or a medial consonant

a. Oral CVˀV

$V_1 \backslash V_2$	i	e	a	o	u
i	10		4	1	
e		6			
a	1		14		
o				13	
u					4

b. Nasal CVˀV

$V_1 \backslash V_2$	ĩ	ẽ	ã	õ	ũ
ĩ	6				
ẽ		2			
ã			11		1
õ					
ũ					15

c. Oral CVCV

$V_1 \backslash V_2$	i	e	a	o	u
i	59		24	28	
e		3	2	2	
a	36		22	5	9
o	3			13	
u			7		23

d. Nasal CVCV

$V_1 \backslash V_2$	ĩ	ẽ	ã	õ	ũ
ĩ	8		3	6	
ẽ					
ã	9		7	1	
õ	3				
ũ	5		4		3

to the first vowel and columns according to the second vowel. The roots with identical vowels fall on the diagonal, and roots with different vowels are off the diagonal. Plain CVV roots are not included because they uniformly have identical vowels, while glottalized CVˀCV roots are not included because there are insufficient examples in the word list to show meaningful patterns.

Among the CVˀV roots (Table 3.3a, b), as mentioned, there are just a few exceptions to the generalization of identical vowels. Most of the exceptions to this generalization are adjacent /a/ and /i/, and many of them show variation, where the alternate forms conform to the generalization. These words are shown in (3.94–3.95) with reconstructed forms (Josserand 1983) and forms from Xochapa (Stark, Johnson, & González de Guzmán 2003), which is affiliated with Alcozauca (Alc).

(3.94)

a. ja̲’yi
[xa˩ʔi˧] ~ [xa˩ʔʒi˧]
/xàˀʒi/
‘son’
(Alc [se˧ʔe˧])

< *saʔji

b. ki̲’a
[ki˩ʔa˧] ~ [kʲa˩ʔa˧]
/kìˀa/
‘cross-sex sibling’
(Alc [ku˧ʔva˧])

c. xi’an ~ xa’an
[ʃĩ˥ʔã˥] ~ [ʃã˥ʔã˥]
/ʃíˀá$_{\text{n}}$/ ~ /ʃáˀá$_{\text{n}}$/
‘hawk’
(Alc [ʃĩʔɲã])

(3.95) a. i̲’a̲ ~ i̲’va̲ b. yi’a̲
[i˧ʔa˩] ~ [i˧ʔva˩] [ʒi˧ʔa˩]
/ìˀà/ ~ /ìˀvà/ /ʒiˀà/
‘salty’ ‘thread’
(ALC [u˩ʔva˩]) (ALC [iʔva])
< *oʔwe < *juʔwe

Alcozauca is located in the state of Guerrero, about 35 km west of Nieves. These forms are apparently all words which derive historically from glottalized disyllabic words (CVˀCV) with intervocalic /ʒ/ (*j) or /v/ (*w). Josserand does not provide a reconstructed form for /kìˀa/ ‘sibling’ (3.94b) or /ʃíˀá$_n$/] ‘hawk’ (3.94c), but the forms from Alcozauca suggest they should be reconstructed with *w and *j, respectively, as the /v/ in the Alcozauca forms (as in Nieves) are the regular realization of *w, and /ɲ/ in the Alcozauca form for ‘hawk’ is the regular realization of *j in nasal contexts (Josserand 1983). There are a two additional words, shown in (3.96), which have adjacent vowels other than [a] and [i].

(3.96) a. chi̲’ó b. sa̲’u̲n
[tʃi˩ʔo˦] [sã˧ʔũ˩]
/tʃìˀó/ /sàˀù$_n$/
‘nest’ ‘fifteen’
(ALC [tʃi˩ʔʒo˥]) (ALC [ʃã˩ʔũ˩])
<*xeʔũ<*uxi õʔõ’

The Alcozauca form for (3.96a) suggests that it too historically had an intervocalic *j, while Josserand reconstructs (3.96b) as a fusion of *uxi ‘ten’ (Nieves [u˧sʲu˩]) and *õˀõ ‘five’ (Nieves [ũ˧ʔũ˩]). Since diphthongs are not legal in plain CVV roots, but the sequences [a]–[i] and [i]–[a] are common in disyllabic CVCV roots, I consider the CVˀV roots with non-identical vowels to be disyllabic, having retained their disyllabic structure even though they have lost their former medial consonant.

As noted by Macaulay (1996) for Chalcatongo Mixtec, the trend towards identity extends into the CVCV roots. The trend in CVCV roots for Nieves Mixtec is shown in Table 3.3c, d. Of the 236 oral CVCV roots in the sample, 120 (51%) have identical vowels, whereas we should expect about 30% identical vowel roots if the vowels were distributed independently according to their observed probabilities of appearing in each vowel position. For example, if the probability of CiCi words was determined only by the marginal probabilities of CiCV words and CVCi words, then we would expect:

$$\begin{aligned} P(\text{CiCi}) &= P(\text{CiCV})P(\text{CVCi}) \\ &= \frac{59+36+3}{236}\frac{59+24+28}{236} = 19.5\% \end{aligned}$$

If 19.5% of the roots in Table 3.3 had two /i/ vowels, we would find 46 such roots, whereas the observed count is 59. The same procedure for each of the vowels produces an expected count of 70 roots with identical vowels, whereas the observed count is 120. According to a binomial test, this difference is highly statistically significant (p = 0.000).

The preference for identical vowels also shows in some suppletive verb forms, shown in (3.97–3.101).

(3.97) a. kixi
[ki˧ʃi˧]
/kiʃi/
RE:do

b. kaja
[ka˧xa˧]
/kaxa/
IR:do

(3.98) a. ki̲xi̲
[ki˧ʃi˩]
/kìʃì/
RE:sleep

b. ku̲ju̲
[ku˧xu˩]
/kùxù/
IR:sleep

(3.99) a. sisi
[si˧si˧]
/sisi/
RE:eat.bread

b. kusu
[ku˧su˧]
/kusu/
IR:eat.bread

(3.100) a. chichi
[ʧi˧ʧi˧]
/ʧiʧi/
RE:bathe

b. kuchu
[ku˧ʧu˧]
/kuʧu/
IR:bathe

(3.101) a. si̱no
[sĩ˩nõ˧]
/sìnu/
RE:run

b. ku̱nu
[kũ˩nũ˧]
/kùnu/
IR:run

The initial vowel change is associated with the change in root mood (described in section §3.4), while the change in the second vowel is a result of harmony or vowel copy.

3.3.5 Palatal phonotactics

There are strong restrictions on the vowels after coronal consonants, such that it is nearly possible to reduce the apico-alveolar and lamino-alveolar consonants to a single place. The surface distribution would then be explained by palatalization triggered by the following vowel. The front vowels /i/, /e/, and /ĩ/, as well as the high back vowel /u/, all typologically attested triggers of palatalization (Bateman 2011), cooccur with /tʲ/ and /^{n}dʲ/ rather than /t/ and /^{n}d/ (3.102–3.105).

(3.102) a. tyito
[tʲito]
/tʲito/
'firewood'

b. ndyí'í
[^{n}dʲi˥ʔi˥]
/^{n}dʲíˀí`/
'purple'

c. *[tito], *[^{n}diʔi]

(3.103) a. tye̱'e̱
[tʲe˧ʔe˩]
/tʲèˀè/
'vine'

b. ndye'e
[^{n}dʲe˧ʔe˧]
/^{n}dʲeˀe/
'see'

c. *[teʔe], *[^{n}deʔe]

(3.104) a. tyí'ín
[tʲĩ˥ʔĩ˥]
/tʲíˀí$_{n}$/
'tiny'

b. *[tĩʔĩ]

(3.105) a. tyutyu
[tʲu˧tʲu˧]
/tʲutʲu/
'paper'

b. ndyu̱'u̱
[^{n}dʲu˧ʔu˩]
/^{n}dʲùˀù/
'lie down'

c. *[tutu], *[^{n}duʔu]

Meanwhile, the other back vowels /o/ and /ũ/ co-occur with /t/ and /^{n}d/ as in (3.106, 3.107) rather than with /tʲ/ and /^{n}dʲ/.

(3.106)	a. to’ó	b. ndó’ó	c.	
	[to˧ʔo˦]	[^{n}do˥ʔo˥]	*[tʲoʔo], *[^{n}dʲoʔo]	
	/toˀó/	/^{n}dóˀó/		
	‘saint’	2P		

(3.107)	a. tu̱’un	b.
	[tũ˩ʔũ˧]	*[tʲũʔũ]
	/tùˀu$_{n}$/	
	‘word’	

In contrast, the distribution of post-alveolar consonants is unrestricted, as shown in (3.108, 3.109).

(3.108)	a. chílí	b. chíín	c. che̱e	d. chúchu
	[ʧi˥li˥]	[ʧĩ˥ĩ˥]	[ʧe˩e˧]	[ʧu˥ʧu˦]
	/ʧílí/	ʧíí$_{n}$ˋ	/ʧèe/	/ˊ\ʧuʧu/
	‘lizard’	‘fingernail’	‘steer’	IPFV\bathe
				‘bathing’

(3.109)	a. chó’o	b. chuun	c. chaa	d. chani
	[ʧo˥ʔo˦]	[ʧũ˧ũ˧]	[ʧa˧a˧]	[ʧã˧nĩ˧]
	/ʧóˀo/	/ʧuu$_{n}$/	/ʧaa/	/ʧani/
	LAT:PROX.1	‘work’	‘a little’	‘hello’[7]
	‘towards here’			

The place contrast between coronal nasals is also contextually neutralized, though in a narrower context. For some speakers, /ĩ/ restricts the distribution of /n/, neutralizing it with /ɲ/, such as in (3.110), while other speakers maintain a contrast, as in (3.111).

(3.110)	a. ñi̱i̱	b. ñi̱i̱	c. ñí’ín	d. ñí’ín
	[ɲĩ˧ĩ˩]	[ɲĩ˧ĩ˩]	[ɲĩ˥ʔĩ˥]	[ɲĩ˥ʔĩ˥]
	/ɲììˊ/	/ɲììˊ/	/ɲíˀí/	/ɲíˀíˋ/
	‘blood’	‘salt’	‘strong’	‘hen’

<OO MIN0882>

[7] The greeting /ʧani/ is used only between compadres, i.e. between the parents and godparents of a child.

(3.111)	a.	nii	b.	ñii	c.	ní’ín	d.	ñí’ín
		[nĩ˧ĩ˩]		[ɲĩ˧ĩ˩]		[nĩ˥ʔĩ˥]		[ɲĩ˥ʔĩ˥]
		/nìì´/		/ɲìì´/		/ní^{ʔ}í/		/ɲí^{ʔ}í`/
		‘blood’		‘salt’		‘strong’		‘hen’

<FC MIN0877>

Furthermore, no evidence has been found of a contrast between [nĩ] and [ɲĩ] in unstressed syllables—neither the second syllable of a disyllabic root nor in functional morphemes.

As noted in §3.2.1, the one context where the apico-alveolar and lamino-alveolar stops contrast is before /a/ and /ã/, as in (3.112, 3.113).

(3.112)	a.	táá	b.	tani	c.	ndaa
		[ta˥a˥]		[tã˧nĩ˧]		[^{n}da˧a˩]
		/táá/		/tani/		/^{n}dàà/
		‘sir’		‘crumble’		‘straight’

(3.113)	a.	tyaa	b.	tyani	c.	ndyaa
		[t^{j}a˩a˧]		[t^{j}ã˧nĩ˧]		[^{n}d^{j}a˧a˧]
		/t^{j}àa/		/t^{j}ani/		/^{n}d^{j}aa/
		‘man’		‘between’		‘watch over’

The limited contrast suggests an alternative analysis under which these words in (3.113) with the palatalized stops before /a/ and /ã/ have an underlying palatal glide, and that this glide is responsible for the palatalized surface form. This alternative analysis is shown in (3.114).

(3.114)	a.	tyaa	b.	tyani	c.	ndyaa
		[t^{j}a˩a˧]		[t^{j}ãnĩ]		[^{n}d^{j}a˧a˧]
		/tjàa/		/tjani/		/^{n}djaa/
		‘man’		‘between’		‘watch over’

This allophonic analysis has the advantage of allowing the unification of the apico-alveolar and lamino-alveolar stops. In addition, as discussed in §3.2.1, palatal off-glides are attested with a few other consonants, shown in (3.115, 3.116).

(3.115)	a.	kusiá’a̲n [ku˧sʲã˥ʔã˩] /kusíˀà$_{n}$/ IR:eat.meal ‘will eat a meal’	b.	kia̲’a [kʲa˩ʔa˧] /kìˀa/ x.sibling ‘cross-sex sibling’	c.	tyimia’an [tʲi˧mʲã˥ʔã˩] /tʲi´–miˀà/ ZO–devil ‘devil’

(3.116)	a.	u̲su̲ [u˧sʲu˩] /ùsiù/ ‘ten’	b.	ku̲su̲ [ku˧sʲu˩] /kùsì/ IR:eat.bread ‘will eat bread’	c.	kia̲ [kʲa˩] /kià/ COP.3.N ‘it is’	d.	sia̲a̲n [sʲã˧ã˩] /siàà$_{n}$/ PROX.2 ‘here by you’

However, the allophonic analysis has a few disadvantages. Phonetically, the palatal off-glide is phonetically quite short and integrated with the preceding consonant. Secondly, the allophonic analysis requires allowing the segment /j/ as a phoneme or deriving it from /ʒ/, admitting the diphthong /ja/ (or the consonant clusters /tʒ/ and /^{n}dʒ/) while not permitting any other diphthongs or consonant clusters. In addition, the /ja/ diphthong (or /tʒ/ and /^{n}dʒ/ clusters) would be quite contextually limited itself—with the exception of the words in (3.115, 3.116), /ja/ would only be found after coronal stops. Finally, some speakers are quite aware of the difference between the apico-alveolar and lamino-alveolar stops, and easily identify the [tʲ] in high vowel contexts as the same as that of /tʲàa/ ‘man’, and not that of /táá/ ‘sir’. In the practical orthography in incipient use in the community, words that have stops in high vowel contexts (e.g. /tʲutʲu/ ‘paper’) are considered to be inaccurate if the palatalization is not explicitly marked (i.e. <tyutyu> is preferred over <tutu>). Though it is analytically possible to ascribe the observed distribution to palatalization and an underlying /ja/ diphthong, the synchronic psychological reality seems to be that of distinct apico-alveolar and lamino-alveolar stops with contextually limited contrast.

In sum, the contrast of /t/ versus /tʲ/ and /^{n}d/ versus /^{n}dʲ/ is only found before /a/ and /ã/. The contrast is neutralized to the lamino-alveolar version before /i/, /u/, /e/ and /ĩ/, and it is neutralized to the apico-alveolar version before /ũ/ and /o/. In addition, /n/ and /ɲ/ are neutralized before /ĩ/, in all contexts for some speakers and in unstressed contexts for all speakers.

3.3.6 Labial phonotactics

In contrast to the coronals, where consonant-vowel phonotactics favor similar adjacent consonants and vowels, the phonotactics of labials disfavor adjacent similarity, a constraint also found in other Mixtecan languages (Mak & Longacre 1960; Silverman 1993). The restricted structures include $C_{LAB}V_{LAB}$, $C_{LAB}VC_{LAB}$ and $V_{LAB}C_{LAB}$, all within a morpheme. The strongest restriction is $*C_{LAB}V_{LAB}$, that is, between a labial consonant and the following vowel. The only instances of a labial consonant (including /k^{w}/ as well as /m/, /v/, /p/ and /^{m}b/) followed by a back vowel are in loanwords, such as in (3.117).

(3.117)	a. mbúrró	b. mbó’ló	c. púntá
	[^{m}bu˥ro˥]	[^{m}bo˥ʔlo˥]	[pu˥nta˥]
	/^{m}búró`/	/^{m}bó^{ʔ}ló`/	/púntá`/
	‘donkey’	‘bunch’	‘point’
	<Sp. [buro]	<Sp. [boluðo]?	<Sp. [punta]

Similarly, $*C_{LAB}VC_{LAB}$ is unviolated, as there are no morphemes with two labial consonants. There are words with sequential labial consonants, but in all cases examined so far, such as those in (3.118), these words are poly-morphemic with a morpheme boundary intervening between the labial consonants.

(3.118)	a. ví’í ví’í	b. va̲’a va
	[vi˥vi˥ʔi˥]	[va˩ʔva˧]
	/ví-ví^{ʔ}í/	/và^{ʔ}a=va/
	bit-bit	good=INT
	‘a tiny bit’	‘very good’

The constraint $*V_{LAB}C_{LAB}$ is a weaker restriction, holding between the first vowel and the medial consonant in disyllabic roots. The oral labial consonants /^{m}b/, /v/ and /k^{w}/ do not follow /u/ or /o/, even though /v/ and /k^{w}/ are well-attested in root-medial position. However, there are words with /m/ after /ũ/, such as in (3.119).

(3.119)	a. ko̲mi̲	b. to̲mi	c. noma̲	d. no̲mi̲
	[kõ˩mĩ˩˥]	[tõ˩mĩ˧]	[nõ˧mã˩]	[nõ˧mĩ˩]
	/kùmì´/	/tùmi/	/numà/	/nùmì/
	‘four’	‘feather’	‘bush’	‘hurry’

A restriction spanning the whole root $*C_{LAB}VCV_{LAB}$ might also apply weakly. Disyllabic words with an initial labial consonant and a final labial vowel, such as those in (3.120, 3.121), are rare.

(3.120)	a. máʼno	b. viko̱	c. vi̱ko̱
	[mã˥ʔnõ˧]	[vi˧ko˩˧]	[vi˧ko˩˧]
	/máˀnu/	/vikò´/	/vìkò´/
	‘sueño’	‘party’	‘cloud’

(3.121)	a. kuaʼno	b. kuaku	c. kuijo
	[kʷã˧ʔnõ˧]	[kʷa˧ku˧]	[kʷi˧xo˧]
	/kʷaˀnu/	/kʷaku/	/kʷixo/
	IR:grow	IR:cry	IR:load

Moreover, the words in (3.121) are arguably bimorphemic, as the initial /kʷ/ is a marginally productive prefix associated with irrealis mood, as discussed in §3.4.1. Note, however, that between labial vowels, as with other vowels, the phonotactics favor identity, as discussed in §3.3.4. There are many disyllabic roots with two labial vowels, and the two vowels have the same vowel quality, as in (3.122).

(3.122)	a. koto	b. joko̱	c. ndyuju	d. ku̱nu
	[ko˧to˧]	[xo˧ko˩˧]	[ⁿdʲuhu]	[kũ˩nũ˧]
	/koto/	/xokò´/	/ⁿdʲuxu/	/kùnu/
	IR:look	shoulder	voice	IR:run

The only exceptions are loanwords, which sometimes also show regularization to the native phonotactics, as shown in (3.123).

(3.123)	a. mbúrró	b. yúgó
	[ᵐbu˥ro˥] ∼ [ᵐbu˥ru˩]	[ʒu˥go˥] ∼ [ʒu˥ku˩]
	/ᵐbúró`/ ∼ /ᵐbúrù/	/ʒúgó`/ ∼ /ʒúkù/
	‘donkey’	‘yoke’
	<Sp. [buro]	<Sp. [ʒuɣo]
	<OO MIN0840> <FC MIN1062>	<MC MIN0652> <FC MIN0695>

3.4 Morphophonology of the verb

This section provides a description of phonological patterns of bimoraic verb stems. These patterns are associated with the lexical semantics but are only marginally productive. Throughout Mixtec languages there is a division between “regular” and “irregular” verb roots, thus designated because the irregular verbs use segmental marking of a particular mood distinction, while within the regular verbs, that mood distinction is unmarked or marked by tone only. The mood distinction is closely associated with certain aspectual distinctions, and because of this, the marking of irregular verbs has often been described in terms of aspect (Bradley 1970; Macaulay 1996; Johnson 1988; Shields 1988) or in tense terminology in pedagogical grammars (R. M. Alexander 1980; Williams 2007; Zylstra 2012; Towne 2012). However, following García Mejía (2012), I refer to these as the mood categories realis and irrealis. I first describe the irregular verbs and then discuss the regular verbs, which also show phonological patterns suggestive of marginally productive morphology.

3.4.1 Irregular verbs

In contrast to regular verbs, which have no segmental marking of the mood categories, irregular verbs may have either mood-marked roots or mood-marking prefixes. The irregular verbs constitute a minority of the verb roots, but they include many common verbs. The irrealis stems can be zero-derived as potential verb forms, which are used to describe future actions as in (3.124a), as well as to make commands and express purposes, while the realis stems are used with other aspects, which must be further marked, as in (3.124b).

(3.124) a. kakú tyí
[ka˧ku˥ɾi˥]
/kakú = tʲí/
IR:lay_egg = 3.ZO
'it will lay an egg'

< OO MIN0317:4:53.5 >

b. kuni ni̲ sakú tyí
[kũ˧ni˧ nĩ˩sa˧ku˥ɾi˥]
/kuni nì = sakú = tʲí/
yesterday PFV=RE:lay_egg=3.ZO
'yesterday it laid an egg'

< OO MIN0317:8:46.5 >

For most of the irregular verbs, as in (3.124), the irrealis stems have initial /k/ or /kʷ/, while the realis stems have initial /s/, suggesting prefixation. Because these prefixes are not found in the majority of verbs, and because there are phonological irregularities, these forms have conventionally been treated as suppletive in other Mixtec varieties (Macaulay 1996). However, Macaulay (1996) argues that the mood marking in Chalcatongo Mixtec should be analyzed as synchronic prefixation with low productivity, and García Mejía

(2012) treats the mood marking in Jicayán Mixtec as synchronic prefixation that applies in one class of verbs. In the description of Nieves Mixtec provided here, I make a distinction in the morphological gloss between verb stems that may be analyzed as involving low-productivity prefixation to a bound root, glossed with the mood feature set off by a colon (realis RE: or irrealis IR:), and truly suppletive verb roots, glossed with the mood feature set off by a period (RE. or IR.).[8]

In some of these verbs, such as those in (3.125, 3.126), there is a correspondence just between /k/ for irrealis (3.125) and /s/ for realis (3.126).

(3.125)	a. kasí	b. kuaku	c. katya	d. ka'ní
	[ka˧si˦]	[kʷa˧ku˧]	[ka˧tʲa˧]	[kã˧ʔnĩ˦]
	/kasí`/	/kʷaku/	/katʲa/	/kaˀní`/
	IR:eat_sweet	IR:laugh	IR:dig	IR:kill

(3.126)	a. sasí	b. saku	c. satya	d. sa'ní
	[sa˧si˦]	[sa˧ku˧]	[sa˧tʲa˧]	[sa˧ʔni˦]
	/sasí`/	/saku/	/satʲa/	/saˀní`/
	RE:eat_sweet	RE:laugh	RE:dig	RE:kill

In other verbs, as in (3.124) above and in (3.127, 3.128), the correspondence is between /kʷ/ in irrealis (3.127) and /s/ in realis (3.128).

(3.127)	a. kuaku (a and u underlined)	b. kueen	c. kua'no	d. kuañi
	[kʷa˨ku˩]	[kʷẽ˧ẽ˧]	[kʷã˧ʔnõ˧]	[kʷã˧ɲĩ˧]
	/kʷàkù/	/kʷee$_{n}$/	/kʷaʔno/	/kʷaɲi/
	IR:cry	IR:buy	IR:grow	IR:step_on

(3.128)	a. saku	b. seen	c. sa'no	d. sañi
	[sa̲ku̲]	[sẽ˧ẽ˧]	[sã˧ʔnõ˧]	[sã˧ɲĩ˧]
	/sàkù/	/see$_{n}$/	/saʔno/	/saɲi/
	RE:cry	RE:buy	RE:grow	RE:step_on

There are also a few verbs as in (3.129, 3.130) with a correspondence between /ku/

[8] Similarly, verbs with recognizable intransitive or repetitive morphology within the couplet are glossed with the feature set off by a colon (INTR: and REP:).

(3.129a, b) or /ka/ (3.129c, d) in irrealis and /si/ in realis (3.130).

(3.129)	a. kuni	b. kunu	c. kaka	d. kata
	[kũ˧nĩ˧]	[kũ˧nũ˧]	[ka˧ka˧]	[ka˧ta˧]
	/kuni/	/kunu/	/kaka/	/kata/
	IR:see	IR:run	IR:walk	IR:sing

(3.130)	a. sini	b. sino	c. sika	d. sita
	[sĩ˧nĩ˧]	[sĩ˧nõ˧]	[si˧ka˧]	[si˧ta˧]
	/sini/	/sinu/	/sika/	/sita/
	RE:see	RE:run	RE:walk	RE:sing

Several verbs as in (3.131, 3.132) have a correspondence between /k/ in irrealis (3.131) and /s/ in realis (3.132), along with vowel changes other than /u/ ~ /i/.

(3.131)	a. kusu	b. ko'o	c. koto	d. ke'en
	[ku˧sʲu˧]	[ko˧ʔo˧]	[ko˧to˧]	[kẽ˧ʔẽ˧]
	/kusi/	/koˀo/	/koto/	/keˀe$_{n}$/
	IR.eat_bread	IR.drink	IR.look	IR.give

(3.132)	a. sisi	b. si'i	c. sito	d. sa'an
	[si˧si˧]	[si˧ʔi˧]	[si˧to˧]	[sã˧ʔã˧]
	/sisi/	/siˀi/	/sito/	/saˀa$_{n}$/
	RE.eat_bread	RE.drink	RE.look	RE.give

Finally, there are a few verbs that have more clearly suppletive alternations between /k/-initial irrealis roots (3.133) and realis roots formed by some other change (3.134).

(3.133)	a. kivi	b. k<u>u</u>j<u>u</u>	c. kuchu	d. kaxi
	[ki˧vi˧]	[ku˧hu˩]	[ku˧tʃu˧]	[ka˧ʃi˧]
	/kivi/	/kùxù/	/kutʃu/	/kaʃi/
	IR.die	IR.sleep	IR.bathe	IR.smash

(3.134)	a. si'i	b. k<u>i</u>x<u>i</u>	c. chichi	d. xaxi
	[si˧ʔi˧]	[ki˧ʃi˩]	[tʃi˧tʃi˧]	[ʃa˧ʃi˧]
	/siˀi/	/kìʃì/	/tʃitʃi/	/ʃaʃi/
	RE.die	RE.sleep	RE.bathe	RE.smash

Even in the roots with the most unpredictable changes, the medial consonant rarely changes, and any vowel changes are in accordance with the phonotactic preference for identical vowel qualities within the couplet, as discussed in §3.3.4.

The analysis of most of the "irregular" verbs in terms of bound vowel-initial roots is somewhat supported by the existence of other verbs that appear to be derived from the same vowel-initial roots. With a few irregular verbs, in addition to the /k/-initial irrealis stems and /s/-initial realis stems, there are associated regular verbs with initial /^{n}d/ as in (3.135–3.138), which have the semantics of the repetitive prefix /na–/ ∼ /^{n}da–/.[9]

(3.135)	a. kwijo	b. sijo	c. ndyijo
	[k^{w}i˧ho˧]	[si˧ho˧]	[$^{n}d^{j}$i˧ho˧]
	/k^{w}ixo/	/sixo/	/$^{n}d^{j}$ixo/
	IR:load	RE:load	REP:load
	‘will load’	‘(has) loaded’	‘hold load’

(3.136)	a. ka̲ka̲	b. si̲ka̲	c. nda̲ka̲
	[ka˨ka˩]	[si˨ka˩]	[^{n}da˨ka˩]
	/kàkà/	/sìkà/	/^{n}dàkà/
	IR.request	RE.request	REP.request
	‘will request’	‘(has) requested’	‘ask for it back’

(3.137)	a. koto	b. sito	c. ndoto
	[ko˧to˧]	[si˧to˧]	[^{n}do˧to˧]
	/koto/	/sito/	/^{n}doto/
	IR:look	RE:look	REP:look
	‘will look’	‘(has) looked’	‘be alert’

(3.138)	a. kaja	b. kixi	c. ndaja
	[ka˧ha˧]	[ki˧ʃi˧]	[^{n}da˧ha˧]
	/kaxa/	/kiʃi/	/^{n}daxa/
	IR.make	RE.make	REP.make
	‘will make’	‘(has) made’	‘make it again’

Note that these repetitive verbs are regular verbs, unmarked for mood. A few other irregular verbs are associated with regular verbs that have initial /n/, as in (3.139) or /^{n}d/ as in (3.140), where the /k/-/s/ verbs are transitive and the /n/ or /^{n}d/ verbs are intransitive.

[9] Repetitive prefixes have several similar but distinct semantic functions, including reversive, iterative, stative and home orientation (i.e. motion towards/from a home base). They could reasonably be analyzed as multiple homophonous prefixes, but lacking a reliable criterion for distinguishing among them, I group them all under a single repetitive category.

(3.139)		a. kuna	b. suna	c. nuna
		[kũ˧nã˧]	[sũ˧nã˧]	[nũ˧nã˧]
		/kuna/	/suna/	/nuna/
		IR:open	RE:open	INTR:open

(3.140)		a. kaji	b. saji	c. ndaji
		[ka˧hi˧]	[sa˧hi˧]	[^{n}da˧hi˧]
		/kaxi/	/saxi/	/^{n}daxi/
		IR:close	RE:close	INTR:close

A couple of other verbs, shown in (3.141–3.142) have the same semantics but with initial /t/ (3.141) or /t^{j}/ (3.142) in the intransitive verb.

(3.141)		a. kaxi	b. xaxi	c. taxi
		[ka˧ʃi˧]	[ʃa˧ʃi˧]	[ta˧ʃi˧]
		/kaʃi/	/ʃaʃi/	/taʃi/
		IR.smash	RE.smash	INTR:smash

(3.142)		a. ka’ndya	b. sa’ndya	c. tya’ndya
		[ka˧ʔ^{n}d^{j}a˧]	[sa˧ʔ^{n}d^{j}a˧]	[t^{j}a˧ʔ^{n}d^{j}a˧]
		/ka^{ʔn}d^{j}a/	/sa^{ʔn}d^{j}a/	/t^{j}a^{ʔn}d^{j}a/
		IR:break_off	RE:break_off	INTR:break_off

3.4.2 Regular verbs

The regular verbs, which constitute the majority of verb roots, are unspecified with respect to mood and aspect. The regular verb roots can be zero-derived as potential verb forms as in (3.143a), or further marked for another aspect as in (3.143b).

(3.143) a. intya̲a̲n kaku léé
[ĩ˧t^{j}ã˧ã˩ ka˧ku˧ le˥e˥]
/it^{j}àà$_{n}$ kaku léé`/
tomorrow be_born baby
‘tomorrow a baby will be born’

<MC MIN0122:6:46.7>

b. ni̲ kaku an kuni
[nĩ˩ka˧ku˧ã˧ kũ˧nĩ˧]
/nì = kaku = a$_{n}$ kuni/
PFV = be_born = 3SF yesterday
‘she was born yesterday’

<OO MIN0317:3:17.5>

Regular verbs in general show trends in the initial consonants which suggest an association between these roots and initial /k/, /n/ and /^{n}d/. As mentioned above, a few verbs with initial /n/ or /^{n}d/ have intransitive semantics, such as those in (3.144), or repetitive semantics, such as those in (3.145, 3.146), as revealed by closely related verbs.

(3.144)	a.	b.
	nuna	nda̱ji
	[nũ˧nã˧]	[^{n}da˧hi˧]
	/nũnã/	/^{n}daxi/
	INTR:open	INTR:close
	‘swing open’	‘swing closed’

(3.145)	a.	b.	c.	d.
	ndoto	ndyijo	ndaja	nda̱ka̱
	[^{n}do˧to˧]	[^{n}d^{j}i˧ho˧]	[^{n}da˧ha˧]	[^{n}da˨ka˩]
	/^{n}doto/	/^{n}d^{j}ixo/	/^{n}daxa/	/^{n}dàkà/
	REP:look	REP:load	REP:make	REP:ask
	‘awake’	‘hold a load’	‘make it again’	‘ask for it back’

(3.146)	a.	b.	c.
	ndyisi	ndi’vi	nu̱’u
	[^{n}d^{j}i˧si˧]	[^{n}d^{j}i˧ʔvi˧]	[nũ˩ʔũ˨]
	/^{n}d^{j}isi/	/^{n}d^{j}i^{ʔ}vi/	/nù^{ʔ}u/
	REP:come	REP:enter	REP:go
	‘come home’	‘enter home’	‘go home’

But for many verbs, no particular semantics are associated with the initial consonants, and other initial consonants are also well-attested.

In a sample of 45 frequent regular bimoraic verb roots, the 12 roots shown in (3.147–3.149) have initial /k/.

(3.147)	a.	b.	c.	d.
	kaku	ka̱chi	ki’vi	ka’yi
	[ka˧ku˧]	[ka˩tʃi˨]	[ki˧ʔvi˧]	[ka˧ʔʒi˧]
	/kaku/	/kàtʃi/	/ki^{ʔ}vi/	/ka^{ʔ}ʒi/
	be_born	say	enter	paint

(3.148)	a.	b.	c.	d.
	kuun	kee	ke̱ta	ka’an
	[kũ˧ũ˧]	[ke˧e˧]	[ke˩ta˨]	[kã˧ʔã˧]
	/kuu$_n$/	/kee/	/kèta/	/ka^{ʔ}a$_n$/
	overflow	produce	drop_into	think

(3.149)	a.	b.	c.	d.
	kana	kani	ka̱’a̱n	ka’vi
	[kã˧nã˧]	[kã˧nĩ˧]	[kã˨ʔã˩]	[ka˧ʔvi˧]
	/kana/	/kani/	/kà^{ʔ}à$_n$/	/ka^{ʔ}vi/
	exit	hit	talk	read

Note that the initial /k/ of these roots does not mark irrealis, as realis verb forms are also formed from the same roots, as shown in (3.143b). Besides the intransitive and repetitive verbs listed in (3.144–3.146), the 10 verbs in (3.150–3.152) have initial /n/.

(3.150)	a. naa	b. nana	c. ni̲’i̲n	d. ne’en
	[nã˧ã˥]	[nã˧nã˧]	[nĩ˧ʔĩ˩]	[nẽ˧ʔẽ˧]
	/naá/	/nana/	/ni^{ʔ}i/	/ne^{ʔ}e/
	fight	go_up	receive	hold

(3.151)	a. naño	b. na̲’an	c. na̲’ma̲
	[nã˧ɲõ˧]	[nã˩ʔã˧]	[nã˧ʔmã˩]
	/naɲu/	/nà^{ʔ}a/	/nà^{ʔ}mà/
	swell	show	confess

(3.152)	a. no̲mi̲	b. na’na̲	c. naní
	[nõ˧mĩ˩]	[nã˧ʔnã˩]	[nã˧nĩ˥]
	/nùmì/	/na^{ʔ}nà/	/naní/
	embrace	get_full	be_scolded

Considering the complementary distribution of /n/ versus /^{n}d/ and /^{n}d^{j}/, determined by the nasal phonotactics discussed in §3.3.3, the eight verbs in (3.153–3.154) with initial /^{n}d/ or /^{n}d^{j}/ may be considered of the same group.

(3.153)	a. ndyayi̲	b. nda’yi̲	c. ndava	d. ndasi
	[^{n}d^{j}a˧ʒi˩]	[^{n}da˧ʔʒi˩]	[^{n}da˧va˧]	[^{n}da˧si˧]
	/^{n}d^{j}aʒì/	/^{n}da^{ʔ}ʒì/	/^{n}dava/	/^{n}dasi/
	shake	yell	jump	wet

(3.154)	a. ndyi̲’i̲	b. ndyiko	c. ndyusa	d. ndo’o
	[^{n}d^{j}i˧ʔi˩]	[^{n}d^{j}i˧ko˧]	[^{n}d^{j}u˧sa˧]	[^{n}do˧ʔo˧]
	/^{n}d^{j}ì^{ʔ}ì/	/^{n}d^{j}iko/	/^{n}d^{j}usa/	/^{n}do^{ʔ}o/
	finish	grind	vomit	suffer

It is possible that some of these roots reflect a repetitive prefix comparable to the verbs in (3.145, 3.146), but no non-repetitive root has been identified for these verbs.

Other initial consonants are also well-attested. Some regular verbs, as in (3.155, 3.156), have initial /t/ or /t^{j}/.

(3.155)	a. tyiin	b. tye’e	c. tyutyu	d. tyivi
	[t^{j}ĩ˧ĩ˧]	[t^{j}e˧ʔe˧]	[t^{j}u˧t^{j}u˧]	[t^{j}i˧vi˧]
	/t^{j}ĩĩ/	/t^{j}e^{ʔ}e/	/t^{j}ut^{j}u/	/t^{j}ivi/
	grab	know	whistle	appear

(3.156)		a. tyaa	b. taan	c. ta̲’vi	d. tani
		[tʲa˧a˧]	[tã˧ã˧]	[ta˩ʔvi˧]	[tã˧nĩ˧]
		/tʲaa/	/taa$_{n}$/	/tàˀvi/	/tani/
		knead	quake	till_soil	collapse

Several verbs, such as those in (3.157), have initial /ʒ/.

(3.157)	a. yata	b. ya̲kuá	c. ya’a	d. ye’e
	[ʒa˧ta˧]	[ʒa˩kʷa˦]	[ʒa˧ʔa˧]	[ʒe˧ʔe˧]
	/ʒata/	/ʒàkʷá/	/ʒaˀa/	/ʒeˀe/
	bake	clean	pass	light

Other verbs, such as those in (3.158), have initial /x/.

(3.158)	a. jaka	b. jama	c. jana
	[xa˧ka˧]	[xã˧mã˧]	[xã˧nã˧]
	/xaka/	/xama/	/xana/
	mix	change	confuse

A few verbs, as in (3.159), have initial /ɲ/.

(3.159)	a. ñu’un	b. ñuu	c. ñe’en
	[ɲũ˧ʔũ˧]	[ɲũ˧ũ˧]	[ɲẽ˧ʔẽ˧]
	/ɲuˀu/	/ɲuu/	/ɲeˀe/
	drag	beat	scratch

A few verbs have initial /s/, as in (3.160).

(3.160)	a. si̲si	b. sa’a̲n	c. sani
	[si˩si˧]	[sã˧ʔã˩]	[sã˧nĩ˧]
	/sìsi/	/saˀà$_{n}$/	/sani/
	numb	smell	step

And just a few attested verbs have initial /ʧ/ (3.161a, b) or /ʃ/ (3.161c, d).

(3.161)	a. chu’u	b. chichi	c. xi̲kó	d. xi̲i̲
	[ʧu˧ʔu˧]	[ʧi˧ʧi˧]	[ʃi˩ko˦]	[ʃi˧i˩]
	/ʧuˀu/	/ʧiʧi/	/ʃìkó/	/ʃìì/
	cook	mature	sell	decompose

In sum, the regular verbs show a strong preference for initial /k/, /n/ or /^{n}d/, which is suggestive of morphological structure, especially when compared to the marginally productive prefixes found in the irregular verbs. However, with the exception of the repetitive verbs marked with /n/ or /^{n}d/, the initial consonant of regular verbs is not associated with any morphological property.

3.5 Summary

This chapter described the segmental phonology of Nieves Mixtec. The consonant inventory is relatively small and tightly constrained by morpheme features and phonotactics. The vowel inventory is almost as large as the consonant inventory, and it is similarly tightly constrained by phonotactics. Finally, the initial consonant of bimoraic verbs is further restricted, only mildly within the regular verbs, but tightly associated with mood within the irregular verbs.

Chapter 4

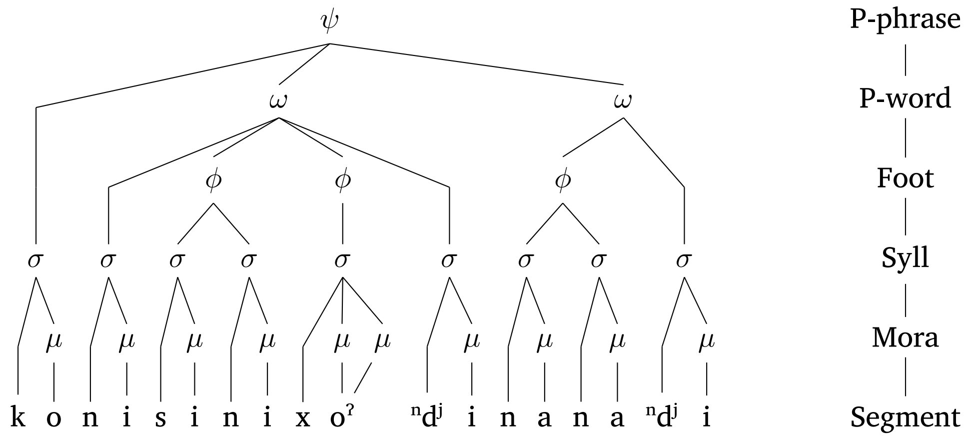
Stress phonology

4.1 Introduction

In this chapter, I provide a phonological characterization of Nieves Mixtec word prosody, showing that Nieves Mixtec word prosody includes a stress system. The chapter is structured as follows. In section §4.2, I summarize previous descriptions of stress systems in other Mixtec varieties. Many of the reported stress systems are similar to the Nieves Mixtec stress system, but the divergence of some descriptions serves to highlight empirical questions. In section §4.3, I show that Nieves Mixtec word prosody meets the phonological criteria for stress systems (discussed in §2.2.4), crucially including the property that one and only one syllable in each word bears primary stress. I then present evidence that the position of stress is determined by a trochaic foot aligned to the root. In section §4.4, I describe how the confluence of a few stress-dependent properties (vowel quantity, glottalization, and nasalization) provide phonological evidence of stress. Finally, section §4.5 describes prosodic patterns of loanword adaptation, which provide further evidence that stress is based on a trochaic foot.

Before turning to the details of the phonology of stress, it is necessary to reiterate the broader assumptions made in this work. By definition, I take stress to be a property of the phonological word, i.e. each phonological word has one and only one primary stress, and secondary stress, if found, is patterned within the phonological word (Hayes 1989; Hyman 2006). As a working hypothesis, I assume that the phonological word is embedded within a conventional prosodic hierarchy (Nespor & Vogel 1986; Selkirk 1986; 2011) that includes nested levels of segments, morae, syllables, feet, phonological words (P-words), and phonological phrases (P-phrases), as schematized in (4.1) below.

(4.1) Schematic of prosodic hierarchy



ko̲	ni̲ sini̲ jo̲'o ndyi̲	náná ndyi̲
[ko˩	nĩ˥(ˌsĩ˧nĩ˧)(ˈxo˩ʔo˧)ⁿdʲi˩	(ˈnáná)ⁿdʲì]
/kò´	nì = sinì–xòˀo = ⁿdʲì	náná` = ⁿdʲì/
NEG	PFV = RE:see–ear = 1P.EX	mother = 1P.EX

'We didn't hear our mother'[1]

I assume there are also higher prosodic domains, but they will not be particularly relevant to the discussion of word prosody, and determining their structure and realization is beyond the scope of this work. Furthermore, while recognizing that Nieves Mixtec may evidence multiple kinds of phonological words (Bickel, Hildebrandt, & Schiering 2009) or recursion in phonological words (Ito & Mester 2009), I take as a starting point just one kind of phonological word, without recursion, and for the phonological processes identified thus far, the prosodic domains in this basic hierarchy are sufficient.

[1] In this chapter, the stressed syllable is marked with the IPA stress mark (ˈ) before the syllable, and in data from Nieves Mixtec, the stressed foot is indicated with parentheses.

4.2 Survey of stress descriptions in Mixtec varieties

This section discusses various claims made in the literature about stress systems in Mixtec varieties. The goal is to summarize what is known about the phonology of stress in Mixtec generally and to open key questions in the analysis of Mixtec prosody. Much less has been written about stress systems than tone systems in Mixtec, but the existing descriptions have raised interest among theoretical linguists. Across Mixtec varieties, there is a common claim of default stress on the initial syllable of canonically bimoraic stems (discussed in §4.2.1). This contrasts with descriptions of final stress in Triqui (a group of non-Mixtec languages within the Mixtecan family) and Yoloxochitl Mixtec (YOL) (discussed in §4.2.2). Among Mixtec varieties, there are also several descriptions of stress shift triggered by particular enclitics (discussed in §4.2.3) and tone-dependent stress shift (discussed in §4.2.4).

4.2.1 Default stress

A consensus in the literature on Mixtec phonology points to default stress on the first syllable of the canonical bimoraic root or on the penultimate mora of the stem or word. For example, in Santo Domingo Nuxaá (NUX), words like those in (4.2), with a prefix and a disyllabic root, "show stress on the penultimate syllable, that is the initial syllable of the root" (McKendry 2013:295)

(4.2) Santo Domingo Nuxaa (NUX)

a.	chivi̲kó	b.	nuyusén
	[tʃi˧ˈβi˩ko˥]		[nũ˧ˈju˧sẽ˥]
	/tʃi´–βìkó/		/nu´–juse$_n$/
	ZO–cloud		WD–pineneedle
	'swallow' (bird)		'pitch-pine tree'

The difference between alignment to the root, the stem or the word and the difference between alignment to the initial edge versus the final edge are differences in terminology and analysis, not differences in the stress facts across Mixtec varieties. As I show in (4.3), the same stress algorithm is found in Ixpantepec Nieves.

Rather than making reference to the root, stem or word, many of the descriptions are stated in relation to the *couplet*, a concept originally introduced by K. L. Pike (1948) which is ambiguously morphological and phonological. The couplet is "the nucleus of the phonological word and usually the stem of the grammatical word" (E. V. Pike & Cowan 1967:1). The couplet's morphological basis is the minimal word and canonical root, both of which are bimoraic across Mixtec varieties. However, the couplet is not necessarily equivalent to either the word or the root. The descriptions of different Mixtec varieties have depended on rather different morphological analyses, which may reflect genuine morphological differences, beyond the differences in theoretical approaches of the descriptions. In different varieties and analyses, words can be longer than bimoraic, and roots can be monomoraic or trimoraic besides the usual bimoraic form. For example, Bradley (1970) treats most trimoraic verbs in the Jicaltepec variety of Pinotepa Mixtec (PIN) as derived by prefixation, but he divides bimoraic verbs into four classes, three of which have suppletive marking of aspect. In contrast, García Mejía (2012) analyzes the verb system of the closely related Jicayán variety of Pinotepa Mixtec as having just five suppletive verbs, and at least 25 bimoraic verbs are analyzed as having prefixation marking mood and separate tonal marking of aspect. In a dictionary count of over 2000 words from Yoloxochitl (YOL) (DiCanio et al. submitted), 66% of the lexicon is bimoraic words, all of which are considered non-derived, and 20% of the lexicon is non-derived trimoraic words. The remaining words are considered derived. On the phonological side, the couplet is apparently generally equivalent to a trochaic foot, though foot-based analyses have only appeared for two varieties in more recent literature, Coatzospan (COA) (Gerfen 1996) and Santo Domingo Nuxaá (NUX) (McKendry 2013). For K. L. Pike (1948), describing the phonology of San Miguel el Grande, which is affiliated with Chalcatongo (CHL), the couplet is a unit of two tonemes forming the nucleus of a word. Because San Miguel el Grande limits tonal configurations to one toneme per mora, a couplet defined this way is equivalent to a bimoraic stem, but in other Mixtec varieties that permit monomoraic tone contours, the couplet has to be defined as bimoraic (e.g. Gerfen 1996; McKendry 2013) or—in analyses with two heterosyllabic short vowels in place of long vowels—as disyllabic (e.g. Hunter & Pike 1963; Pankratz & Pike 1967; E. V. Pike & Cowan 1967).

Generalizing across Mixtec varieties, Josserand (1983:180) defines the couplet as "composed of two syllables and carrying stress on the first of these two," implying that all Mixtec varieties have the same stress behavior. Besides the data from Santo Domingo Nuxaa shown in (4.2), several other descriptions support the characterization of stress in Mixtec as falling on the first vowel of the couplet. In Ayutla (AYU) (Pankratz & Pike 1967:292), there is a "unit of time on the first syllable" of most couplets, realized as devoicing between the vowel and the following consonant or as lengthening of the following consonant. In the Jicaltepec variety of Pinotepa Mixtec (PIN) (Bradley 1970:17), stress is described as falling on the first of two syllables in a "microsegment", which is meant to indicate a couplet in cross-linguistic terms. According to the description, stressed vowels in Jicaltepec sound longer, and stress interacts with vowel quality and tone pitch. In Acatlan (ACA) (E. V. Pike & Wistrand 1974), each word has one stressed syllable, and in disyllabic stems, it is the first syllable that is stressed. Stress is marked by lengthening of either the stressed vowel or the following consonant. In Diuxi (DIU) (E. V. Pike & Oram 1976:321–322), the first vowel of a non-compound stem bears a stress that induces vowel lengthening. In Mixtepec (MIX) (E. V. Pike & Ibach 1978:271–272), the first vowel of the couplet is usually louder than other vowels, and in couplets that do not have a couplet-medial glottal stop, the first vowel of the couplet has longer duration than other vowels. In Atatlahuca (ATA) (R. M. Alexander 1980:6–8)—under an analysis in which enclitics are not part of the word and every vowel is the nucleus of a syllable—disyllabic words have initial stress, and polysyllabic words are stressed on the penultimate syllable. In Silacayoapan (SIL) (North & Shields 1977:21), stress is said to fall on the first syllable of the couplet, as long as no vocalic enclitic is attached. Likewise in Alacatlatzala (ALA) (Zylstra 1980:16), stress is said to fall on the first syllable of the couplet, as long as no vocalic enclitic attaches.

In sum, default stress on the first syllable of the couplet is widely reported in Mixtec. As I describe in §4.3, the data from Ixpantepec Nieves supports this same stress placement, on the first syllable of the couplet. Section §4.3.2 also discusses the two analyses of alignment to the right edge of the stem or the left edge of the root.

4.2.2 Final stress

These descriptions of stress on the first syllable of the couplet in Mixtec contrast with descriptions of final stress in most other Otomanguean languages, including Zapotec (Chávez-Peón 2008; 2010), and Triqui (DiCanio 2008; DiCanio 2010). The comparison with Triqui is particularly relevant, because it is within the Mixtecan language family, and several distributional properties that are considered evidence of final stress in Triqui have parallels in Mixtec. Furthermore, one Mixtec variety, that of Yoloxochitl (YOL) has been described to have final stress, partially on the basis of these same distributional properties (DiCanio p.c., DiCanio et al. submitted).

In Yoloxochitl, the minimal word is bimoraic as in other Mixtec varieties, but stress falls on the final syllable (DiCanio et al. submitted:13), as shown in (4.3).[2]

(4.3)	a. kaà	b. kakà	c. yakà
	[ˈka˧a˨]	[ka˧ˈka˨]	[ja˧ˈka˨]
	/kāà̆/	/kākà̆/	/jākà̆/
	‘metal’	‘lime (stone)’	‘granary’

Note that in the case of monosyllabic roots (4.3a), the algorithm that assigns stress to the final syllable produces the same result as the algorithm that assigns stress to the initial syllable. But the resulting stressed syllable differs in the case of roots that are bimoraic and disyllabic (4.3b, c). It is also reported that trimoraic roots are not uncommon in Yoloxochitl, and as a consequence, there are minimal pairs as in (4.4), showing contrastive vowel length in the stressed syllable (DiCanio et al. submitted:11).

(4.4)	a. ndokò	b. ndokòò
	[^{n}do˧ˈko˨]	[^{n}do˧ˈko˨o˨]
	/^{n}dōkò̆/	/^{n}dōkò̆ò̆/
	‘crayfish’	‘get out of bed’

The evidence of final stress reported by DiCanio et al. (submitted) is durational. In bimoraic disyllabic words like those in (4.3b, c), final vowels are 30%–50% longer than ini-

[2] In the phonemic transcriptions, I have used the diacritic of a LM contour on the vowels that bear a Λ tone—a mid-low tone level between M and L—, for consistency with other varieties that have a surface Λ tone (Atatlahuca, Xochapa, and Nuxaa; see §6.4.1 and §6.4.2). However, if an analysis of Yoloxochitl surface Λ as an underlying LM contour is even possible, it is not as apparent as it is in the other varieties.

tial vowels, and medial consonants are about 20% longer than initial consonants. These differences are smaller than those reported in a similar study of Itunyoso Triqui (DiCanio 2010), where in comparable disyllabic words, final vowels are found to be 50% longer than initial vowels, and medial consonants are found to be 50% longer than initial consonants. It is also possible that the reported effects are influenced by word/phrase boundary effects (i.e. domain-final lengthening) rather than word prominence effects (i.e. stress). Nevertheless, the longer durations in both vowels and consonants in the final syllables in Yoloxochitl can be interpreted as evidence of final stress.

The distribution of tone and nasality can also be considered evidence supporting final-syllable prominence in Yoloxochitl (C. DiCanio p.c.). In bimoraic roots, the first mora licenses five tones (H, M and L, plus LM and LH), while the second syllable licenses at least eight tones (H, M, L, LM and LH, plus Λ,[3] ΛH and HΛ) (DiCanio et al. 2012). Similarly, the nasality of non-final vowels is predictable from (or co-determined with) the nasality of the syllable onset, while final vowels after voiceless consonants license a nasality contrast (DiCanio et al. submitted). This parallels the situation in Itunyoso Triqui, where a vowel nasality contrast is only licensed in final syllables, and the final syllable licenses four level tones and five contour tones, compared to just three level tones in non-final syllables (DiCanio 2010). Since contrast reduction is cross-linguistically associated with prosodically weak syllables, at least in the cases of tone (mentioned in §2.2.4) and vowel quality (mentioned in §2.3), these phonological distributions point toward final-syllable prominence. On the other hand, both of these distributional trends are widely reported in Mixtec, in varieties where final stress is not reported. For example, in Atatlahuca (ATA), just three level tones are licensed on the initial mora of bimoraic words in isolation, while these three tones plus two more ([Λ] and [MH]) are licensed in the second mora (R. M. Alexander 1980). (See §6.4.2 for discussion of the Atatlahuca tone system.) In Santo Domingo Nuxaa (NUX), out of seven possible surface tone patterns in isolated bimoraic words, the first mora bears [M] tone in all but two patterns, which both

[3]Following (McKendry 2013), I use "Λ" to denote the mid-low tone level between M and L, in Mixtec varieties that have four surface tone levels.

have [H] tone on the first mora, and the second mora bears any of five tones (McKendry 2013). As I discuss in chapter 6, contour tones in Ixpantepec Nieves can likewise surface on the final mora of bimoraic words in various phrasal contexts, but contour tones on the first mora only occur under the influence of morphological tone. This again results in somewhat higher tone density on the final mora of the couplet, relative to the first mora. As discussed in §3.3.3, the orientation of nasality to the final vowel is a property general to Mixtec (Marlett 1992). The nasality of all voiced segments in a morpheme (both vowels and consonants) can be reasonably well modeled across Mixtec varieties as a property that associates to the final vowel of the morpheme and spreads leftwards. In most varieties (including Yoloxochitl), medial voiceless consonants block nasal spreading, leaving the final vowel as the only nasal segment in the nasal disyllabic couplets that have a voiceless medial consonant. In some varieties, medial voiceless consonants are transparent to nasal spreading or targets of nasalization (e.g. *t → ^{h}n in Atatlahuca), and in some varieties (including Ixpantepec Nieves), medial voiceless consonants block nasalization of the final vowel. But in the majority of Mixtec, the phonotactics of nasality leaves the final vowel of the couplet as the privileged context for the nasal contrast.

In sum, stress falling on the final vowel of the couplet is reported in Yoloxochitl Mixtec, just as in Triqui and Zapotec. The evidence of stress includes vowel lengthening and greater contrasts in tone and nasality on the final vowel. However, since the final vowel of the couplet is a privileged context for tone and nasal contrasts in many Mixtec varieties, either these properties in Yoloxochitl are not licensed by stress, or else the possibility of final stress should be reconsidered in other Mixtec varieties.

4.2.3 Morphologically-conditioned stress

The descriptions of two Mixtec varieties, Silacayoapan (Sil) (North & Shields 1977) and Alacatlazala (Ala) (Zylstra 1980), mention stress shift that is conditioned by certain vocalic enclitics. Out of all the existing phonological descriptions of Mixtec varieties, Silacayoapan is the variety that is geographically and linguistically closest to Nieves Mixtec. A similar phenomenon is found in Nieves Mixtec (discussed in §4.3.2), so despite the exceptional nature of stress shift by a limited number of enclitics, it is of particular interest to us here.

In Alacatlazala Mixtec, the exceptional stress shift is said to be limited to a single enclitic, /=ì/ 1S (Zylstra 1980:28). The description for Silacayoapan Mixtec first says the process “takes place when /i/ or /e/ are postposed to a nonverbal couplet”, but the following sentence describes the triggering conditions as “single-vowel enclitic person markers” (North & Shields 1977:31). According to the list of pronominal enclitics provided by Shields (1988:406–407), the intersection of these two descriptions consists of two enclitics, /=ì/ ∼ /=è/ 1S and /=í/ 1P.IN. However, North and Shields (1977:31) provide four examples of /=ì/ ∼ /=è/ 1S and one of /=à/ 3F.FRM. These are shown in (4.5–4.6).

(4.5) Silacayoapan Mixtec (SIL)

a. ja̱’yi i̱
[ha˩ʔˈʒi˥i˩]
/hàˀʒī=i̱/
child=1S
‘my child’

b. ja̱ta̱ i̱
[ha˩ˈta˥i˩]
/hàtà=i̱/
back=1S
‘my back’

c. chíi̱n a̱
[ʧĩ˥ˈĩ˩ã˩]
/ʧíì$_n$=à/
ring=1S
‘my ring’

(4.6)

a. ve’e i̱
[ve˧ˈʔe˥e˩]
/veˀe=ì/
house=1S
‘my house’

b. jé’e̱ i̱
[he˧ˈʔe˥e˩]
/héˀè=ì/
ring=1S
‘my ring’

According to the description, the stressed syllable in these words also obtains a H tone as part of the same process, but in the cited data, the tone change is shown in the /=ì/ ∼ /=è/ 1S examples but not with the /=à/ 3F.FRM example. The assimilation of /i/ to the preceding /e/ in (4.6) is described as a separate process particular to /=i/ 1S.

In §4.3.2 I show that the comparable phenomenon that sounds like stress shift in Nieves is actually a perceptual effect of the confluence of two phonological processes unrelated to stress. Enclitics with L tone can cause the formation of a HL falling contour tone, and vocalic enclitics can cause the formation of long vowels or diphthongs. These effects create a perceptual impression of syllable prominence, especially when combined.

However, the phonetic properties associated with stress in the first syllable of the couplet are unaffected, indicating that the first syllable of the couplet remains stressed.

4.2.4 Tone-dependent stress

The descriptions of several Mixtec varieties discuss phenomena of tone-dependent stress, in which the placement of stress is influenced by the tone sequence of the word. The tone dependence of this phenomenon helps illuminate the role of tone in the perceived stress shift in the Mixtec varieties of Alacatlatzala, Silacayoapan and Ixpantepec Nieves, just discussed in the previous subsection. Of the Mixtec stress systems described as tone-dependent, the one described for Ayutla (AYU) Mixtec (Pankratz & Pike 1967:293) has received the most attention in the theoretical literature. The stressable domain in Ayutla Mixtec includes the couplet and any following syllables (enclitics), preferring H tone on the stressed syllable and L tone on the immediately post-tonic syllable. The favored stress position is the first position within the stressable domain that satisfies both of these requirements, as in (4.7–4.8).[4]

(4.7) Ayutla Mixtec (AYU)

	a.		b.		c.
a.	xíni̱’	b.	láxá ra̱	c.	sa̱ta̱’ ka̱ ra̱
	[ˈʃĩ˥nĩ˩ʔ]		[la˥ˈʃa˥ɾa˩]		[sa˩ta˩ˈka˥ɾa˩]
	/ʃínìˀ/		/láʃá=ɾa/		/sàtàˀ=ka=ɾa/
	‘hat’		orange=3M		buy=AUG=3M
			‘his orange’		‘he will buy more’

(4.8)

a.	xa̱ku̱’	ka̱sá’	b.	naya̱’	sa̱síi̱’
	[ˈʃa˩ku˩	ˈka˥a˩sa˥ʔ]		[ˈna˧ja˩	ˈsa˥a˩si˥i˩ʔ]
	/ʃàkùˀ	kàsáˀ/		/nājàˀ	sàsíìˀ/
	few	son-in-law		dog	NEG.IPFV:eat
	‘a few sons-in-law’			‘the dog is not eating’	

The stressed H tones in (4.7a, b) are underlying tones, while the crucial surface H tones in (4.7c) and (4.8) are results of a phonological tone process conditioned by the preceding underlying glottal stop. If no H.L sequence is found within the stressable domain, the

[4]The underlying forms for the data from Ayutla Mixtec are not provided in the source, but have been added here in order to make the morphological structure clear. The underlying tones and final glottalization are generally clear from other data and tone rules in the source, but there may be some errors.

stress falls on the first syllable of a M.L sequence, as in (4.9).

(4.9)	a. chitya̲	b. toto̲-ra	c. lúlú láxá ɾà
	[ˈʧi˧tʲa˩]	[ˈto˧to˩ɾa˩]	[ˈlu˥lu˥ la˧ˈʃa˧ɾa˩]
	/ʧītʲà/	/tōtò = ɾa/	/lúlú láʃá = ɾa/
	‘banana’	clothing = 3M	small orange = 3M
		‘his clothing’	‘his orange is small’

The surface M tones in (4.9c) are also a result of a phonological tone process. If neither of the sequences H.L and M.L are in the stressable domain, the stress falls on the first H tone of the stessable domain, as in (4.10).

(4.10)	a. xíñú’ ra	b. kunu̲’ ra	c. kútátán’ ra
	[ˈʃĩ˥ɲũ˦ɾa˥]	[kũ˧nũ˩ˈɾa˥]	[ku˥ˈta˥tã˦ɾa˥]
	/ʃíɲúˀ = ɾa/	/kūnùˀ = ɾa/	/kú–tátá$_n$ˀ = ɾa
	pineapple = 3M	tobacco = 3M	IPFV.ku–heal = 3M
	‘his pineapple’	‘his tobacco’	‘he is taking meds’

Note that in (4.10c), the first syllable of the word is a prefix, outside the stressable domain, and so its H tone does not attract stress. Finally, if there is no H tone, stress falls on the first syllable of the couplet, as in (4.11).

(4.11)	a. ki̲si̲-a’	b. te̲sa̲va̲
	[ˈki˩si˩a˩ˀ]	[te˩ˈsa˩va˩]
	/kìsì = aˀ/	/tè–sàvà/
	pitcher = 3F	3M–young
	‘her pitcher’	‘boy’

Similar stress systems are described for the Mixtec varieties from Molinos (MOL) (Hunter & Pike 1963:25), Huajuapan (HUA) (E. V. Pike & Cowan 1967:7), and Mixtepec (MIX) (E. V. Pike & Ibach 1978:272). In all the varieties where tone-dependent stress is described, the stress falls on or after the first syllable of the couplet. And in all of them, the preferred stress position is the first syllable of a falling tone sequence, and the default position is the first syllable of the couplet. However, in two varieties (Ayutla and Mixtepec) where lengthening of the first vowel of the couplet is also mentioned, the tone-dependent stress is distinguished from that lengthening. The lengthening of the couplet is not influenced by tone sequence, while the tone-dependent stress is associated with loudness.

de Lacy (1999; 2002) heavily depends on these stress systems (especially that of

Ayutla Mixtec) in the development of an Optimality Theoretic typology of tone-sensitive stress systems. The association of stress to tone finds parallels in other tone-sensitive stress systems, such as Lithuanian (Blevins 1993), which stresses the first H tone syllable, and these systems have an inverse in stress-sensitive tone systems, such as Lamba (L. S. Bickmore 1995), which associates any H tone to all the stressed syllables of a word. In de Lacy's analysis, the preferences found in the Mixtec systems—H tone in stressed position and L tone in post-tonic position—are parallel to sonority-driven stress systems, such as the stress systems of Takia and Kiriwina (de Lacy 2003). In Takia, the stress algorithm favors high sonority [a] over mid sonority [e, o], and it favors [e, o] over low sonority [i, u]. In Kiriwina, the stress algorithm favors low sonority [i, u] in immediately post-tonic position.

However, contrary evidence is found in the segmental lengthening in Ayutla Mixtec and Mixtepec Mixtec, reported to be independent of the described tone-dependent stress. This segmental lengthening has led Hyman (2006:247) and McKendry (2013:62) to suggest that the stress is fixed on the first syllable of the couplet, and that the described system of tone-dependent stress is a perceptual effect and not phonological stress. The acoustic properties of these varieties might help disambiguate the nature of the described stress systems, but the acoustic properties are still unknown. The only published phonetic study of any of these varieties—Herrera Zendejas (2009) for Ayutla Mixtec—does not address stress or vowel duration.

The original description of Ayutla Mixtec mentions one phonological alternation which could be considered evidence of the phonological nature of the tone-dependent stress system. The first vowel of a restricted set of couplets can delete, and it is said to be more common when that vowel would not be the position of the tone-dependent stress (Pankratz & Pike 1967:294). The alternation occurs in couplets with initial /s, ʃ/ and medial /t, k, n/, as shown in (4.12–4.13).

(4.12) Ayutla Mixtec (AYU)

a. xi̲to̲
['ʃto˩]
/ʃìtò/
'bed'

b. xi̲to̲ a'
['ʃto˩a˩ˀ]
/ʃìtò = aˀ/
bed = 3F
'her bed'

c. xa̲ku̲ xi̲to̲
['ʃa˩ku˩ 'ʃi˥to˩]
/ʃàkùˀ ʃìtò/
few bed
'a few beds'

(4.13) a. kuéí sáná ra
['kʷe˥i˥ 'sna˥ɾa˩] ~ ['kʷe˥i˥ sa˥'na˥ɾa˩]
/kʷéí sáná = ɾa/
horse belong = 3M
'his horse'

b. ni̲xika̲ ra
[ni˩'ʃka˧˩ɾa˩] ~ [ni˩'ʃi˧ka˩ɾa˩]
/nì–ʃīkà = ɾa/
PFV–RE:walk = 3M
'he walked'

In (4.12a, b), where the couplet-initial vowel deletes, the vowel has L tone, a less preferred stress position than in (4.12c), where the vowel has a H tone due to a phonological tone process. In (4.13a), where the couplet-initial vowel is not stressed, the vowel deletion is reported as optional. But in (4.13b), the vowel deletion is also reported as optional, even though the couplet-initial vowel is stressed when not deleted, and it is the first vowel of a falling M.L tone sequence. Furthermore, as shown in (4.14–4.15), there are also examples where the deletion occurs regardless of the suitability of stressing the first vowel of the couplet.

(4.14) Ayutla Mixtec (AYU)

a. xta̲'
[ʃta˩ˀ]
/ʃtàˀ/
'tortilla'

b. ku̲mí' xta̲'
[ku˩mi˥ ʃta˥a˩ˀ]
/kùmíˀ ʃtàˀ/
four tortilla
'four tortillas'

(4.15) a. xti̲'
['ʃti˩ˀ]
/ʃtìˀ/
'nose'

b. xti̲' ra
[ʃti˩'ɾa˥]
/ʃtìˀ = ɾa/
nose = 3M
'his nose'

In (4.14), the couplet-initial vowel is deleted whether or not the tone process creates a H.L tone sequence (4.14b). In (4.15), the couplet-initial vowel is deleted whether or not the addition of an enclitic causes the stress to shift off of the couplet (4.15b).

In sum, most descriptions of stress in other Mixtec varieties have indicated default stress on the first vowel of the couplet (§4.2.1), but some descriptions have indicated final stress (§4.2.2) or mobile stress, dependent on either the inflectional morphology (§4.2.3) or the tone pattern (§4.2.4). The divergent descriptions suggest that more careful investigation of these phenomena are necessary. Just a few descriptions indicate the basis of the stress observations or provide arguments based on phonological distributions or stress-dependent processes. Instead, many of the descriptions implicitly rely on direct perception of stress or on impressions of vowel duration, perceived loudness or tone variants. On the one hand, it is possible that different Mixtec varieties involve different stress systems, but on the other hand, the phonetic correlates—such as segmental duration, perceived loudness and tone variants—could instead be effects of prosodic boundaries, morphological domains, or tone sequences. As the following description of the Nieves Mixtec stress system shows, it is difficult to disambiguate the effects of morphological and prosodic domains. However, distributional arguments point to couplet-initial stress. The following chapter (chapter 5) provides evidence that this couplet-initial stress has observable phonetic effects, apart from the effects of tone sequence.

4.3 Phonological description of stress

This section provides an overview of the phonological properties of stress in Nieves Mixtec, beginning by demonstrating in §4.3.1 that the phenomenon in question fits the typological category of word-level stress, rather than being lexical tone or phrasal accent, or an epiphenomenon of these. The next subsection (§4.3.2) summarizes the placement of primary and secondary stress, and analyzes the alignment of the stressed foot to the morphological root.

4.3.1 Diagnostics of stress

As discussed in section §2.2, the typological category of stress generalizes and formalizes an intuition of rhythmic beats in languages like English (Liberman & Prince 1977). Attempts to identify a cross-linguistic phonetic definition of stress, as reviewed in section §2.3, have found an assortment of acoustic measures that are each associated with stress in some languages, but none of which are associated with stress in all stress systems studied. Instead, each language that displays a stress system does so by a confluence of phonological and phonetic factors suggesting a rhythmic organization. Formal definitions of stress have depended on the notion of *headship* within a prosodic hierarchy. The head of a prosodic domain is the most prominent element within the domain, and the only necessary properties of a stress system (Hyman 2006) are those listed in (4.16).

(4.16)
a. The stress-bearing unit is the syllable: only syllables are prosodic heads in a stress system, neither higher (feet) nor lower (morae or segments) elements.
b. Stress is cumulative: only one syllable in a domain (e.g. foot, word, phrase) bears the highest prominence within that domain.
c. Stress is obligatory: every word (or at least every content word) must have a stressed syllable.

Hayes (1995:24–26) and Hyman (2006) each list a variety of properties that are typical of stress systems. These properties are listed in (4.17), generalizing across some differences in naming the properties.

(4.17)
a. Rhythmic distribution: When multiple stressed syllables occur within a word or phrase, these stressed syllables tend to non-adjacent.
b. Hierarchical organization: Stress systems typically have multiple degrees of stress, associated with morphological and/or prosodic hierarchies.
c. Lack of assimilation: Stress does not spread to neighboring syllables, as tone often does.
d. Privativity: The default value of stress is the absence of stress.

e. Demarcation: A common function of stress is providing a cue to morphological or word boundaries.

As Hyman (2006) argues, the properties in (4.17) may also be found in non-stress low-density tone languages, and might not be found in some stress systems. He additionally considers (4.16c) to be the only sufficient criterion for determining if a language has a stress system, as non-stress tone languages may take the syllable as tone bearing unit and forbid multiple tones per word.

The crucial properties of the Nieves Mixtec stress system are listed in (4.18), meeting all the criteria in (4.16).

(4.18)
a. Syllabic head: The stress is born by the syllable alone, as the unstressed syllable in disyllabic feet is weaker than the stressed syllable, nor can prominence fall on sub-syllabic elements, e.g. the second mora of a long syllable.
b. Cumulative: Within each foot, only the initial syllable is stressed, and within the word, only the initial syllable of the last root bears primary stress.
c. Obligatory: Every content word has a stressed syllable, though some function words do not.

It also has each of the properties listed in (4.19), meeting the criteria in (4.17).

(4.19)
a. Rhythmic distribution: Neighboring trochaic feet in compound words and in phrases create alternating rhythm.
b. Hierarchical organization: The secondary stress found on initial elements of compounds is subordinate to the primary stress of words, which are in turn subordinate to the accent of prosodic phrases.
c. Lack of assimilation: Though H and L tones spread in certain conditions, prominence of stress is fixed and does not assimilate.
d. Privativity: Syllables that are not the head of a foot are all unstressed, regardless of other details of prosodic structure.
e. Demarcation: The stress serves to identify the root.

Before considering the phonological factors that instantiate the rhythmic prominence of stress in Nieves Mixtec, we turn to the details of stress placement.

4.3.2 Stress placement

Nieves Mixtec maintains a close parallelism between the morphological structure and the prosodic structure. In the minimal word, consisting only of a bimoraic root, stress falls on the first syllable as in (4.20).

(4.20)
a. síká
[(ˈsi˥ka˥)]
/síká`/
'far'

b. ja̲'yi
[(ˈxa˩ʔʒi˧)]
/xà^{ʔ}ʒi/
'child'

c. lu̲ndyu̲
[(ˈlu˧^{n}d^{j}u˩)]
/lù^{n}d^{j}ù/
'stump'

In the case of CVV roots, the root forms a single heavy stressed syllable as in (4.21).

(4.21)
a. yáá
[(ˈʒa˥a˥)]
/ʒáâ/
'tongue'

b. ñí'ín
[(ˈɲĩ˥ʔĩ˥)]
/ɲí^{ʔ}í/
'hen'

c. nuù
[(ˈnũ˧ũ˩)]
/nuù´/
'face'

The position of stress is fixed, as it does not change with the addition of monomoraic functional morphemes. The stress position in the minimal word, as in (4.22), does not shift with the addition of prefixes, as in (4.23), or clitics, as in (4.24).

(4.22)
a. ndyichi
[(ˈ^{n}d^{j}i˧tʃi˧)]
/^{n}d^{j}itʃi/
'raised'

b. nana
[(ˈnã˧nã˧)]
/nana/
'go up'

(4.23)
a. kundyichi
[ku˧(ˈ^{n}d^{j}i˧tʃi˧)]
/ku–^{n}d^{j}itʃi/
INCH–raised
'stand up'
<MC MIN0324:2:14.6 >

b. nánana
[nã˥(ˈnã˧nã˧)]
/ˆ\na–nana/
IPFV\REP–go_up
'is going up'
<MO MIN0949:38.9>

(4.24) a. ni̱ si̱ku̱ndyichi ra
[nĩ˧si˩ku˩(ˈⁿdʲi˧tʃi˧)ɾa˧]
/nì = sì–ku–ⁿdʲitʃi = ɾa/
PFV = HAB–INCH–raised = 3M
'he was standing'

<MC MIN0324:6:12.9>

b. ko̱ ni̱ nana ka̱ ra
[ko˩nĩ˦(ˈnã˧nã˧)ɣa˩ɾa˩]
/kò´ = nì = nana = kà = ɾa/
NEG.RE= PFV= go_up= more= 3M
'he didn't go up anymore'

<MC MIN1001:3:44.4>

Functional morphemes are overwhelmingly monomoraic. As shown in (4.22–4.24), monomoraic morphemes are not stressable, and they depend prosodically on a root. In contrast to the stress system described for Silacayoapan Mixtec (North & Shields 1977), mentioned in §4.2, in Nieves Mixtec the stress is maintained on the first syllable of the root even when the 1S enclitic / = ì/ is added to the root, as in (4.25).

(4.25) a. ja̱'yi i̱
[(ˈxa˩ʔji˨˩)]
/xàˀʒí = ì/
child = 1S
'my child'

b. sa̱ta̱ i̱
[(ˈsa˩tᵊi˨˩)]
/sàtà´ = ì/
back = 1S
'my back'

c. ve'e i̱
[(ˈve˧ʔi˩)]
/veˀe = ì/
house = 1S
'my house'

To restate the description from Silacayoapan Mixtec, stress is described as shifting to the second vowel of the root when the 1S enclitic is hosted by a non-verb root, with the tone of the newly stressed vowel changing to H. This is exemplified by the examples in (4.26).

(4.26) Silacayoapan Mixtec (North & Shields 1977:31)

a. ja̱'yi i̱
[ha˩ʔˈʒi˥i˩]
child = 1S
'my child'

b. ja̱ta̱ i̱
[ha˩ˈta˥i˩]
back = 1S
'my back'

c. ve'e i̱
[ve˧ˈʔe˥e˩]
house = 1S
'my house'

In Nieves Mixtec, vocalic enclitics do likewise fuse with the final syllable of the root, and there are comparable tone changes associated with some roots (discussed in §6.3), but the initial syllable of the root does not destress.[5]

Since the canonical roots are bimoraic, and functional morphemes do not perturb the placement of stress, the described data could be modeled by two distinct metrical stress algorithms, stated in (4.27).

[5]There is often a perceptual impression of prominence on the / = i/ enclitic, especially where floating +H tones are involved, but as suggested for the cognate pattern in Diuxi (Daly 1978), an impression of stress on the enclitic may be due to misperception of a HL falling contour tone as prominence.

(4.27) a. ALIGN-LT: Align the stressed trochaic foot to the left edge of the root.

b. ALIGN-RT: Align the stressed trochaic foot to the right edge of the root.

These two algorithms are not mutually exclusive, as the phonology can enforce both constraints simultaneously. However, they do make different predictions regarding the stress patterns in a few components of the lexicon. These include words with vocalic enclitics, loanwords, trimoraic roots, and compounds. We discuss each of these in turn.

ALIGN-LT could apply equally well at any point in the phonological derivation, as long as an index to the initial root boundary is available. In contrast, ALIGN-RT must apply prior to the syllable fusion processes conditioned by vocalic enclitics, such as in (4.25). Otherwise, stress could fall on prefixes in words that have both a prefix and a vocalic enclitic, as in (4.28).

(4.28) a. síndye̲’e̲ i̲
[si˥(ˈⁿdʲe˩ʔi˥˩)]
/´\si–ⁿdʲèˀè´=ì/
IPFV\RE–look=1S
‘I am looking’

<MC MIN0379:0:15.1>

b. kúnúú an
[ku˥(ˈnũ˥ã˧)]
/´\ku–núú=a$_{n}$/
IPFV\INCH–LOC.face=3.N
‘It is on top’

<OO MIN0568:3:53.3>

In words like those in (4.28), the vocalic enclitic reduces the long root vowel to a short vowel. However, the reduced length does not cause the stress to shift onto the prefix. The stress remains on the root.

Some native trimoraic words are arguably monomorphemic. These words derive etymologically from monomoraic prefixes and canonical bimoraic roots, but loss of productivity in one or the other has obscured the morphological structure. These words depart somewhat from the otherwise strong association between stress and the root. In these cases, stress falls on the initial mora of the etymological root rather than the initial mora of the contemporary root. Or under the monomorphemic analysis, the stress falls on the syllable containing the penultimate mora, i.e. the penultimate syllable in the case of short vowels as in (4.29) and the final syllable in the case of a long vowel as in (4.30).[6]

(4.29)	a. indyiví	b. chí’iño̲	c. chi̲ko̲ndo̲
	[ʔi˧(ˈⁿdʲi˧vi˥)]	[ʧi˥(ˈʔi˧ɲo˩)]	[ʧi˩(ˈko˧ⁿdo˩)]
	/iⁿdʲiví/	/ʧí.iɲò/	/ʧìkòⁿdò̃́/
	‘sky’	‘foam’	‘elbow/knee’
	< *aⁿdevi	< *tɨ–ijuₙ	

(4.30)	a. siva̲’a	b. kotóó	c. tyíkui̲í
	[sɨ˧(ˈva˩ʔa˨)]	[ko˧(ˈto˥o˥)]	[tʲi˥(ˈkʷi˩i˥)]
	/sivàˀa/	/kotóó/	/tʲíkʷìí/
	‘old’	‘like’	‘water’
	< vàˀa ‘good’?		< kʷíî ‘clear’

The preservation of stress on the etymological roots of these words contrasts with the placement of stress on the initial mora of arguably bimorphemic bimoraic stems, such as the irregular verbs, discussed in §3.4.1. Several of these verbs are shown in (4.31, 4.32).

(4.31)	a. kaku	b. kuañi	c. kuni	d. kaka
	[(ˈka˧ku˧)]	[(ˈkʷã˨ɲĩ˩)]	[(ˈkũ˧nĩ˥)]	[(ˈka˧ka˧)]
	/kaku/	/kʷàɲì/	/kuní/	/kaka/
	IR:lay_egg	IR:step_on	IR:see	IR:walk

(4.32)	a. saku	b. sañi	c. sini	d. sika
	[(ˈsa˧ku˧)]	[(ˈsã˨ɲĩ˩)]	[(ˈsĩ˧nĩ˥)]	[(ˈsi˧ka˧)]
	/saku/	/sàɲì/	/siní/	/sika/
	RE:lay_egg	RE:step_on	RE:see	RE:walk

As shown, the stressed syllable of the bimoraic stems includes the etymological prefix (4.31a, b, 4.32a, b) or coincides with the etymological prefix (4.31c, d, 4.32c, d), associated with verbal mood. The stressed modal elements in irregular verbs as in (4.31, 4.32) are more productive than the unstressed etymological prefixes in trimoraic roots as in (4.29, 4.30). On that basis, the modal elements might be expected to be outside the stressable domain, but instead they are stressed. In the irregular verbs, stress placement on the etymological root rather than the modal element could be achieved by defective feet or iambic feet. Since the irregular verbs are stressed on the initial vowel of the bi-

[6] The reconstruction of /iⁿdʲiví/ as *aⁿdevi is based on orthographic usage in early texts discussed by Terraciano (2001), so it reflects 16th century Mixteca Alta pronunciation rather than Proto-Mixtec directly. The reconstruction of /ʧíʔiɲò/ as *tɨ-ijuₙis due to Josserand (1983), and the morphological analysis is uncertain.

moraic stem, this is evidence that stress placement is based on a strictly bimoraic trochaic foot. Since the initial syllable of the irregular verbs is stressed while the initial syllable of trimoraic roots is unstressed, these words support the analysis based on the ALIGN-RT stress algorithm.

As discussed in detail in §4.5, loanword adaptation allows roots that are longer than bimoraic, and loanwords maintain the stress position found in the Spanish source word. As a result, stress in loanwords is not strongly aligned to either edge. Loanwords may have antepenultimate stress as in (4.33) or even pre-antepenultimate stress as in (4.34), rather than on the penultimate mora as found in native roots.

(4.33)	a. telécfo̲no̲ [te˧(ˈle˥fõ˨)nõ˩] < [teˈlefono] ‘telephone’	b. sáva̲to̲ [(ˈsa˥va˨)to˩] < [ˈsaβaðo] ‘Saturday’	c. lúne̲xe̲ [(ˈlũ˥nẽ˨)ʃe˩] < [ˈlunes] ‘Monday’

(4.34) miérko̲le̲xe̲
[(ˈmjẽ˥ɾko˨)le˩ʃe˩]
< miércoles [ˈmjeɾkoles]
‘Wednesday’

Similarly, stress in loanwords may be far from the left edge, as in (4.35).

(4.35)	a. sevastyáa̲n [se˧va˧(ˈstʲã˥ã˨)] < [seβasˈtjan] ‘Sebastian’	b. kopuntadórá [ko˧pu˧nta˧(ˈðo˥ɾa˥)] < [komputaˈðoɾa] ‘computer’

However, because penultimate stress and final stress are most common in the Spanish source words, most loanwords have penultimate stress as in (4.36) or final stress with a long vowel as in (4.37).

(4.36)	a. sandyáví [sa˧(ˈⁿdʲa˥.vi˥)] < [sanˈtjaɣo] ‘Santiago’	b. chiváto̲ [ʧi˧(ˈva˥to˩)] < [ʧiˈβato] ‘billy goat’	c. lamétá [la˧(ˈmẽ˥ta˥)] < [liˈmeta] ‘bottle’

(4.37) a. josée̲
[ho˧(ˈse˥e˨)]
/xoséè/
'José'

b. dañée̲l
[da˧(ˈɲẽ˥ẽ˨l)]
/daɲéèl/
'Daniel'

c. melóo̲n
[mẽ˧(ˈlõ˥õ˨)]
/me(ˈlóò$_{n}$)/
'melon'

These words effectively conform to the ALIGN-RT constraint, though the cause of this alignment pattern is faithfulness to the source word stress, not the native phonology. In addition, the vowel lengthening in words with final stress (4.37) supports the hypothesis that stress is based on a strictly bimoraic foot.

In compounds—both nominal compounds and verbal compounds—primary stress falls on the last root in the word. The initial root is less prominent, but several variable phenomena—discussed in the following subsections—suggest that the initial root in many compounds retains a lesser degree of prominence. I propose here that the initial root in compounds generally receives secondary stress, exemplified for nouns in (4.38) and verbs in (4.39).

(4.38) a. jiko̲ nda'a̲
[(ˌhi˧ko˩)(ˈ^{n}da˥ʔa˨˩)]
/xikò´–^{n}daˀà´/
neck–hand
'wrist'

<MC MIN0002:10:36.6>

b. ji'ndyi sa̲'a̲
[(ˌhi˧^{n}dʲi˧)(ˈsa˨ʔa˨˩)]
/xiˀ^{n}dʲi–sàˀà´/
butt–foot
'heel'

<MC MIN0002:15:00.1>

(4.39) a. kuni jo̲'o
[(ˌkə˧nə˧)(ˈxo˩ʔo˨)]
/kuni–xòˀo/
IR:see–ear
'listen'

<MC MIN0119:6:55.7>

b. kata sá'á
[(ˌka˧ta˧)(ˈsa˥ʔa˥)]
/kata–sáˀá`/
IR:sing–foot
'dance'

<MC MIN0449>

However, if the initial root is monosyllabic, it may destress and reduce to a monomoraic syllable, exemplified for nouns in (4.40) and for verbs in (4.41).

(4.40) a. ve’e ñu̱’u̱ ~ viñu̱’u̱
[(ˌve˧e˧)(ˈɲũ˧ʔũ˩)]~[vi˧(ˈɲũ˧ʔũ˩)]
/veˀe–ɲùˀù/
house–religious
‘church’

<MC MIN1225>

<MC MIN0082:15:60.0>

b. ka̱a ko̱mi̱
[ka˧(ˈkõ˩mĩ˩˨)]
/kàa–kòmì´/
iron–four
‘four o’clock’

<OO MIN0521>

<FC MIN0869>

(4.41) a. ka’a̱n jíkí
[ka˧(ˈxi˩ki˥)]
/kaˀà$_n$–xíkí`/
speak–play
‘joke’

<OO MIN0956>

b. ya̱a̱ nda’a̱
[ʒa˧(ˈⁿda˧ʔa˩˨)]
/ʒàà–ndaˀà´/
separate–hand
‘abandon’

<MC MIN1223>

The prominence of the last root in compounds suggests influence of the ALIGN-RT stress constraint. Contrary to the prediction of the ALIGN-LT constraint, the leftmost stressable syllable is not the most prominent, especially in words with destressed and reduced initial roots as in (4.40, 4.41). Notably, the prosodic headship of the last root can not be attributed to semantic headship. In noun compounds, the first root is consistently the semantic head, and the second root is the modifier. For example, /xikò´–ndaˀà´/ ‘wrist’ (4.38a) is compositionally the hand’s neck, and /kàa–kòmì´/ ‘four o’clock’ (4.40b) is compositionally the fourth bell. Among verb compounds, some such as (4.41a) are composed of two verbal roots, which can be analyzed as either left-headed or copulative compounds. The other verbal compounds are left-headed, with an initial verb root modified by the second root, which is usually a noun as in (4.39, 4.41b).

4.4 Stress-dependent properties

As shown, Nieves Mixtec maintains a close parallelism between the morphology and the prosodic structure. As a result, much of the evidence for stress contrasts could arguably be attributed to morphological differences. However, there are several distinct distributional differences between stressable and non-stressable morphemes, which together indicate the relevance of stress rather than a coincidence of strictly morphological properties. The phonological properties discussed in the following sections are: vowel quantity in §4.4.1, glottalization in §4.4.2 and nasality in §4.4.3. Alongside a few related synchronic alternations, these distributional differences demonstrate the legitimacy of distinguishing between stressed and unstressed syllables. These same phenomena also support the distinction between unstressed and secondary stressed syllables and between secondary stressed and primary stressed syllables, though the status and distribution of secondary stress merits further investigation that is beyond the scope of this dissertation.

4.4.1 Vowel quantity

As discussed in §4.2.1, minimal words and canonical roots are bimoraic across Mixtec. According to the analysis used here, these "couplets" are either disyllabic with short vowels or monosyllabic with long vowels. In contrast, affixes and most clitics are monosyllabic with short vowels. As a result, there are three possible approaches to the analysis of vowel quantity (4.42).

(4.42)
a. Disyllabic couplets: CVV couplets are lexically specified as disyllabic, but may reduce to monosyllables by phonological processes
b. Phonemic vowel length: CVV couplets are lexically specified with long vowels but may reduce to short vowels by morphological processes or destressing
c. Stress-to-weight: CVV couplets are not specified for vowel length, but they lengthen to CVV to make a heavy syllable when stressed.

K. L. Pike (1948) considered CVV couplets in San Miguel el Grande Mixtec to be disyllabic, and descriptions of other Mixtec varieties during the following half century followed that analysis. Without framing it as an issue of stress or prosody, he discusses several distributional differences and processes that place couplets in prominent positions and monomoraic clitics in other positions. Macaulay (1987; 1996) continues the disyllabic analysis in discussion of San Miguel el Grande Mixtec and the neighboring variety of Chalcatongo, treating identical vowels in both CVV and CVCV couplets as vowel harmony. However, two kinds of correspondences between disyllabic and monosyllabic forms are distinguished. Fast speech "contraction" synchronically derives monosyllabic forms from underlying disyllabic forms, while prefixes and "phrasal affixes" are underlyingly monosyllabic, with only etymological association to disyllabic forms. Tranel (1995; 1996) reanalyzes the data from San Miguel el Grande in terms of moraic theory and autosegments, treating CVV couplets with identical vowels as monosyllabic, but treating both plain CVV couplets with non-identical vowels (which are found in San Miguel el Grande) and glottalized CV^{ʔ}V couplets as disyllabic. Gerfen (1999) argues that the evidence for or against the disyllabic analysis in Coatzospan Mixtec is inconclusive and ultimately irrelevant. In his view, the bimoraic structure of canonical roots is necessary and sufficient to describe the phonology, and the syllable structure does not matter. He does not mention any processes that might affect phonological vowel length, as his evidence for stress is all from glottalization and phonetic duration. McKendry (2013:67–75) treats both plain CVV and glottalized CV^{ʔ}V couplets as monosyllabic. When these couplets are in stressed position, they have long vowels. However, only the final root in compounds is stressed, so when a monosyllabic couplet is the initial root in a compound, it is not stressed and it reduces to a short vowel. McKendry does not explicitly reject a stress-to-weight analysis, but as she considers the monomoraic form to be a "reduced" form, the description indicates a phonemic vowel length analysis. McKendry notes that the reduction of initial monosyllabic couplets avoids stress clash, though in her analysis, there is never more than one stressed syllable in a word, even in compounds where both roots are disyllabic. Following McKendry, I maintain a phonemic vowel length analysis in this dissertation.

The basic facts in Nieves Mixtec are the same as reported for other Mixtec varieties. Plain CVV and glottalized CV^{ʔ}V couplets occur only in stressed positions. In contrast, short vowels may appear in any unstressed position or in stressed positions as the initial syllable of a CVCV or CV^{ʔ}CV couplet. As in other varieties, there are suggestive correspondences between some roots and clitics, which highlight the more general prosodic differences between bimoraic roots and monomoraic clitics. For example, some of the pronominal enclitics are reduced forms of independent pronouns or nouns, such as the enclitic /=^{n}dó/ 'you (PL)' and the independent pronoun /^{n}dóˀó/ 'you (PL)' as in (4.43), or the enclitic /=ɲá/ 'she' and the noun /ɲaˀà´/ 'woman' as in (4.44).

(4.43) ndó'ó síta ndó
[(ˈ^{n}do˥ʔo˥) (ˈsi˥ta˧)^{n}do˥]
/^{n}dóˀó ´\sita = ndó/
2P IPFV\RE:sing = 2P
'you all are singing'

<OO MIN0085:3:43.2>

(4.44) a. jo̱'o ñá
[(ˈxo˩ʔo˧)ɲã˥]
/xòˀo = ɲá/
ear = 3F
'her ear'

<MC MIN0288:3:58.4>

b. iin ña'a̱
(ˈĩ˧ĩ˧) (ˈɲã˧ʔã˧˦)]
/ii$_{n}$ ɲaˀà´/
one woman
'a woman'

<MC MIN0190:4:39.1>

Similarly, the discourse deictic enclitic /=ká/ as in (4.45a) is a reduced form of the spatial medial deictic /káa/ as in (4.45b).

(4.45) a. nuu̱ yito̱ ká
[(ˌnũ˧ũ˧˦)(ˈʒi˥to˧)ga˥]
/nuù´–ʒitò´ = ká/
face–tree = MED
'on the tree'

<MC MIN0385:7:11.0>

b. to̱mi káa
[(ˈtõ˩mĩ˧) (ˈka˥a˧)]
/tùmi káa/
feather MED
'that feather'

<OO MIN0077:11:11.0>

And the realis verbal negation marker /kò´=/ as in (4.46a) is a reduced form of the negative existential /kòò´/ as in (4.46b).

(4.46) a. ko̱ chúun-ra
[ko˩(ˈtʃũ˥ũ˦)ɾa˧]
/kò´ = ˆ\tʃuu$_{n}$ = ɾa/
NEG.RE = IPFV\work = 3M
'he doesn't work'

<OO MIN0397:6:07.9>

b. ko̱o̱ yo̱o̱
[(ˈko˩o˦) (ˈʒo˧o˩)]
/kòò´ ʒòò/
NEG.exist moon
'the moon isn't out'

<MC MIN0010:20:11.6>

Following Macaulay (1987), I consider these correspondences to be etymological rather than synchronic, as many enclitics are not so easily identified with contemporary roots.

They serve to illustrate the distributional restrictions, not regular morphophonological processes.

In a few cases there is evidence of synchronic vowel shortening in compounds and proclitics. I analyze these contexts as involving optional secondary stress. Examples of shortening in compounds, shown above in (4.40, 4.41), are repeated in (4.47, 4.48) for convenience, along with two more examples in (4.49).

(4.47) a. ve’e ñu̱’u̱ ~ viñu̱’u̱
[(ˌve˧e˧)(ˈɲũ˧ʔũ˩)]~[vi˧(ˈɲũ˧ʔũ˩)]
/veˀe–ɲùˀù/
house–religious
‘church’

<MC MIN1225>

<MC MIN0082:15:60.0>

b. ka̱a ko̱mi̱
[ka˨(ˈkõ˩mĩ˩˧)]
/kàa–kòmì´/
iron–four
‘four o’clock’

<OO MIN0521>

<FC MIN0869>

(4.48) a. ka’a̱n jíkí
[(ˌkã˧ã˨)(ˈxi˩ki˦)] ~ [ka˨(ˈxi˩ki˦)]
/kaˀà$_n$–xíkí`/
speak–play
‘joke’

<OO MIN0956>

b. ya̱a̱ nda’a̱
[(ˌʒa˨a˩)(ˈⁿda˧ʔa˩˧)]~[ʒa˨(ˈⁿda˧ʔa˩˧)]
/ʒàà–ndaˀà´/
separate–hand
‘abandon’

<MC MIN1223>

(4.49) a. nda’a̱ yo̱jó ~ ndáyo̱jó
[(ˌⁿda˧a˦)(ˈʒo˩ho˥˦)]~[ⁿda˥(ˈʒo˩ho˥˦)]
/ⁿdaˀà´–ʒòxó/
hand–metate
‘pestle’

<MO MIN0963>

b. yu’u̱ yé’é ~ yu̱yé’é
[(ˌʒu˧u˩)(ˈʒe˧˥ʔe˥)]~[ʒu˩(ˈʒe˧˥ʔe˥)]
/ʒūˀù´–ʒéˀê /
mouth–door
‘entryway’

<MO MIN0963>

Similarly, there is a set of stressable proclitics that initiate relative clauses, locative expressions or oblique verb arguments. These stressable proclitics may take primary stress, secondary stress or no stress depending on the prosodic context. For example, the locative/dative marker /nuù´/ may bear primary stress when its complement is unstressable, as in (4.50), or secondary stress when its complement (or the first word of the complement) is stressable, as in (4.51).

(4.50) ke’én nuu̲ ra
[(ˈkẽ˧ʔẽ˥) (ˈnũ˧ũ˩)ɾa˦]
/keˀé$_{n}$ nuù´=ra`/
IR:give on=3M
‘give it to him’

< OO MIN0319:7:58.6 >

(4.51) na̲kunúu rí nuu̲ yito̲
[nã˨kũ˩(ˈnũ˥ũ˦)ɾi˥ (ˌnũ˧ũ˥)(ˈʒi˥to˩)]
/`\na–ku–núu=ɾí nuù´=ʒitò´/
PFV\REP–INCH–face=3ZO on=tree
‘it (animal) got up on the tree’

<MC MIN0385:7:00.6>

But in some instances where the complement is stressable, the proclitic is unstressed and reduces to a short vowel as in (4.52, 4.53).

(4.52) nuu̲ káa kua̲’a yito̲
[nũ˩(ˈka˥a˦) (ˈkʷa˩ʔa˨) (ˈʒi˧to˩)]
/nù=´\kaa kʷàˀa ʒitò´/
on=IPFV\stand many tree
‘where there are many trees’

<MC MIN0385:6:09.8>

(4.53) ki̲xi̲ ra sí’in tyi̲na ra nuu̲ si̲to
[(ˈki˥ʃi˨)ɾa˩ si˥(ˈtʲĩ˩nã˨)ɾa˧ nũ˧(ˈsi˩to˨)]
/´\kìʃì=ɾa síˀi$_{n}$=tʲìna=ɾa nuù´=sìto/
IPFV\RE:sleep with=dog=3M on=bed
‘he is sleeping with his dog on a bed’

< MC MIN0385:0:23.2 >

Similarly, /síˀi$_{n}$/ ‘with’ may bear primary stress when its complement is unstressable, as in (4.54), or secondary stress when it’s complement is stressable, as in (4.55).

(4.54) ka’a̲n sí’in ra ná nana ra
[(ˈkã̰˧ã̰˩) (ˈsḭ̃˥ḭ̃˦)ɾa˧ nã˥(ˈnã˧nã˧)ɾa˧]
/kaˀà$_{n}$ síˀi$_{n}$=ɾa ná=nana=ɾa/
talk with=3M OPT=go_up=3M
‘tell him to go up’

<MO MIN0949>

(4.55)	si̱ka’a̱n na	sí’in aparátó
	[si˩(ˈkã̰˧ã̰˩)nã˩	(ˌsĩ˥ĩ˧)a˧pa˧(ˈɾa˥to˥)]
	/sì–kaˀà$_{\text{n}}$ = na`	síˀi$_{\text{n}}$ = apaɾátó`/
	HAB–talk = 3P	with = device
	‘they would talk with a device’	

< MC MIN0148:1:03.8 >

But in some instances as in (4.56, 4.57), it is unstressed and reduces to a short vowel.

(4.56)	ki̱xi̱ ra	sí’in tyi̱na ra	nuu̱ si̱to
	[(ˈki˥ʃi˩)ɾa˩	si˥(ˈtʲĩ˩nã˨)ɾa˧	nũ˧(ˈsi˩to˨)]
	/´\kìʃì = ɾa	síˀi$_{\text{n}}$ = tʲina = ɾa	nuù´ = sìto/
	IPFV\RE:sleep	with = dog = 3M	on = bed
	‘he is sleeping with his dog on a bed’		

< MC MIN0385:0:23.2 >

(4.57)	kua̱’a̱n i̱	sí’in nánà i̱
	[kʷã̰˧ʔĩ˩	si˥(ˈnã˥ni˥˩)]
	/kʷàˀà$_{\text{n}}$ = ì	síˀi$_{\text{n}}$ = nánà` = ì/
	RE:go = 1S	with = mother = 1S
	I was going with my mother	

< MC MIN0148:0:10.5 >

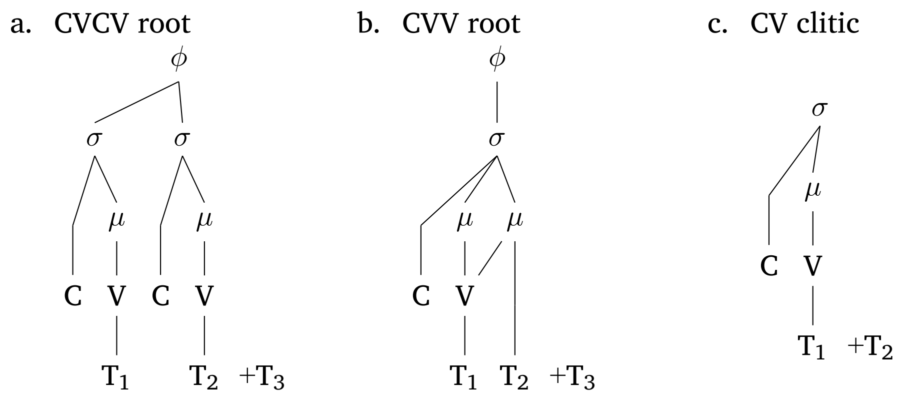
When a stressable monosyllabic morpheme is either the first root in a compound or cliticized to a stressed word, it may bear secondary stress. However, the secondary stress is optional because monosyllabic morphemes in those contexts can cause stress clash, as shown by the bracketed metrical grids in (4.58).

(4.58)	a.	(. X)	b.	(. X)	word
		(X) (X .)		. (X .)	feet
		(ˌ^{n}daá) (ˈʒò hó)		^{n}dá (ˈʒò hó)	

Destressing the monosyllabic morpheme as in (4.58b) avoids the stress clash encountered in (4.58a). In contrast, disyllabic morphemes are always stressed (either primary or secondary stress), since disyllabic roots that are the initial root in a compound do not create the context for stress clash.

The basis for considering monosyllabic roots to have underlying long vowels rather than stress-dependent lengthening rests on the distribution of tone. As described in §6.2, the distribution of tone in monosyllabic roots is quite similar to the distribution of tone in disyllabic roots and unlike the distribution of tone in monomoraic clitics. Regardless of their syllabic structure, canonical roots may sponsor up to three underlying tone targets—one for each mora, plus a floating tone. In contrast, monomoraic clitics may sponsor only two underlying tone targets—one associated to the vowel and one floating tone. This distribution is schematized in (4.59).

(4.59) Schematics of tone distribution



The similarity between the tone distribution on disyllabic roots (4.59a) and on monosyllabic roots (4.59b) indicates that the monosyllabic roots are underlyingly bimoraic, and thus the vowel in those roots is underlyingly long.

As shown, the distribution of vowel length and the stress-dependent alternations support the phonemic vowel length analysis. I treat CVV and CV^{ʔ}V roots as monosyllabic, as stress clash avoidance provides a motivation for destressing initial monosyllabic roots in compounds, as in McKendry's analysis of Santo Domingo Nuxaá Mixtec (McKendry 2013:67–75). In contrast to Santo Domingo Nuxaá Mixtec, the destressing process in Nieves Mixtec is optional, as variation is observed. When a monosyllabic root is the initial root in a compound, it may either bear secondary stress and retain bimoraic structure, or it may destress and reduce to a monomoraic syllable. Finally, I treat CVV and CV^{ʔ}V roots as underlyingly long, because the distribution of tone indicates they are underlyingly bimoraic.

4.4.2 Glottalization

As discussed in §3.3.2, there are two sources of phonetic glottalization in Nieves Mixtec. Contrastive glottalization is a prosodic feature associated with the stressed vowel of lexically marked roots, while epenthetic glottalization fills empty onset positions root-initially and at word boundaries. The distributions of both kinds of glottalization show the close relationship between prosodic structure and morphological structure.

First, the contexts for glottal epenthesis mark the initial boundaries of the prosodic word and the stressed foot. The stressed foot usually coincides with a bimoraic root, but the evidence shows that it is the prosodic domains and not the morphology that determines the distribution of epenthesis. As described in §3.3.2, glottal epenthesis is observed word-initially as in (4.60), even when that doesn't coincide with the stressed position.

(4.60) a. intya̲a̲n
[ʔĩ˧(ˈtʲã˧ã˩)]
/iₙtʲààₙ/
DIV:tomorrow
'tomorrow'

<MC MIN122:10:30>

b. u̲n kúu
[ʔũ˩(ˈku˩u˥)]
/ùₙ´=´\kuu/
NEG.IR=IPFV\POT
'cannot'

<OO MIN0792>

In (4.60), the epenthesis is both word-initial and utterance-initial, but as shown in (4.61–4.63), being word-initial is sufficient to condition glottal epenthesis.

(4.61) sindye'e i indivi
[si˥(ˈⁿdʲe˧ʔi˥˧) ʔi˧(ˈⁿdi˧vi˥)]
/\si–ⁿdʲeˀé=ì iₙⁿdʲiví/
IPFV\RE–watch=1S DIV:sky
'I am looking at the sky'

<MC MIN0379:0:15.1>

(4.62) a na'a o a un kuaa o
[ʔa(ˈnãʔo) ʔaũ(ˈkʷao)]
/a=naˀa=va a=ùₙ´=kʷaa=va/
Q=early=INT Q=NEG.IR=dark=INT
'is it early or late?'

<FC MIN1071>

(4.63) tyina kanakaa tyi insiyo ve’e tyi
[(ˈtʲĩnã) kənə̃(ˈkaa)ɾi ʔĩ(ˈsijo) (ˈvḛḛ)ɾi]
/tʲina ku–na–kaa = tʲi ii$_n$–siʒo veˀe = tʲi/
dog INCH–REP–sit = 3.ZO one–side house = 3.ZO
‘the dog is sitting beside its house’

< MC MIN0159:7:00.5 >

In (4.60a) and (4.61), epenthesis is observed on the unproductive vocalic prefix /i$_n$/ DIV. In (4.60b) and (4.62), the epenthesis is observed on the first proclitic of the prosodic word. And in (4.63), the epenthesis is observed on the destressed first element of the compound /ii$_n$–siʒo/ ‘beside’.

Besides in the word-initial position, glottal epenthesis is observed in the stressed syllable, even when that does not coincide with the word-initial position, as in (4.64, 4.65).

(4.64) a. ni̲ ku’e’ve sa̲’a̲ i̲
[nĩ˧ku˩(ˈʔe˧ʔve˧) (ˈsa˧ʔi˧˩)]
/nì = ku–eˀve sàˀà´ = ì/
PFV = INCH–hurt foot = 1S
‘I hurt my foot’

<OO MIN0316>

b. si̲’ii kuíká ndyi̲
[si˩(ˈʔi˧i˧) (ˈkʷi˥ka˥)^{n}dʲi˩]
/sì–ii kʷíká` = ^{n}dʲì/
HAB–EXIST rich = 1P.EX
‘we were rich’

<FC MIN0730:3:23.2>

(4.65) a. tá iin tá iin rí
[ta˥(ˈʔĩ˧ĩ˧) ta˥(ˈʔĩ˧ĩ˧)ɾi˥]
/tá = ii$_n$ tá = ii$_n$ = tʲí/
each = one each = one = 3.ZO
‘each animal’

<OO 2013JUN05>

b. ilo tyi uju
[(ˈʔi˧lo˧) tʲi˧(ˈʔu˧hu˧)]
/ilo` tʲi = uhu`/
rabbit and = deer
‘rabbits and deer’

<MC MIN0338:11:58.6>

In (4.64), the epenthesis is observed between a prefix and the root, while in (4.65), the epenthesis is observed between a proclitic and the root.

In contrast, there is no glottal epenthesis before vowel-initial morphemes that are not in the initial position of either the prosodic word or the stressed foot. There is no epenthesis before vocalic enclitics as in (4.66).

(4.66) a. ni̲ sita-i̲
[nĩ˩(ˈsi˧təi˩)]
/nì = sita = ì/
PFV = RE:sing = 1S
'I sang'

<OO MIN0086:0:20.0>

b. sísi-ún
[(ˈsi˥sũ˥)]
/´\sisi = ú$_n$/
IPFV\RE:eat.bread = 2S.FAM
'you are eating (tortilla)'

<OO MIN0090:3:11.8>

Nor is there epenthesis before pretonic vowels that are not word-initial, as in (4.67, 4.68).

(4.67) jaá ná u̲n nandojó na
[(ˈxaa) nãũnã(ˈ^{n}doho)nã]
/xaá ná = ù$_n$´ = na–^{n}doxó = na`/
thus OPT = NEG.IR = REP–forget = 3P
'so they won't forget'

<FC MIN0921>

(4.68) sika'an-na si'in aparato
[si(ˈkã̰ã̰)nã (ˌsii)apa(ˈɾato)]
/si–kaˀa$_n$ = na siˀi$_n$ = apaɾato/
HAB–talk = 3P with = device
'they would talk with a device'

< MC MIN0148:1:03.8 >

No epenthesis is observed before /ù$_n$´/ in (4.67) nor the first /a/ of /apaɾátó/ in (4.68), because they are not initial in the prosodic word.

Note that epenthesis is not observed on the first /a/ of /apaɾátó/ in (4.68) even though it is the first syllable of the polysyllabic root. In words where the stressed position does not coincide with the initial syllable of the root, such as loanwords as in (4.68) or trimoraic roots as in (4.69), the glottal epenthesis coincides with the stress position rather than with the initial syllable of the root.

(4.69) a. chi'iño
[tʃi(ˈʔiɲo)]
/tʃi.iɲo/
foam

b. si'ini
[si(ˈʔini)]
/si.ini/
late

There are relatively few vowel-initial polysyllabic loanwords and just these two attested cases of trimoraic roots with glottalization in this position. Their exceptionality demonstrates how closely aligned morphology and prosody are in Nieves Mixtec while illustrating the importance of distinguishing between them.

Second, only roots, as stressable morphemes, can be marked for glottalization, and only stressed vowels can be associated with contrastive glottalization. Within disyllabic glottalized roots, the contrastive glottalization is most associated with the stressed first vowel. The phonetic realization of glottalization varies across speakers, prosodic contexts, and speech rates, from a segmental glottal stop to distributed voice quality. When the glottalization is localized, it is realized at the end of the first syllable, either as rearticulation of the vowel or as interruption of the vowel as in (4.70).

(4.70) a.

tyi̲na	nda’yi̲ rí
[tʲĩnã	ⁿdaʔjiɾi]
/tʲìna	ⁿdaʔʒì = tʲí/
dog	yell = 3.ZO

‘the dog will bark’

<MC MIN0400:1:41.5>

b.

va̲si	kua’no	ná’no rí
[vasi	kʷaʔno	naʔnoɾi]
/vàsi	kʷaˀno	náˀno = tʲi/
IPFV.come	IR:grow	PL:big = 3.ZO

‘they are growing big’

<OO MIN0333:4:08.0>

When the glottalization is realized as distributed voice quality as in (4.71), the non-modal phonation may extend into neighboring syllables, but it is focused around the first syllable of the root.

(4.71) a.

tyi̲na	ndá’yi̲ tyí
[(ˈtʲĩ˧nã˧)	(ˈⁿda̰˥ʒḭ˩)tʲi˩]
/tʲìna	´\ⁿdaˀʒì = tʲí
dog	IPFV\yell = 3.ZO

‘the dog is barking’

<MC MIN0400:0:30.8>

b.

sikuu tyi	kityí na’no
[si(ˈkuu)ɾi	(ˌkiɾi)(ˈna̰no)]
/sì–kuu = tʲí	kitʲí = náˀno/
HAB–COP = 3.ZO	3.ZO = PL:big

‘they were big ones’

<OO MIN0333:8:05.3>

Regardless of how the glottalization in disyllabic roots is realized, the glottalization is more closely associated with the stressed syllable. In contrast, unstressable clitics and prefixes, like the unstressed second syllable of disyllabic roots, cannot be marked for glottalization. They are produced with modal phonation except as a consequence of proximity to a glottalized root. In sum, there is no glottalization contrast licensed in prefixes and clitics because they are unstressable, unlike the stressable roots which do license a glottalization contrast. And within the stressed root, the glottalization is most closely associated with the stressed vowel.

Finally, with compounds and stressable proclitics, the underlying glottalization of a morpheme is generally not realized under secondary stress and never realized when the morpheme destresses. For example, the initial elements of the compounds in (4.72) are underlyingly glottalized disyllabic roots, but they have no perceptible glottalization, either impressionistically or by examination of acoustic plots.

(4.72) a. ki̱’vi̱ ló’o̱-i̱
(ˌkìvì)(ˈlóʔì)]
kìˀvì–lóʔò = ì/
F.sibling–little.SG = 1S
‘my (F) baby sister’

<MC MIN0122:3:00.4>

b. ji’ndyi sa̱’a̱
[(ˌhīⁿdʲī)(ˈsàʔà)]
/xiˀⁿdʲi-sàˀà´/
butt-foot
‘heel’

<MC MIN0002:15:00.1>

Similarly, the stressable proclitics in (4.73) retain their bimoraic structure but have no apparent surface glottalization.

(4.73) a. ma̱’ní síyá
[(ˌmãnĩ)(ˈsija)]
/màˀní = síʒá`/
center = chair
‘between the chairs’

<MC MIN0170:3:46.0>

b. si’in aparato
[(ˌsii)apa(ˈɾato)]
/siˀi$_n$ = apaɾato/
with = device
‘with a device’

< MC MIN0148:1:03.8 >

The compounds in (4.74, 4.75) have a monosyllabic initial element, and thus they may be pronounced with either secondary stress or no stress on the initial element.

(4.74) a. ve’e ñu̱’u̱ ∼ viñu̱’u̱
[(ˌvee)(ˈɲũʔũ)] ∼ [vī(ˈɲũʔũ)]
/vēˀē-ɲùˀù/
house-religious
‘church’

<MC MIN1225>

<MC MIN0082:15:60.0>

b. tu̱’un ndá’ví ∼ tu̱ndá’ví
[(ˌtṵ̀ṵ̄)(ˈⁿdáʔví)] ∼ [tù(ˈⁿdáʔví)]
/tṵ̀ˀṵ-ⁿdáˀvî /
word-humble
‘Mixtec language’

<OO MIN0905>

<MC MIN0010:26:15.5>

(4.75) a. nda’a̱ yo̱jó ∼ ndáyo̱jó
[(ˌⁿdāá)(ˈʒòhó)] ∼ [ⁿdá(ˈʒòhó)]
/ⁿdāˀà´-ʒòxó/
hand-metate
‘pestle’

<MO 2013OCT04>

b. yu’u̱ yé’é ∼ yu̱yé’é
[(ˌʒūù)(ˈʒě̃ʔé)] ∼ [ʒù(ˈʒě̃ʔé)]
/ʒūˀù´-ʒéˀê /
mouth-door
‘entryway’

<MO 2013OCT04>

The variants with secondary stress retain a long initial vowel and may retain surface glottalization as in (4.74b) or lose glottalization as in (4.74a, 4.75). The variants with no stress reduce to a short initial vowel and have no surface glottalization. Finally, the words in (4.76), formed by reduplication of glottalized roots, have no surface glottalization in the unstressed copy.

(4.76)

a. ví'í ví'í
[vi(ˈviʔi)]
/víˀí–víˀí/
bit–bit
'a little bit'

<FC MIN0897>

b. kityí yá'á yá'á
[(ˌkitʲi)ʒa(ˈʒaʔa)]
/kitʲí = ʒáˀá–ʒáˀá/
3.ZO = tan–tan
'the tan one'

<FC MIN1089>

The incidence of surface glottalization demonstrates the dependence of glottalization on stress. The underlying glottalization is always realized in syllables that bear primary stress, optionally realized in syllables bearing secondary stress, and never realized in unstressed syllables.

4.4.3 Nasalization

As discussed in §3.3.3, the distribution of nasalization in native vocabulary makes it possible to derive segmental nasality from a morpheme-level nasal feature. But nasalization is also a prosodic feature, in that the vowel nasalization contrast is more dependent on neighboring segments in unstressed position than in stressed position. In unstressed position, a nasal vowel may co-occur with a nasal onset or an empty onset, but not an oral onset. This is shown for prefixes in (4.77) and clitics in (4.78).

(4.77)

a. nakava ra
[nã(ˈkava)ɾa]
/na–kava = ɾa/
REP–turn = 3M
'he will fall down'

<MC MIN0534>

b. intya̱a̱n
[ʔĩ˧(ˈtʲã˧ã˩)]
/i$_{n}$tʲàà$_{n}$/
DIV:tomorrow
'tomorrow'

<MC MIN0122>

c. kuákana
[kʷa(ˈkãnã)]
/kʷá–kana/
IMP.MOT–exit
'get out!'

<MC MIN0930>

(4.78)	a. kaka na	b. u̱n kúu	c. náni̱ tó
	[(ˈka˧ka˩)nã˩]	[ʔũ˩(ˈku˩u˦)]	[(ˈnã˥ni˩)to˩]
	/kàkà = na`/	/ù´ = ´\kuu/	/nánì´ = tó/
	IR:request = 3P	NEG.IR=IPFV\POT	PL:long = 3.WD
	‘they will request’	‘cannot’	‘they (sticks) are long’
	<MO MIN0940>	<OO MIN0792>	<OO MIN1049>

The prefix /kʷá–/ in (4.77c) and the clitic / = tó/ in (4.78c) have vowels that are etymologically nasal. The prefix /kʷá–/ is related to the verb /kʷáˀá$_{n}$/ ‘go (IMP)’, and the clitic / = tó/ is related to /ʒitò´/ ‘tree’, which Josserand (1983) reconstructs as /*jutuˀ$_{n}$/ in Proto-Mixtec. The distribution of nasality in the second syllable of disyllabic roots, as in (4.79), is quite similar.

(4.79)	a. kani	b. sa̱’u̱n	c. yito̱	d. a̱ji̱n
	[(ˈkãnĩ)]	[(ˈsãʔũ)]	[(ˈʒito)]	[(ˈʔãxĩ)]
	/kánì´/	/sàʔù$_{n}$/	/ʒitò´/	/àxì$_{n}$´/
	SG:long	fifteen	wood	delicious

A nasal vowel may co-occur with a nasal onset, as in (4.79a), or with an empty onset, as in (4.79b). But a nasal vowel does not co-occur with an oral onset, as in (4.79c), except that the onset /x/ is permitted with nasal vowels, as in (4.79d). In contrast, nasal vowels in stressed position, as in (4.80, 4.81), occur in a less restricted context.

(4.80)	a. nu̱ni̱	b. ñu̱tyí	c. u̱ni̱	d. a̱ji̱n
	[(ˈnũ˧nĩ˩)]	[(ˈɲũtʲĩ)]	[(ʔũnĩ)]	[(ˈʔãxĩ)]
	/nùnì´/	/ˈɲùtʲí/	/ùnì/	/àxì$_{n}$´/
	corn	sand	three	delicious

(4.81)	a. tu̱ún	b. túni̱	c. tyika̱jín
	[(ˈtũũ)]	[(ˈtũnĩ)]	/tʲi˧kã˩xĩ˦/
	/tùú$_{n}$/	/túnì/	/tʲi–kàxí$_{n}$/
	black	very	3.RND–kaxi$_{n}$
			‘big tostada’

A nasal vowel may co-occur with a nasal onset, as in (4.80a, b), whether the rest of the morpheme is nasal or not, and it may appear without an onset as in (4.80c, d), as long as the following vowel is nasal. In addition, a stressed nasal vowel may appear with a voiceless onset, if the vowel is long, as in (4.81a), or if the following vowel is nasal, as in

(4.81b, c).

As with glottalization, nasalization may be lost due to destressing. When a nasal monosyllabic morpheme destresses, as the initial element of a compound as in (4.82) or a proclitic as in (4.83), the vowel may lose its nasality.

(4.82) ka’a̱n jíkí
[ka(ˈxìkí)]
/kàˀà$_{n}$-xíkí`/
speak-play
‘joke’

<OO 2013OCT02>

(4.83) kixi ra — si’in tyina ra
[(ˈkiʃi)ɾa — si(ˈtʲĩnã)ɾa]
/´\kiʃi = ɾa — síˀi$_{n}$ = tʲina = ɾa/
IPFV\RE:sleep with = dog = 3M
‘he is sleeping with his dog’

<MC MIN0385:0:23.2>

The vowels of /kaˀa$_{n}$/ (4.82) and /siˀi$_{n}$/ (4.83) oralize because they are unstressed and the syllables have voiceless onsets. If the syllable has a nasal onset or an empty onset, as in (4.84), the vowel stays nasal.

(4.84)	a.	b.	c.
	nuu̱ sito	iin iin tyi	u’un u’un
	[nũ(ˈsito)]	[ʔĩ(ʔĩĩ)ɾi]	[ʔũ(ˈʔũʔũ)]
	/nuù´ = sìto/	/ii$_{n}$–ii$_{n}$ = tʲí/	/uˀu$_{n}$–uˀu$_{n}$/
	on = bed	one–one = 3.ZO	NEG–NEG
	‘on a bed’	‘each animal’	‘no’

This denasalization process causes the vowels of destressed roots to conform with the nasalization restrictions observed in prefixes and unstressable clitics.

4.5 The prosody of loanword adaptation

The adaptation of loanwords from Spanish into Nieves Mixtec is sensitive to the prosodic structure of both languages. The general pattern is that the loanword stress pattern matches the Spanish source word stress pattern, and that syllable obtains a high tone with a following (sometimes floating) low tone; any preceding syllables have mid tones. The basic fact of the loanword stress matching the source word stress holds true even if the stress is far from root-initial, as in (4.85a), or far from penultimate, as in (4.85b).

(4.85)	a.	kopuntadóɾá [kōpūntā(ˈðóɾá)] <computadora [komputaˈðoɾa] 'computer'	b.	miéɾkoleхe [(ˈmjéɾkò)lèʃè] <miércoles [ˈmjeɾkoles] 'Wednesday'

However, this general process yields different surface patterns depending on the position of stress and the presence or absence of a final consonant in the Spanish source word. The specifics of tonal alignment supports the proposal that stress in Nieves Mixtec is based on a trochaic moraic foot.

There are at least two strata of loanwords from Spanish,[7] distinguished in practice here primarily by speakers' metalinguistic judgments of words as being 'true' Mixtec or how 'the elders spoke' versus other words that reflect how 'people speak now'.[8] The strata

[7] I leave aside from this discussion loanwords which probably came into Nieves Mixtec through Nahuatl (Nordell 1984) as well as those which could have come from either the original Nahuatl word or from the Spanish adaptation. Some of these loanwords have different tonal and segmental adaptation, while violating native phonotactics of vowel quality and nasality. My categorization of words into this Nahuatl stratum versus the other "older" words is probably not very reliable, but I have held them apart (8 of about 100 identified loanwords) in order to not confuse the analysis of the other words, while there are not enough of these Nahuatl words to analyze on their own. Examples of these loanwords include: /kūmálí/ 'child's godmother' (<Nah. /komale/ <Sp. /komadɾe/), /ᵐbālī/, /ᵐbáà/ 'child's godfather' (<Nah. /kompale/ <Sp. /kompadɾe/), /ʒúʧù/ 'knife' (Nah. <goʧilo < Sp. /kuʧiʎo/), /sákō/ 'opossum' (<Nah. /tɬakwaːtzin/ cf. Sp. /tlakwaʧe/), /kólò/ 'turkey' (<Sp. /gwaxolote/ <Nah. /weʃoːloːtɬ/). There is another cluster of exceptional loanwords which don't conform to the patterns described here because they are conforming to a morphological template. Two of these, /ná-vélâ/ and /tá-vélô/ differ only in that the initial /a/ of 'abuela' and 'abuelo' is parsed as part of noun-class prefix, and so it gets the high tone appropriate to those two prefixes. Another case is /ʧivíʒâ/ 'nanny goat' (<chiva), where the final syllable /va/ in the source word is expanded to two syllables, and the stress is shifted over from the expected syllable, /ʧi/. The initial /ʧi/ syllable is common among animals, as if it were a noun class prefix, though two others /tʲi-/ and /ⁿdʲi-/ are also associated with animals, and /ʧi-/ is less productive than these. But /ʧivíʒâ/ parallels /ʧivátô/ 'billy goat' (<chivato), a straightforward adaptation, and so morphological reanalysis by analogy may have helped support the prosodic reanalysis. Finally, /inímà/ 'soul/heart' (<alma or ánima) has an initial /i/ that seems to be the class prefix for the divine (cf. /i̯ⁿdʲivi/ 'sky', /i̯tʲa̧a̧/ 'tomorrow', /i̯i̯/ 'sacred') though that noun class is not used productively anymore, as far as I can tell. There are a few additional suspected loan words which don't follow the patterns described here, and I don't have any basis to identify a cause of their exceptionality. These are: /kóɾá/ 'corral' (<Sp. /koˈral/), /ʧèlò/ 'calf' (<Sp. /beˈsero/), /ʧeˀla/ 'dragonfly' (<Sp. /liˈβelula/), /ᵐbóˀló/ 'ball shape' (<Sp. /boˈluðo/), /ˈá̧xélá/ 'Angela' (<Sp. /ˈaŋxela/), /ˈʃìkāmā/ 'jícama' (<Sp. /ˈxikama/), /kātā/ 'sing' (<Sp. /ˈkanta/).

[8] In natural speech, the eldest consultant (FC) alternately uses both contemporary and older

also differ in the extent to which they surpass the native segmental inventory or violate phonotactic constraints, and as I describe here, they are also associated with variation in prosodic adaptation strategies. I will refer to these strata as contemporary and older, on the basis of speakers' metalinguistic judgment, without intending a claim as to what correlates of time determine the distinction. Though there may be some recent phonological change in both Nieves Mixtec and Oaxacan Spanish, there have also been shifts in bilingualism, language dominance, and attitudes about both languages, as well as increased contact with other Mixtec varieties, other Spanish varieties, and English (cf. Sicoli 2007; Perry 2009).

I first describe the pattern for source words that have non-final stress and open final syllables, which require minimal adaptation (4.5.1), then discuss processes of vowel epenthesis and lengthening (4.5.2), which are partially motivated by foot minimality, and then variation in tonal melodies (4.5.3), which is restricted by the foot.

4.5.1 Loanwords with minimal adaptation

Words with penultimate stress constitute the overwhelming majority of attested loanwords. This trend is partly due to penultimate stress being the most frequent pattern in Spanish (Núñez Cedeño & Morales-Front 1999:211). The stress on the penultimate syllable is replicated in the loanword, and when the source word has an open final syllable, the loanword is produced with minimal adaptation, particularly in contemporary forms. Often, as in (4.86-4.87), there are no segmental changes.

(4.86)	a. mésá	b. kóchí	c. yúntá
	[(ˈmésá)]	[(ˈkótʃí)]	[(ˈʒúntá)]
	<mesa [ˈmesa])	<cochi [ˈkotʃi]	<yunta [ˈʒunta]
	'table'	'pig'	'yoke of oxen'

forms, while the other consultants generally use the contemporary forms in natural speech and only use the older forms for certain particularly well-established words or when teaching about the older forms.

(4.87)	a. pátó [(ˈpátó)] <pato [ˈpato] ‘duck’	b. lóró [(ˈlóɾó)] <loro [ˈloɾo] ‘parrot’	c. kuvétá [kū(ˈvétá)] <cubeta [kuˈβeta] ‘basin’

In other cases, there are minor changes in the consonants (4.88-4.89) or vowel quality changes in unstressed syllables (4.90).

(4.88)	a. kándó [(ˈká^{n}dó)] <caldo [ˈkaldo] ‘broth’	b. kuénté [(ˈkʷénté)] <puente [ˈpwente] ‘bridge’	c. tyiránté [tʲī(ˈɾánté)] <tirante [tiˈɾante] ‘brace’

(4.89)	a. mbúrró [(ˈ^{m}búró)] <burro [ˈburo] ‘donkey’	b. píndo̱ [(ˈpí^{n}dò)] <pinto [ˈpinto] ‘speckled’	c. chiváto̱ [tʃī(ˈvátò)] <chivato [tʃiˈβato] ‘billy goat’

(4.90)	a. páñí [(ˈpáɲí)] <paño [ˈpaɲo] ‘shawl’	b. pirátó [pī(ˈɾátó)] <aparato [apaˈɾato] ‘device’	c. lamétá [lā(ˈmétá)] <limeta [liˈmeta] ‘bottle’

In some older loanwords, a pretonic vowel or a whole pretonic syllable is deleted altogether (4.91).

(4.91)	a. kuáyi̱ [(ˈkʷáʒì)] <caballo [kaˈβaʒo] ‘horse’	b. chíto̱ [(ˈtʃítò)] <gatito [gaˈtito] ‘cat’	c. léka̱ [(ˈlékà)] <talega [taˈleɣa] ‘bag’

When the Spanish source word has antepenultimate stress and an open final syllable, the loanword similarly shows little or no segmental adaptation, and the stress is replicated on the antepenultimate syllable (4.92-4.93), even though antepenultimate stress does not occur in native words.

(4.92)	a. éri̱ka̱ [(ˈʔéɾì)kà] < [ˈeɾika] ‘Érica’	b. yési̱ka̱ [(ˈʒésì)kà] < [ˈʒesika] ‘Yésica’	c. sáva̱to̱ [(ˈsáva̱)to̱] <sábado [ˈsaβaðo] ‘Saturday’

(4.93) a. núme̱ro̱
[(ˈnúmè)ɾò]
< número [ˈnumeɾo]
'number'

b. teléfo̱no̱
[tē(ˈléfò)nò]
< teléfono [teˈlefono]
'telephone'

4.5.2 Vowel lengthening and syllable repair

For source words with final stress, the loanword adaptation process adds a mora, either by lengthening the stressed vowel or by word-final epenthesis, and the positioning of that mora is influenced by syllable structure constraints. The data indicate that the addition of the mora is motivated by foot minimality, while the word-final epenthesis is additionally motivated by coda avoidance, and a principle of minimal violation limits the application of stressed vowel lengthening to just those cases where there is no word-final epenthesis.

In the few examples where the source word is stressed on a final open syllable, shown in (4.94), the loanword has a matching stress pattern, but with a long stressed vowel.

(4.94) a. joséé̱
[xō(ˈséè)]
< 'José' [xoˈse]
'Joseph'

b. totʃéé̱
[tō(ˈtʃéè)]
< 'Ché' [ˈtʃe]
'Joe'[9]

c. kaféé̱
[kā(ˈféè)]
< 'café' [kaˈfe]
'coffee'

But when there is a word-final consonant in the source word, the loanword may either lengthen the final vowel, as in (4.95a,b), or epenthesize a vowel after the consonant, as in (4.95c), but not both.

(4.95) a. juáa̱n
[(ˈxʷą́ą̀)]
< [ˈxwan]
'Juan'

b. tomáa̱s
[tō(ˈmáàs)]
< [toˈmas]
'Tomás'

c. máxi̱
[(ˈmáʃì)]
< [toˈmas]
'Tomás'

We will examine the syllable repair processes before returning to vowel lengthening.

In native vocabulary, the syllable is strictly codaless,[10] and independent of stress

[9]The [tō] of [tō(ˈtʃéè)] may be a reduced form of /toˀó/ 'saint'

[10]The only attested exceptions to this generalization are a few polite expressions in particularly formal speech. Three greetings are shown in (4.1), and three ways of expressing thanks are shown in (4.2).

position, in many loanwords where the source word had a final consonant, there is some process that repairs the syllable structure to avoid a word-final coda. The most common process in older loanwords is epenthesis of a front vowel after the consonant, to move it from coda position into onset position. In most of the attested cases, the consonant is /s/ adapted as /ʃ/, as in (4.96-4.97), but cases of epenthesis with /l/ and /n/ are also attested (4.98).

(4.96)	a.	lúne̱xe̱ [(ˈlúnè)ʃè] < lunes [ˈlunes] ‘Monday’	b.	márte̱xe̱ [(ˈmártè)ʃè][11] < martes [ˈmaɾtes] ‘Tuesday’	c.	júve̱xe̱ [(ˈxúvè)ʃè] < jueves [ˈxweβes] ‘Thursday’

(4.97)	a.	viérne̱xe̱ [(ˈvjéɾnè)ʃè)] < viernes [ˈbjeɾnes] ‘Friday’	b.	ndyóxi̱ [(ˈⁿdʲóʃì)] < ‘Dios’ [ˈdjos] ‘God’

(4.1)	a.	cháá [ʧa˥a˥] /ʧáá/ F.hello ‘hello’	b.	táát [ta˥a˥ð] /táá = t father = M.FRM ‘hello, sir’	c.	náán [nã˥ã˥n] /náá = n mother = F.FRM ‘hello, ma’am’

(4.2)	a.	ko̱ñá’a̱ [ko˩ɲã˥ʔã˩] /kò´–ɲàˀa/ NEG–thing ‘no problem’	b.	ko̱ñá’a̱t [ko˩ɲã˥ʔã˩ð] /kò´–ɲàˀa = t/ NEG–thing = M.FRM ‘no problem, sir’	c.	ko̱ñá’a̱n [ko˩ɲã˥ʔã˩n] /kò´–ɲàˀa = n/ NEG–thing = F.FRM ‘no problem, ma’am’

The greeting in (4.1a) is used by women to greet anyone, and by men to greet women who are not older than them. The other greetings are used by men to greet older men (4.1b) and to greet older women (4.1c). Similarly, (4.2a) is used with anyone not older than the speaker, and (4.2b, c) are used with older men and women, respectively.

[11] Notably, word-internal consonant clusters are rarely repaired, either by epenthesis or deletion. This may reflect a tolerance of complex onsets, but complex onsets are not found in native vocabulary any more than codas are. Another possibility is that the consonant clusters are parsed as heterosyllabic with an excrescent vowel, comparable to reduced vowels found in native vocabulary, particularly in pretonic positions.

(4.98)	a. miyéle̱	b. néle̱	c. listóni
	[mī(ˈʒélè)]	[(ˈnélè)]	[lī(ˈstóní)]
	< [miˈɣel]	< [daˈɲel]	< listón [lisˈton]
	‘Miguel’	‘Daniel’	‘ribbon’

In other instances, the final consonant is deleted. The attested examples, shown in (4.99), seem to be older loanwords, and in all three cases, the source word has penultimate stress and a final /s/.

(4.99)	a. káló	b. lápí	c. Lasi Niévé
	[(ˈkáló)]	[(ˈlápí)]	[lāsə̄(ˈɲévé)]
	< [ˈkaɾlos]	< lápiz [ˈlapis]	< [lasˈnjeves]
	‘Carlos’	‘pencil’	‘Las Nieves’[12]

When the source word ends in /n/, and there is no final epenthesis as in (4.98c), the /n/ is realized as nasalization in the preceding vowel, as in (4.100). The attested examples of this all have final stress, and so they also have lengthening of the final vowel. It is unclear whether they all belong to the contemporary stratum, or if perhaps some such as (4.100a) are contemporary while others such as (4.100c) are older.

(4.100)	a. sevastyáa̱n	b. sadóo̱n	c. melóo̱n
	[seva(ˈstʲą́ą̀)]	[sa(ˈðǫ́ǫ̀)]	[mē̜(ˈlǫ́ǫ̀)]
	< [seβasˈtjan]	< ‘azadón’ [asaˈðon]	< ‘melón’
	‘Sebastian’	‘hoe’	‘melon’

Other final consonants, in contemporary loanwords, are retained (4.101-4.102), but in contrast to the older loanwords where a vowel was epenthesized after a retained final consonant (4.96-4.98), here the stressed vowel is lengthened in the case of final stress, and no further change is found in the case of non-final stress (4.102a).

(4.101)	a. dañée̱l	b. davíi̱d	c. grabáa̱r
	[dā(ˈɲę́ę̀l)]	[dā(ˈvíîd)]	[gɾā(ˈβááàɾ)]
	< [daˈɲel]	< [daˈβið]	< ‘grabar’
	‘Daniel’	‘David’	‘record’

[12] The central church in Nieves is dedicated to *la Virgen de las Nieves*, and *Las Nieves* has become the colloquial toponym, replacing the former name, Yuku̱ Yi’a̱ /ʒukù´ ʒiˀà´/ ‘mount thread’, or Icpactepec in Nahuatl.

(4.102) a. kárlós
[(ˈkáɾlós)]
< [ˈkaɾlos]
'Carlos'

b. lwí̱is
[(ˈlwîs)]
[ˈlwis]
'Luís'

To summarize, the following adaptation processes are noted thus far:

(4.103) a. The stress position in the source word is matched in the loanword.

b. In older loanwords, vowel epenthesis or consonant deletion avoids word-final consonants.

c. In loanwords with final /n/, the /n/ may be converted to nasalization on the preceding vowel.

d. In cases where the stressed syllable is in final position, the vowel is lengthened.

Since the vowel lengthening occurs only when the loanword has final stress and is not predictable directly from the source word stress pattern, the vowel length is a characteristic of native phonology more than the adaptation process *per se*. And the requirement that final stressed syllables have long vowels, while non-final syllables do not, suggests that stress is based on a moraic trochee.

4.5.3 Assignment of the tonal melody

The tonal melodies of loanwords can broadly be categorized into two patterns. All of these loanwords have a H tone on the first mora of the stressed foot, but the second mora may bear either a H tone or a L tone. Several factors are associated with this variation, but notably, the variation does not extend beyond the stressed foot. In either case, any tones before the stressed foot are M and any tones after the stressed foot are L. Focusing on the tones within the stressed foot, I will refer to the two patterns as HH and HL.

Several loanwords are attested with both tone patterns, and a few of these are shown in (4.104, 4.105) to illustrate the difference.

(4.104) a. telépo̲no̲ ∼ teléfóno̲
[tē(ˈléfò)nò] ∼ [tē(ˈléfó)nò]
< [teˈlefono]
'telephone'
<OO MIN0977> <MC MIN0642>

b. chiváto̲ ∼ chivátó
[tʃī(ˈvátò)] ∼ [tʃī(ˈvátó)]
< [tʃiˈβato]
'billy goat'
<FC MIN0711> <OO MIN0840>

(4.105) a. sáva̲to̲ ∼ sábádo̲
[(ˈsávà)tò] ∼ [(ˈsáβá)ðò]
< [ˈsaβaðo]
'Saturday'
<FC MIN0740> <OO MIN0977>

b. miérko̲le̲xe̲ ∼ miérkóle̲s
[(ˈmjéɾkò)lèʃè] ∼ [(ˈmjéɾkó)lès]
< [ˈmjeɾkoles]
'Wednesday'
<MO MIN0993>

As shown, in the HL pattern (the initial variant in (4.104, 4.105)), the stressed vowel bears a H tone and the immediately following vowel bears a L tone. Preceding vowels as in (4.104) bear M tone, and following vowels as in (4.104a, 4.105) bear L tone. The HH pattern (the second variant in (4.104, 4.105)) differs only in that the immediately post-tonic vowel bears H tone. In the HH pattern, there is still a following L tone in the phonological representation even when the stressed foot is in word-final position. As described in detail in §6.2.3, words may bear a final floating tone which is not realized in phrase-final position but may trigger tone changes in other contexts. Loanwords in the HH pattern with the stressed foot in final position show the effects of a final floating L tone. For example, in isolation the words in (4.106) appear with final HH tones.

(4.106) a. kóchí
[(ˈkótʃí)]
/kótʃî/
<kochi [ˈkotʃi]
'pig'

b. lamétá
[lā(ˈmétá)]
/lamétâ/
<limeta [liˈmeta]
'bottle'

c. kuéndá
[(ˈkʷéⁿdá)]
/kʷéⁿdâ/
<cuenta [ˈkwenta]
'property'

And on hosts that do not condition tone changes (4.107), the pronominal clitics /=ɲá/

'she', /=ɾa/ 'he' and /=na/ 'they' have high, mid and mid tones, respectively.

(4.107)
a. me̱e-ñá
[(ˈmḛ̀ḛ̄)ɲá]
/mḛ̀ḛ=ɲą́/
EMPH=3SF.FAM
'she'
<FO 2013JUN17>

b. tyi̱na-ra
[(ˈtʲḭ̀ną̄)ɾā]
/tʲḭ̀ną=ɾa/
dog=3M.FAM
'his dog'
<OO MIN0353>

c. laa-na
[(ˈlāā)nā]
/laa=ną/
bird=3P
'their bird'
<OO MIN0204>

But attached to loanword hosts, these clitics surface with low tone (4.108).

(4.108)
a. kóchí-ñá
[(ˈkóʧí)ɲà]
/kóʧî=ɲá/
pig=3SF.FAM
'her pig'
<FO 2013JUN17>

b. lamétá-ra
[lā(ˈmétá)ɾà]
/lamétâ=ɾa/
bottle=3M.FAM
'his bottle'
<OO MIN0469>

c. kuéndá-na
[(ˈkʷé^{n}dá)ną̀]
/kʷé^{n}dâ=na/
property=3P
'their property'
<OO 2013OCT02>

Similarly, certain adjectives, such as the plural diminutive /válî/, form a single prosodic word with the noun they modify (see §6.2.3 for discussion). After nouns that do not condition tone changes (4.109), /válî/ surfaces with high tones.

(4.109)
a. uju válí
[(ʔūhū)(ˈválí)]
/uxu-válî/
deer-little.PL
'fawns'
<FC 2013MAY31>

b. xá'án válí
[(ʃą́ʔą́)(ˈválí)]
/ʃą́ˀą́-válî/
hawk-little.PL
'little hawks'
<OO 2013JUN19>

c. ñí'í válí
[(ɲḭ́ʔḭ́)(ˈválí)]
/ɲḭ́ˀḭ́-válî/
hen-little.PL
'little hens'
<OO 2013JUN19>

But after loanword nouns, just as after native words that have final L tone (as described in §6.2.3), the trailing L tone from the loanword displaces the H tone on the first vowel of /válî/ (48).

(4.110)
a. kóchí válí
[(kóʧí)(ˈvàlí)]
/kóʧî-válî/
pig-little.PL
'piglets'
<FC 2013JUN07>

b. pátó válí
[(pátó)(ˈvàlí)]
/pátô-válî/
duck-little.PL
'ducklings'
<OO 2013JUN19>

c. lóró válí
[(lóɾó)(ˈvàlí)]
/lóɾô-válî/
parrot-little.PL
'little parrots'
<OO 2013JUN19>

In sum, the patterns of tone assignment in loanwords suggest alignment to a trochaic foot. The stressed syllable has H tone, and the second syllable of the stressed foot has either H tone or L tone. Syllables before the stressed foot have M tone, and syllables after the stressed foot have L tone. In the case that the final mora of the word has H tone, the word sponsors a floating +L tone. In conjunction with the pattern of vowel lengthening in just the loanwords that have stress in the final syllable, loanword prosody supports the conclusion that stress in Nieves Mixtec is based on a moraic trochee.

4.6 Summary

This chapter presented a phonological description of the stress system in Nieves Mixtec. I showed phonological evidence that Nieves Mixtec word prosody meets the definition of stress and that stress is based on a trochaic foot aligned to the root. This analysis is supported by the distributions of vowel quantity, glottalization, and nasalization, as well as the patterns of prosodic adaptation in loanwords.

Chapter 5

Acoustics of stress

5.1 Introduction

This chapter presents an acoustic study of stressed syllables and matched unstressed syllables in a controlled corpus of utterances. As reviewed in detail in §2.3, there is considerable variation across languages in how word stress is realized acoustically, and just a few studies have rigorously distinguished primary stress from secondary stress and word stress from phrasal accent. The reviewed literature is summarized in Table 5.1, repeated from §2.3 for convenience. As a cross-linguistic trend, more prominent syllables tend to have longer segmental duration, more peripheral or more open vowel quality, higher intensity, and shallower spectral tilt. Several studies also report higher pitch and higher periodicity associated with stressed syllables. Besides the cross-linguistic variation, the definition of word stress in terms of any one acoustic correlate or any set of correlates is complicated by the fact that each of the acoustic measures associated with stress is also associated with segmental type or other prosodic categories like phrasal accent, tone and phonation type.

Two previous studies have addressed the acoustic properties of stress in other Mixtec varieties, San Juan Coatzospan (COA) Mixtec (Gerfen 1996) and Santo Domingo Nuxaa (NUX) Mixtec (McKendry 2013). In both of these varieties, stress falls on the initial

Table 5.1: Acoustic properties correlated with the phonological categories of interest. See §2.3 for references and discussion.

Acoustic Property	Phonological System			
	Phrasal Stress	Word Stress	Tone	Phonation
Vowel Duration	English, Dutch, Nahuatl, Mixtec	English, Dutch, Greek, Spanish, Tongan, Arabic, Menominee, Nahuatl, Raramuri, Pirahã, Chickasaw, Papiamentu, Maˈya, Zapotec, Triqui, Mixtec	Mandarin, Mixtec	Hmong, Mixtec
Vowel Intensity	English, Dutch, Swedish, Spanish	Spanish, Berber, Quechua, Tongan, Pirahã, Chickasaw, Papiamentu, Mixtec, Zapotec	Mandarin, Maˈya	Mazatec
Consonant Duration	English, Dutch	Dutch, English, Raramuri, Pirahã, Greek, Triqui	Mandarin	Korean
Vowel Quality	English	English, Arabic, Maˈya, Tongan, Papiamentu	Shuijingping Hmong, Fuzhou	Western Cham
Mid-band spec tilt	English, Swedish	Dutch, Spanish, Nahuatl	Triqui	Yi, Gujarati, Mazatec, Triqui
Low-band spec tilt		Tongan, Nahuatl	Mandarin, Vietnamese, Hmong	Korean, Yi, Gujarati, Mazatec, Zapotec, Hmong, Triqui
Periodicity		Tongan	Mazatec	Mazatec, Yi, Zapotec, Hmong
Fundamental Frequency	English, Swedish, Quechua, Spanish, Berber	Nahuatl, Quechua, Menominee, Tongan, Creek, Chickasaw	Papiamentu, Maˈya, Creek, Chickasaw, Mandarin, Kyungsang Korean, Triqui, Zapotec, Gujarati, Mazatec	Korean, English, Arabic, Triqui, Western Cham

syllable of the couplet, just as in Nieves Mixtec. These studies have focused on just a couple of acoustic properties, finding evidence that longer durations and higher intensity are associated with word stress or phrasal stress in these varieties.

Gerfen (1996:184–210) compared the vowel durations in two verb roots in Coatzospan Mixtec. Simple verbs, which bear stress on the initial vowel, were contrasted with the same roots in a construction that Gerfen analyzes as a compound verb, where the verb root does not show evidence of stress. Such pairs were recorded with five speakers, for the two verb roots shown in (5.1, 5.2).[1]

(5.1)	a.	kutyu kuii burru [kutʲuˈkʷii ˈβuru] /kutʲu–kʷii βuru/ plow–slow burro ‘the burro will work slowly’	b.	kuii kutyu burru [ˈkʷii ˈkuʔᵘtʲu ˈβuru] /kʷii kutʲu βuru/ slow plow burro ‘the burro will work SLOWLY’
(5.2)	a.	tyɨvi kuii burru [tʲɨβiˈkʷii ˈβuru] /tʲɨβi–kʷii βuru/ blow–slow burro ‘the burro will blow slowly’	b.	kuii tyɨvi burru [ˈkʷii ˈtʲɨβi ˈβuru] /kʷii tʲɨβi βuru/ slow blow burro ‘the burro will blow SLOWLY’

The vowel durations of the verbs /kutʲu/ ‘plow’ and /tʲɨβi/ ‘blow’ are compared in stressed position (5.1b, 5.2b) and in unstressed position (5.1a, 5.2a). The durations of both the initial and second vowels of the verb root were longer in the stressed condition (5.1b, 5.2b), with the stressed vowel being much longer. In the stressed condition, the initial vowel was statistically significantly longer than the second vowel, while in the unstressed condition, there was no statistically significant difference. The longer duration of vowels in the stressed condition is evidence that these vowel are prosodically prominent, though an interpretation as phrasal stress is also possible. It is not clear on what grounds the “compound” verbs should be considered compounds. The second root in the “compound” is an adverb /kʷii/ ‘slowly’, which is preposed for topicalization in (5.1b, 5.2b), without changing the semantics of the utterance. The vowel duration effect is evidence that

[1]The data source does not indicate tone. In Coatzospan Mixtec, besides the contrastive glottalization licensed on stressed vowels, non-contrastive pre-glottalization of voiceless consonants occurs after stressed vowels, such as [ˈkuʔᵘtʲu] in (5.1b).

the two roots form some phonological domain, but no argument is provided as to why it should be considered a word domain with word stress rather than a phrasal domain with phrasal stress. On the other hand, even if the observed increase in duration is properly a phonetic effect of phrasal stress, the association of phrasal stress to the initial vowel of the root rather than the final vowel is evidence that the initial vowel is the head of the prosodic word as well.

McKendry (2013:230–286) presents two studies examining the vowel duration and intensity in mono-morphemic disyllabic nouns in Santo Domingo Nuxaa Mixtec. In the first study, the nouns were in information focus constructions, as in (5.3).[2]

(5.3)

nìdiko-dá	kiti	kañìni
[nĩ˩ˈði˩ko˧ða˥	ˈki˧ti˧	ka˧ˈɲĩ˩nĩ˧]
/ni\`–ðikō´=ðá\`	kitī´	kaɲìnī/
PFV–sell=1FRM	animal	day.before.yesterday

‘I sold animals the day before yesterday’

The prompts included eleven nouns, with two verbs and three pronominal enclitics, varied to produce different surface tone patterns on the nouns. The initial vowels of the target nouns were found to have longer duration and higher intensity than the second vowels, independent of tone pattern or vowel quality. The second study compares these results to the vowel duration and intensity of the same nouns in corrective focus constructions, as in (5.4, 5.5).

(5.4) Corrective Focus on Noun

ña’à	chi	**kiti**	nìdiko-dá	kañìni
[ˈɲã˧ˀã˩	ʧi˧	**ˈki˧ti˧**	nĩ˥ˈði˧ko˧ða˥	ka˧ˈɲĩ˩nĩ˧]
/ɲaˀà	ʧi¯	**kitī´**	ni\`–ðikō´=ðá\`	kaɲìnī/
no	because	**animal**	PFV–sell=1FRM	day.before.yesterday

‘No, because I sold ANIMALS the day before yesterday

(5.5) Corrective Focus on Verb

ña’à	chi	**nì seen-dá**	kiti	kañìni
[ˈɲã˧ˀã˩	ʧi˧	**nĩ˧ˈsẽ˩ẽ˧ða˥**	ˈki˧ti˧	ka˧ˈɲĩ˩nĩ˧]
/ɲaˀà	ʧi¯	**ni\`–seē$_{\mathbf{n}}$=ðá\`**	kitī´	kaɲìnī/
no	because	**PFV–RE:buy=1FRM**	animal	day.before.yesterday

‘No, because I BOUGHT animals the day before yesterday’

[2]The transcriptions are adapted from the source for readability.

The nouns under corrective focus (5.4) and outside of corrective focus (5.5) had longer vowel duration in the first syllable than in the second syllable, just as in the information focus condition (5.3), though the magnitude of the effect differed across conditions. However, the intensity difference between syllables was only marginally significant, and both syllables of the nouns under contrastive focus had much greater intensity than in the other conditions. These results suggest that increased vowel duration is a consistent correlate of word stress in Santo Domingo Nuxaa Mixtec, while both vowel duration and intensity are manipulated in phrasal prosody.

The study presented in this chapter focuses on the acoustics of stress, while stepping back from the phonological aspects of distinguishing word stress from phrasal stress or primary stress from secondary stress. Phonetic variables that are cross-linguistically associated with stress were measured for each syllable. Effects of segment type and tone are controlled in this study, while potential effects of phrasal accent and phonation type are outside the scope of this investigation. The results indicate that the acoustic correlates of stress include the segmental durations and vowel quality primarily and, secondarily, properties of the intensity spectrum.

5.2 Methods

This section describes the data sample and analysis procedures. The utterances were recorded in translation elicitation sessions with two native speakers. The target syllables were tonic, pre-tonic or post-tonic in verbs or post-verbal nouns, and all the acoustic properties in Table 5.1 were examined, each of which has been found to be associated with stress in other languages. The study uses a broad but incomplete sample of the full design matrix, and the analysis uses discriminant analysis and mixed effects regression to estimate the acoustic correlates of the prosodic position of the syllable.

5.2.1 Sample

The utterances analyzed in this study represent a controlled sample of syllables in pre-tonic, tonic or post-tonic position in prosodic words that have a single root, exemplified by the words in (5.6).

(5.6)	a. kásika ra	b. si̱ kási ra	c. síká si
	[ka˥(ˈsi˧ka˧)ɾa˧]	[si˨(ˈka˥si˦)ɾa˧]	[(ˈsi˩ka˦)si˧]
	/˄\ka–sika = ɾa/	/sì = ˄\kàsi = ɾa/	/síká = si/
	IPFV\RE:walk = 3M	now=IPFV\pick=3M	far=3S.FRM
	‘they are walking’	‘he is picking now’	‘he is going far away’

The syllables were chosen to represent a balanced cross-section of phonological possibilities attested in all prosodic positions. The syllables are composed of any of four onsets (/k/, /s/, /ⁿd ∼ⁿdʲ/ and /n/) and two vowels (/a/ and /i/). The vowels included both oral and nasal vowels, but none of them were phonologically long or glottalized. These segments were chosen for their broad distribution and well-defined segment boundaries. In addition, the syllables were followed by one of three consonants (/k/, /s/, or /n/) within the word. (In the case of post-tonic syllables, the following consonant is in an enclitic. Most of the target words have enclitics, and post-tonic target utterances were excluded if they did not have an enclitic.) In spite of the broad distribution of these segments, certain phonotactic restrictions and morphological gaps prevent the appearance of every target syllable in all positions. Though these gaps would be problematic in a traditional ANOVA design, they are manageable within the mixed effects regression analysis used here. Finally, for each syllable type, at least two target utterances were obtained with different tonal melodies. The two utterances differ at least on the tone of the target syllable, and might or might not differ in other syllables. The target syllables included in the primary analysis were never initial or final in the utterance, and utterances with a pause immediately before or after the target word were also excluded. Most of the target words are the same for all speakers, but in general it was not possible to record the exact same sentences with all the speakers. The corpus inventory for each speaker is shown in Table 5.2, and the coverage of the corpus is shown in Table 5.3, where a gap indicates an empty cell in the 72-cell design matrix (3 syllable positions $\times$ 4 onsets $\times$ 2 vowels $\times$ 3 following

Table 5.2: Token inventory of the corpus included in the analysis

Speaker	Total Tokens	Pre-tonic	Tonic	Post-tonic
MO	242	85	91	66
MC	327	104	142	81

Table 5.3: Design matrix coverage of the corpus, calculated over segment types, ignoring tone categories

Speaker	Total Gaps	Pre-tonic	Tonic	Post-tonic
MO	18 / 72	8 / 24	6 / 24	4 / 24
MC	26 / 72	10 / 24	6 / 24	10 / 24

consonants), ignoring tone categories. The full list of elicited utterances for speaker MO is provided in Appendix C Table C.1 and for speaker MC in Appendix C Table C.2.

For the pre-tonic items, the target syllable is either a prefix or a proclitic. Example utterances for the pre-tonic syllables /ni/ and /na/ are shown in (5.7, 5.8) with following /k/.

(5.7) tyiló’o̱ kaa ni̱ kani ra
[tyi˩lo˥ʔo˨ ka˥a˦ **nĩ**˩(ˈkã˧nĩ˧)ɾa˧]
/tyì–lóˀò káa nì = kani = ɾa/
3M–little MED PFV = hit = 3M.FAM
‘That boy hit’

<MO MIN0952>

(5.8) tyiló’o̱ ká nákani ra kwéndó
[tʲi˩lo˥ʔo˩ka˥ **nã**˥(ˈkã˧nĩ˧)ɾa˧ kʷe˥ⁿdo˥]
/tʲì–lóˀò = ká ´\na–kani = ɾa kʷéⁿdó`/
3M–little = MED IMPF\REP–say = 3M.FAM story
‘The boy is telling a story’

<FC MIN0992>

Among the utterances for pre-tonic /ni/, almost all of them use the perfective proclitic /ni = / as in (5.7). The utterances for pre-tonic /na/ used either the repetitive prefix /na–/ as in (5.8) or the optative proclitic /na = /. Example utterances for the pre-tonic syllables

/^{n}d^{j}i/ and /^{n}da/ are shown in (5.9, 5.10), also with following /k/.

(5.9)	ndo'o̱	ndyikuáñí	kuu a
	[^{n}do˧ʔo˩	**^{n}d^{j}i**˧(ˈk^{w}ã˥ɲĩ˥)	ku˧a˧]
	/ndo^{ʔ}ò	^{n}d^{j}ik^{w}áɲí`	kuu = a/
	tail	ZO:squirrel	COP = 3NEUT
	'It is a squirrel's tail'		

<MC MIN1005>

(5.10)	si ni̱ ndaka'a̱n ra
	[si˧nĩ˩**^{n}da**˩(ˈkã˧ʔã˩)ɾa˩]
	/si = nì = ^{n}da–ka^{ʔ}à$_{n}$ = ɾa/
	now = PFV = REP–talk = 3M.FAM
	'He already started talking'

<MO MIN0951>

The animal class prefix /^{n}d^{j}i–/ and repetitive prefix /^{n}da–/ are relatively unproductive, so there are some empty cells for these syllables. An example utterance for the pre-tonic syllable /si/ is shown in (5.11), and one for the pre-tonic syllable /ka/ is shown in (5.12), each with following /k/.

(5.11)	tyi̱ló'o̱	si̱kani ra
	[t^{j}i˩lo˥ʔo˩	**si**˩(ˈkã˧nĩ˧)ɾa˧]
	/t^{j}ì–ló^{ʔ}ò	sì–kani = ɾa/
	3M–little	HAB–hit = 3M.FAM
	'The boy would hit'	

<MC MIN1009>

(5.12)	ni̱ kakani	ta'an ra
	[nĩ˩**ka**˩(ˈkã˧ni˧)	tã˥ʔã˧ɾa˧]
	/nì = ka–kani	tá^{ʔ}a$_{n}$ = ɾa/
	PFV = PL–hit	RECP = 3M.FAM
	'They hit each other'	

<MO MIN0955>

There are no prefixes or proclitics with the syllables /ki/ or /sa/, so there are gaps there.

For the tonic items, the target syllable is initial within a root. Nasal phonotactics (§3.3.3) prevents root-initial /n/ co-occuring with root-medial /k/, /s/, or /^{n}d/, and root-initial /^{n}d/ co-occuring with root-medial /n/, so there are gaps there. Example utterances for the tonic syllables /ni/ and /na/ are shown in (5.13, 5.14) with following /n/.

(5.13) chindyáa ndyíni̱no
[tʃi˧^{n}d^{j}a˥a˦ ^{n}d^{j}i˥(ˈ**ni**˩no˧)]
/tʃi–^{n}d^{j}áa ^{n}d^{j}í–nìno/
put–stuck LAT–high
'Stick it higher'

<MC MIN0975>

(5.14) si̱ ni̱ nana ra
[si˧nĩ˩(ˈ**nã**˧nã˧)ɾa˧]
/sì = nì = nana = ɾa/
now = PFV = go_up = 3M.FAM
'He already went up'

<MC MIN0970>

Example utterances for the tonic syllables /^{n}d^{j}i/ and /^{n}da/ are shown in (5.15, 5.16), with following /k/.

(5.15) tyi̱ló'o̱ káa ni̱ ndyi̱ko̱ ra̱ tátá ra
[t^{j}i˩lo˥ʔo˩ ka˥a˦ nĩ˩(ˈ**^{n}d^{j}i**˧ko˩)ɾa˩ ta˩ta˦ɾa˧]
/t^{j}ì–ló^{ʔ}ò káa nì = ^{n}d^{j}ìkò = ɾa tátá = ɾā/
3M–little MED PFV = follow = 3M.FAM father = 3M.FAM
'That boy followed his father'

<MO MIN0935>

(5.16) si̱ ni̱ nda̱ka̱ ra kotó ra
[si˧nĩ˩(ˈ**^{n}da**˧ka˩)ɾa˩ ko˧to˦ɾa˧]
/sì = nì = ^{n}dàkà = ɾa kotó = ɾa/
now = PFV = REP:request = 3M.FAM shirt = 3M.FAM
'He already asked for his shirt'

<MC MIN0976>

Example utterances for the tonic syllables /si/ and /sa/ are shown in (5.17, 5.18), with following /k/.

(5.17) kuáyi̱ si̱ síka rí
[k^{w}a˥ji˧ si˩(ˈ**si**˥ka˦)ɾi˥]
/k^{w}áʒì sì = ˥\sika = ɾí/
horse now = IPFV\RE:walk = 3ZO
'The horse is walking now'

<OO MIN0904>

(5.18) si̲ ni̲ saku ra
[si˧nĩ˩(ˈ**sa**˧ku˧)ɾa˧]
/sì = nì = saku = ɾa/
now = PFV = RE:cry = 3M.FAM
'He already cried'

<MO MIN0938>

Example utterances for the tonic syllables /ki/ and /ka/ are shown in (5.19, 5.20), with following /k/.

(5.19) si̲ ni̲ ki̲ki ra
[si˧nĩ˩(ˈ**ki**˩ki˧)ɾa˧]
/sì = nì = kìki = ɾa/
now = PFV = sew = 3M.FAM
'He already sewed'

<MO MIN0958>

(5.20)	kuáyi̲	si̲ ka̲ka̲-rí	kwi'i
	[kʷa˥ji˩	si˩(ˈ**ka**˧ka˩ɾi˥	kʷi˩ʔi˧]
	/kʷáʒì	sì = kàkà = ɾí	kʷìˀi/
	horse	now = IR:request = 3ZO	fruit

'The horse will soon ask for a fruit'

<OO MIN0905>

For the post-tonic items, the post-tonic syllable is final within the root. Example utterances for the post-tonic syllables /ni/ and /na/ with following /n/ are shown in (5.21, 5.22).

(5.21)	na̲káa	kúma̲ni̲ na
	[nã˩ka˥a˧	ku˥(ˈmã˩**nĩ**˩)nã˧]
	/nà–káa	ˆ\ku–mànì´ = naˋ/
	3P–MED	IPFV\INCH–want = 3P

'They are lacking'

<OO MIN0959>

(5.22)	me̲ena	kána na	kwa̲'an na
	[mẽ˩ẽ˧nã˧	(ˈka˥**nã**˧)nã˧	kʷã˩ʔã˧nã˧]
	/mèe = naˋ	ˆ\kana = naˋ	kʷàˀa_n = naˋ/
	EMPH = 3P	H\go_out = 3P	IPFV.go = 3P

'They are going out'

<OO MIN0960>

Example utterances for the post-tonic syllables /^{n}dʲi/ and /^{n}da/ are shown in (5.23, 5.24), with following /n/.

(5.23) tyívi landyi na
[t^{j}i˥vi˧ (ˈla˧^{n}**d^{j}i**˧)na˧]
/˄\t^{j}ivi la^{n}d^{j}i = na`/
IPFV\appear navel = 3P
'Its belly is seen'

<MO MIN0953>

(5.24) u̲nju̲ú kuéndá na kia̲
[ũ˩xu˩u˧ (ˈk^{w}e˥^{n}**da**˥)na˩ kja˩]
/ù$_{n}$xùú k^{w}é^{n}dá` = na` kuu = ɲà/
NEG.COP property = 3P COP = 3NEUT
'It's not their property'

<OO MIN0962>

The syllables /^{n}d^{j}i/ and /^{n}da/ are not found root-finally in plain (non-glottalized) verbs or adjectives, and they are rare root-finally in nouns as well. As a result, it was only possible to record one tonal melody for these syllables. Example utterances for the post-tonic syllables /si/ and /sa/ with following /n/ are shown in (5.25, 5.26).

(5.25) na̲yiví kási na kwi̲'i
[nã˩ʒi˧vi˧ (ˈka˥**si**˧)nã˧ k^{w}i˩ʔi˧]
/nà–ʒiví ˄\kàsi = na` k^{w}ì^{ʔ}i/
3P–person IPFV\choose = 3P fruit
'The people are choosing fruit'

<OO MIN0957>

(5.26) nándyukú na ju̲sa̲ ná
[nã˥^{n}d^{j}u˧ku˥na˧ (ˈxu˩**sa**˩)nã˧]
/˄\na–^{n}d^{j}ukú = na` xùsà´ = na`/
IPFV\REP–search = 3P incense = 3P
'They are looking for incense'

<MC MIN0944>

Example utterances for the post-tonic syllables /ki/ and /ka/ with following /n/ are shown in (5.27, 5.28).

(5.27) na̱yiví kásijíkí na
[nã˩ʒi˧vi˦ ka˥si˧(ˈxi˥**ki**˥)nã˧]
/nà–ʒiví ˆ\ka–si–xíkí = naˋ/
3P–person IPFV\PL–RE–play = 3P
'The people are playing'

< MC MIN0946 >

(5.28) na̱yiví ni̱ si̱ka̱ na
[nã˩ʒi˧vi˦ nĩ˩(ˈsi˧**ka**˩)nã˩]
/nà–ʒiví nì = sìkà = na/
3P–person PFV = RE:request = 3P
'The people asked'

< MC MIN0947 >

As shown in these examples, the target words all have lexical roots, hypothesized to bear word stress, but there are differences in lexical category and syntactic position that are not controlled here. Though we are working without a well-articulated model of phrasal prosody, it seems likely that many of these words are also prosodically prominent within a phonological phrase, and some words are probably prominent within higher prosodic domains as well, as most of the utterances are just one to three words long, and many of the target words are utterance-final. As such, we cannot distinguish here between acoustic effects that are strictly associated with stress accent and acoustic effects that are triggered by higher prosody but localized to the stressed syllable. Disentangling these effects is left for future research.

5.2.2 Elicitation and annotation

The elicitation method depended primarily on translation elicitation, working from Spanish, with limited use of modeling the utterance. Because the speakers differed in familiarity with the orthography, it was not possible to depend directly on a written prompt to maintain consistent utterances across speakers. But the meanings of some prefixes and clitics do not transparently translate, so that it was sometimes necessary to prompt the speaker with both the translation and an attempted production of the utterance itself. In these cases, to avoid priming or corrective focus, the utterance used in the analyzed sample would be a later repetition rather than the immediate response to the attempted production. The data was elicited in three two-hour sessions, with one or two short breaks in each session. Each block of utterances (pre-tonic, tonic, or post-tonic) was recorded in a separate session, and the order of the blocks was different for each speaker. The order of utterances within the block was not randomized, but was instead ordered thematically with adjacent pairs of tonally contrasting words, to maintain the style of a meaning-based elicitation session. The expected overall effect of this ordering is some amount of narrow focus around the target syllable. Any main effect of focus will have a comparable influence in the measurements at all prosodic positions, though if there is an interaction between focus and prosodic position, it will appear here indistinguishable from an effect of prosodic position.

The analysis examines acoustic measurements cross-linguistically associated with stress: duration of the segments, vowel height, vowel intensity profile, periodicity, and pitch. For each utterance, the segment boundaries for the target syllable and the following consonant were annotated by the author by visual inspection of the spectrogram in Praat (Boersma & Weenink 2013), according to standard practice. The consonant spans included the period of closure or constriction and any aspiration after the release. The raw RMS vowel intensity as well as measures of low-band spectral tilt (H1-H2) and mid-band spectral tilt (H1-A2) were extracted automatically via a modified version of the script of Remijsen (2004). The spectral tilt measures are corrected for the filtering effect of the formants (Iseli et al. 2007). F0 measurements were extracted automatically via a modified version of Prosody Pro (Xu 2013).

5.2.3 Statistical analysis

Because the phonological distinction of stress is based on multi-dimensional phonetic cues, the initial step of the statistical analysis compares the utility of all the acoustic properties for distinguishing between stressed and unstressed syllables in order to identify which acoustic properties are potentially most important. This is done via discriminant analysis, where each of the acoustic properties are z-score normalized and these properties are projected onto a single linear dimension that best separates the group of stressed syllables from the group of unstressed syllables. The method does not take into account the categorical control variables, but the method is still useful for ranking the acoustic properties by approximate relevance to the stress contrast.

Then, in order to understand more specifically the relationship between each acoustic measure and the stress contrast, a linear mixed-effects regression model is fit for each phonetic property. Instead of using the phonetic properties to predict the stress status of the syllable, each mixed-effects model uses stress status and the control variables to predict a single phonetic property. In addition, in the regression models we distinguish among unstressed syllables by their position relative to the stressed syllable—pre-tonic and post-tonic syllables. For each acoustic measure, that measurement is treated as the dependent variable, with syllable position (Syll) as the predictor of interest, treatment coded with Syll = tonic as the baseline. Categorical control variables consisting of the onset (C1), vowel (V), following consonant (C2), and surface tone category (Tone) are sum coded, while the duration of the surrounding three syllables, a reference duration (RefDur) indicative of speech rate, is a centered scalar control variable. The syllable types (sequences of C1-V-C2) are taken as random effect groups, so syllable position (Syll) and tone (T) are within-group factors, while the segment types are between-group factors. The random effects include intercept terms as well as slopes on the within-group factors of syllable position and tone. Because of the systematic gaps in the data, variable interaction effects generally cannot be consistently estimated or evaluated, so the analysis is limited to main effects, except in two cases. In the case of vowel quality (F1), the interaction between vowel type and syllable position is reliably estimated and important for interpreting the main effects, and in the case of F0, the interaction between tone and syllable position is unreliable but crucial for interpreting the main effects. The speakers are analyzed separately, because there are only two speakers.

For each regression analysis, as recommended by Barr, Levy, Scheepers, and Tily (2013), I report the overall statistical significance of the predictor of interest Syll based on a likelihood ratio (X^2) test of nested models with and without the predictor Syll, with the full random effects structure. In Appendix C, I report in tabular format the fixed effect parameter estimates for each full model, along with their 95% confidence intervals and statistical significance according to t-tests, which are based on the standard error and assumed normality. These should be understood as post-hoc tests and taken with the caveat that the distributions of some parameters diverge from normal. The reported t-test significance judgements are not corrected for multiple comparisons, but the p-values are conservative (Hox 2002) as they are calculated using the minimum degrees of freedom $J - p - 1$ (Bryk & Raudenbush 1992), where J is the number of random effects groups in the term with the fewest groups (the number of syllable types here), and p is the number of fixed-effect parameters.

5.3 Results

In order to provide a summary of the multi-dimensional phonetic correlates of stress, the initial step of the analysis compared the importance of the phonetic measures in a discriminant analysis, where the phonetic properties are jointly used to predict the stress status (stressed or unstressed) of the syllable. The discriminant analysis indicates that each of the segmental duration measures is relevant to the stress contrast for both speakers, while associations between stress status and the other phonetic properties differ between speakers. Then, in order to control for the effects of segment type and tone, as well as to better understand the relationships between the phonetic properties and the stress contrast, we turn to linear mixed-effects regression models for each phonetic property. The regression analyses confirm the importance of the duration measures and show that the data from both speakers show an association with syllable position for intensity, vowel quality, and CPP periodicity, while other phonetic correlates still differ between speakers.

Table 5.4: Standardized discriminant coefficients (DC), structure coefficients (SC) and statistical significance (p(df)) of the discriminant analysis factors, for (a) speaker MO and (b) speaker MC.

a. Speaker MO				b. Speaker MC			
	DC	SC	p(23)		DC	SC	p(21)
VDur	0.838	0.692	0.000	VDur	0.628	0.698	0.000
Int	-0.080	-0.009	0.482	Int	0.335	0.468	0.012
C1Dur	0.348	0.479	0.008	C1Dur	0.466	0.692	0.000
C2Dur	0.767	0.716	0.000	C2Dur	0.242	0.439	0.018
F1	-0.038	0.208	0.159	F1	-0.038	0.415	0.025
H1–A2	-0.319	-0.031	0.442	H1–A2	-0.272	-0.192	0.190
H1–H2	0.059	0.027	0.450	H1–H2	0.542	0.261	0.115
CPP	-0.039	0.044	0.418	CPP	0.347	0.463	0.013
HNR	0.158	0.368	0.035	HNR	-0.378	-0.107	0.314
F0	0.116	0.071	0.368	F0	0.015	0.086	0.349

5.3.1 Discriminant analysis

Here I present the results of the discriminant analysis. The results of the discriminant analysis are summarized in Table 5.4, where positive coefficients indicate that higher values of that phonetic measure are associated with stressed syllables, and negative coefficients indicate that higher values of that phonetic measure are associated with unstressed syllables. The standardized discriminant coefficients indicate the unique contribution of the acoustic measures to the discriminant dimension, while the structure coefficients indicate the simple correlations between the acoustic measures and the discriminant, where a value of 1.0 is the maximum possible association between an acoustic measure and the discriminant. High structure coefficients indicate phonetic properties that could be useful cues of the phonological contrast, while high discriminant coefficients suggest that those phonetic properties are probably necessary cues. The statistical significance values shown are based on the structure coefficients as Pearson's correlations, with $df = N - 2$, where N is the number of syllable types (C1-V-C2).

The results indicate that the segmental duration measures, especially vowel duration, are useful for distinguishing stressed from unstressed syllables for both speakers. For each of the duration measures, for both speakers, stressed syllables are associated with longer duration, with $p < 0.02$. However, the other measures are not as reliably useful.

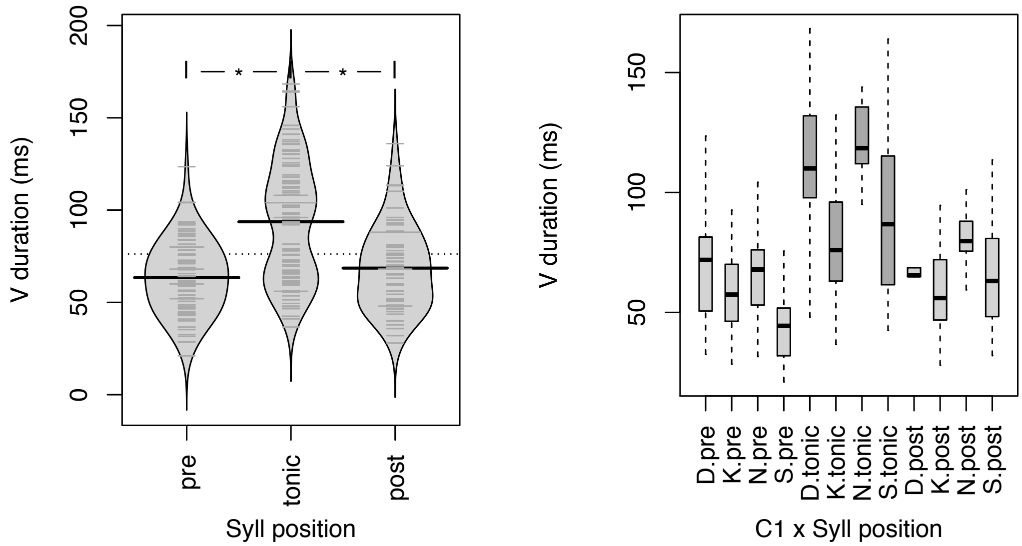
For speaker MO, the only other measure with a structure coefficient that reaches statistical significance is HNR periodicity. The discriminant coefficient for HNR is relatively small, but it indicates that stressed vowels tend to have higher HNR periodicity. In contrast, for speaker MC, the structure coefficients for intensity, F1 (vowel height), and CPP periodicity reach statistical significance, and low-band spectral tilt has a high discriminant coefficient even though its structure coefficient does not reach statistical significance. The stressed vowels have higher intensities, higher F1 (lower vowels), steeper low-band spectral tilt and higher CPP periodicity.

5.3.2 Vowel duration

In order to control for the effects of segment type and tone, as well as to better understand the relationships between these phonetic properties and the stress contrast, we now turn to linear mixed-effects regression models. First we test whether stressed (tonic) vowels have longer duration than unstressed (pre-tonic and post-tonic) vowels. From the cross-linguistic trends summarized in Table 5.1, we expect that if vowel duration is associated with stress, the tonic vowels will have longer duration than pre-tonic or post-tonic vowels. For both speakers, we find that the vowels in stressed syllables do have a longer duration than the vowels in pre-tonic syllables or post-tonic syllables, as shown in Figures 5.1, 5.2.

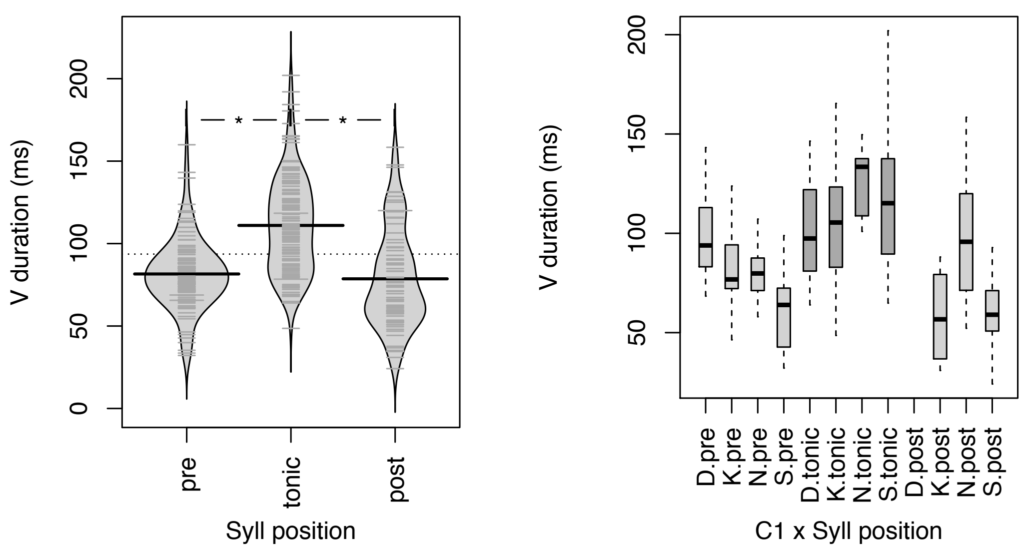
For speaker MO (Figure 5.1), syllable position is a highly statistically significant predictor of vowel duration ($X^2 = 25$; p(2) = 0.000). The model estimate for the duration of the tonic vowels is 91 ms, while the pre-tonic vowels are 23 ms shorter (CI = [-31, -15]; t = -5.8; p(df = 12) = 0.000) and the post-tonic vowels are 22 ms shorter (CI = [-28, -15]; t = -6.8; p(df = 12) = 0.000). The vowel duration regression model for speaker MO is shown in Appendix C Table C.3.

Likewise for speaker MC (Figure 5.2), syllable position is a highly statistically significant predictor of vowel duration ($X^2 = 20$, p(2) = 0.000). The model estimate for the duration of the tonic vowels is 105 ms, while the pre-tonic vowels are 27 ms shorter (CI = [-39, -16]; t = -4.6; p(df = 10) = 0.000) and the post-tonic vowels are 33 ms shorter



a. b.

Figure 5.1: Vowel duration distributions for speaker MO (a) by syllable position and (b) by onset and syllable position



a. b.

Figure 5.2: Vowel duration distributions for speaker MC (a) by syllable position and (b) by onset and syllable position

(CI = [-41, -26]; t = -8.4; p(df = 10) = 0.000). The vowel duration regression model for speaker MC is shown in Appendix C Table C.4.

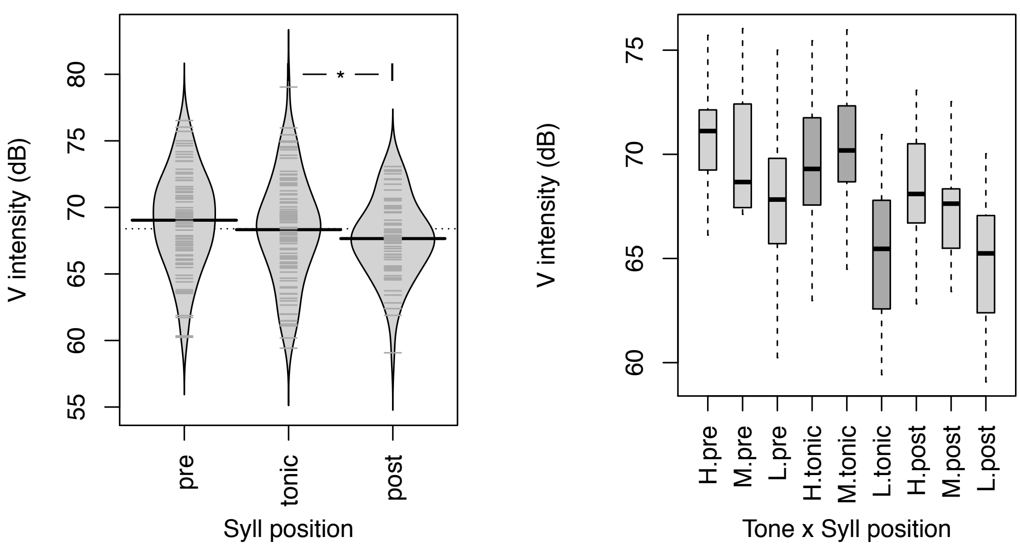
For both speakers, the largest effect size of a control variable—that of onset type—is comparable to the effect of syllable position. For example, vowels after [n] onset are 28 ms longer than after [s] onset in the data from speaker MO, and 26 ms longer in the data from speaker MC. The breakdown by onset and syllable position in Figures 5.1b, 5.2b show that any interactions between onset type and syllable position do not limit the generality of the main effect of syllable position.

5.3.3 Vowel intensity

Next we test whether stressed syllables have higher intensity than unstressed syllables. From the cross-linguistic trends summarized in Table 5.1, we expect that if there is an association between vowel intensity and stress, the stressed vowels will have higher intensity than the unstressed vowels. For both speakers, vowel intensity is associated with prosodic position of the syllable, but as shown in Figure 5.3 and Figure 5.4, the effect of position on vowel intensity differs between the two speakers.

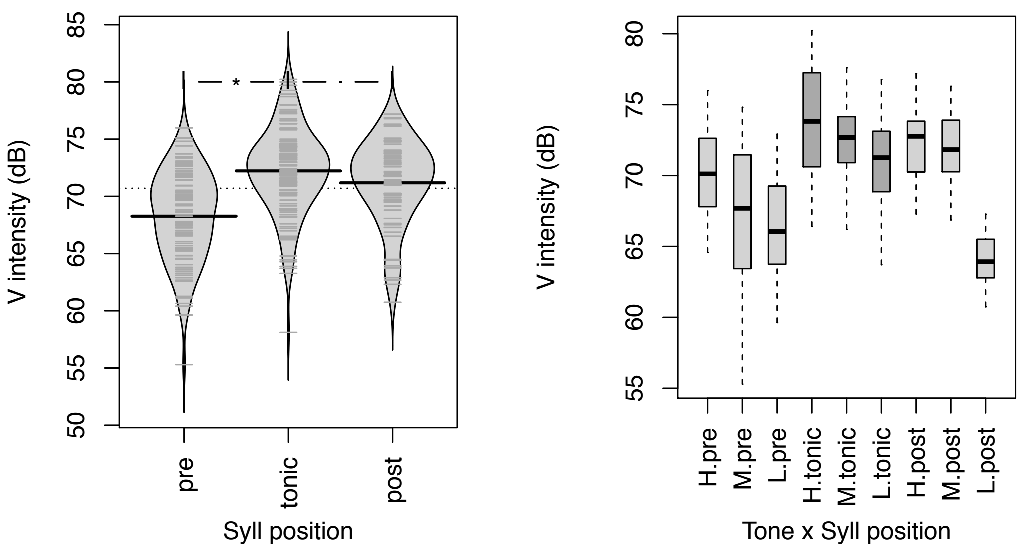
For speaker MO (Figure 5.3), syllable position is a statistically significant predictor of vowel intensity ($X^2 = 10$, p(2) = 0.007). The post-tonic vowels are estimated at 1.9 dB lower intensity (CI = [-2.9, -1.0]; t = -4.0; p(df = 12) = 0.001) than the tonic vowels at 68.8 dB, while the pre-tonic vowels have numerically 0.2 dB higher intensity than the tonic vowels, a difference that is not statistically significant (CI = [-0.9, 1.3]; t = 0.4; p(df = 12) = 0.349). The intensity regression model for speaker MO is shown in Appendix C Table C.5.

Similarly for speaker MC (Figure 5.4), syllable position is a highly statistically significant predictor of intensity ($X^2 = 23$, p(2) = 0.000), but the post-tonic vowels have just 1.6 dB lower intensity (CI = [-3.1, -0.1]; t = -2.2; p(df = 10) = 0.028) than the tonic vowels at 72.0 dB, while the pre-tonic vowels have 4.1 dB lower intensity (CI = [-5.1, -3.2]; t = -8.8; p(df = 10) = 0.000) than the tonic vowels. The intensity regression model for speaker MC is shown in Appendix C Table C.6.



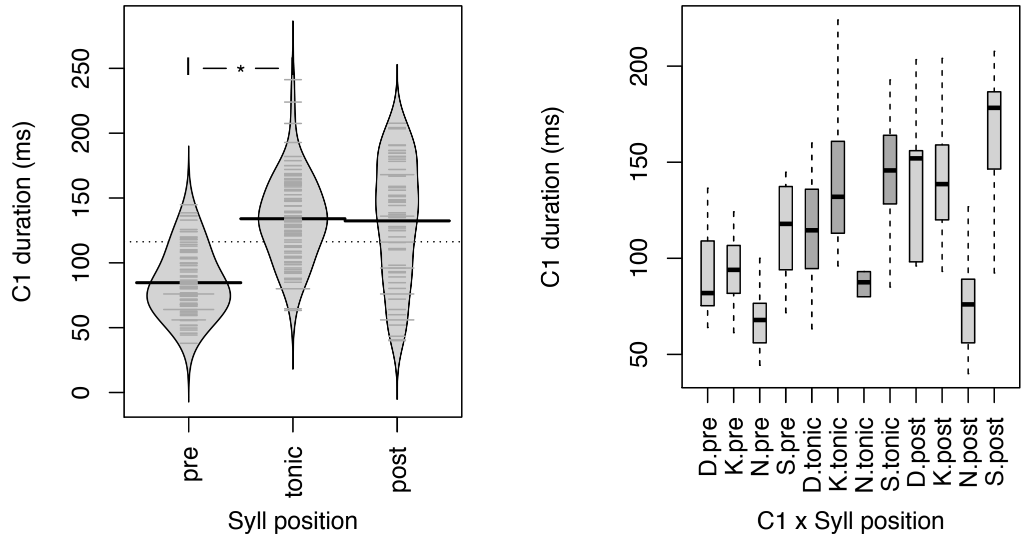
a. b.

Figure 5.3: Vowel intensity distributions for speaker MO (a) by syllable position and (b) by tone and syllable position.



a. b.

Figure 5.4: Vowel intensity distributions for speaker MC (a) by syllable position and (b) by tone and syllable position.



a. b.

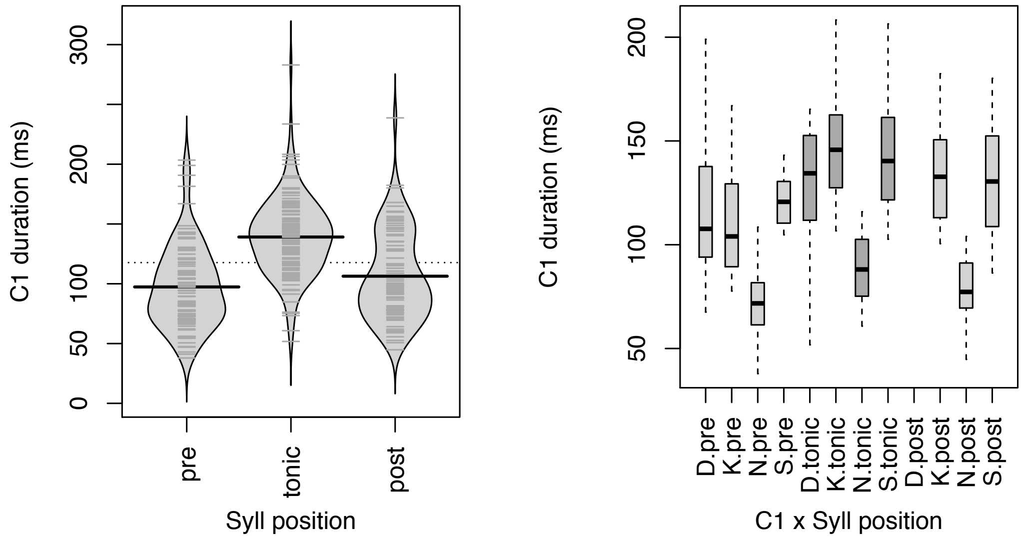
Figure 5.5: Onset duration distributions for speaker MO (a) by syllable position and (b) by onset and syllable position

The largest effect of the control variables, that of tone category, is comparable to the effect of syllable position. For speaker MO (Figure 5.3), H tone vowels are estimated at 4.1 dB higher intensity than L tone vowels. For speaker MC (Figure 5.3), H tone vowels are estimated at 3.8 dB higher intensity than L tone vowels. The intensity differences associated with tone are to be expected from the phonetic association between pitch and intensity (Fant, Kruckenberg, & Liljencrants 2000).

5.3.4 Onset duration

Next we test whether the onsets of stressed syllables have longer duration than the onsets of unstressed syllables. From the cross-linguistic trends summarized in Table 5.1, we expect that if onset duration is associated with stress, the stressed onsets will have longer duration than unstressed onsets. The results for onset duration shown in Figures 5.5, 5.6 indicate that there may be a reliable difference between the onsets in pre-tonic position and the onsets in tonic position, but the onsets in tonic position and the onsets in post-tonic position do not differ reliably.

For speaker MO (Figure 5.5), syllable position is a statistically significant predictor



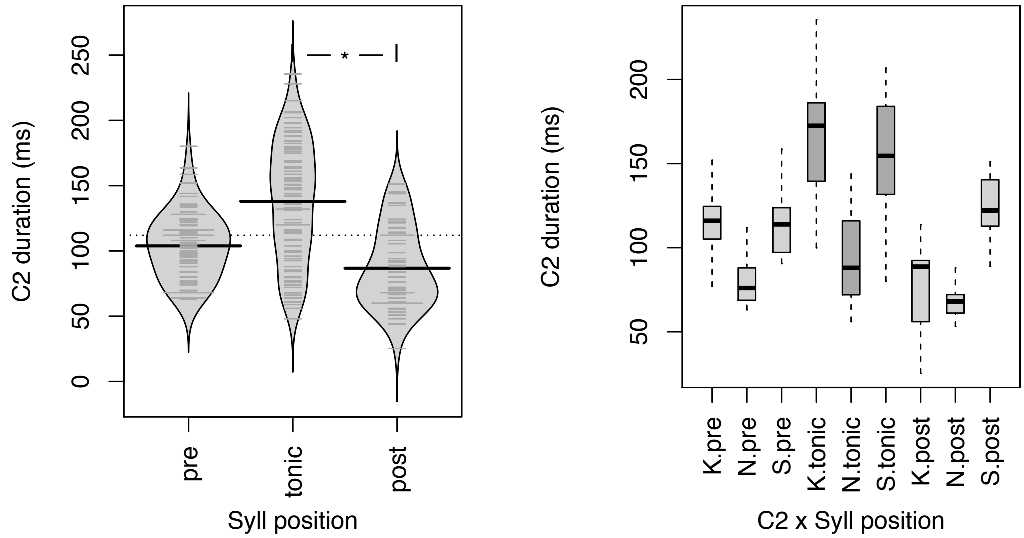
a. b.

Figure 5.6: Onset duration distributions for speaker MC (a) by syllable position and (b) by onset and syllable position

of onset duration ($X^2 = 9$, p(df = 2) = 0.011). The onset duration in tonic position is estimated at 116 ms, with the pre-tonic onsets 9 ms shorter, a difference that is statistically significant (CI = [-16, -1]; t = -2.3; p(df = 12) = 0.019). The difference between post-tonic onsets and tonic onsets is smaller and not statistically significant (CI = [-3.2, 12.6]; t = 1.2; p(d = 12) = 0.133). The onset duration regression model for speaker MO is shown in Appendix C Table C.7.

For speaker MC (Table C.8), the onsets of tonic syllables likewise have longer duration than the onsets of pre-tonic syllables, but the overall effect of syllable position is not statistically significant ($X^2 = 4$, p(df = 2) = 0.139). The onset duration in tonic position is estimated at 124 ms, with the pre-tonic onsets 10 ms shorter (CI = [-18, -2]; t = -2.3; p(df = 10) = 0.021). The difference between post-tonic onsets and tonic onsets is smaller and not statistically significant (CI = [-12.7, 3.9]; t = -1.0; p(d = 10) = 0.162).

The effect size of syllable position is small compared to the effects of the control factors. As shown in Figures 5.5b, 5.6b, the differences associated with syllable position are much smaller than the differences between consonant types, such as the difference between [n] and [s], where [n] is 46 ms shorter than [s] for speaker MO and 45 ms shorter



a. b.

Figure 5.7: Following consonant duration distributions for speaker MO (a) by syllable position and (b) by following consonant and syllable position

than [s] for speaker MC.

5.3.5 Following consonant duration

Next we test whether the consonants after stressed vowels have longer duration than the consonants after unstressed vowels. From the few other languages mentioned in Table 5.1 which show an association between stress and the duration of following consonants, we expect that if there is an association, the consonants after stressed vowels will be longer than than those after unstressed vowels. The results for the durations of the following consonants, shown in Figures 5.7, 5.8, indicate that the consonant after a post-tonic syllable (i.e. the onset of an enclitic) is reliably shorter than the consonant after a tonic syllable (i.e. the medial consonant of a root), while the data from the two speakers differ in regard to the difference between the consonant after a tonic syllable and the consonant after a pretonic syllable (i.e. the initial consonant of the root).

For speaker MO (Figure 5.7), syllable position is a highly statistically significant predictor of the durations of following consonants ($X^2 = 28$, p(2) = 0.000). The model estimates 128 ms as the duration of consonants after a tonic syllable, with consonants

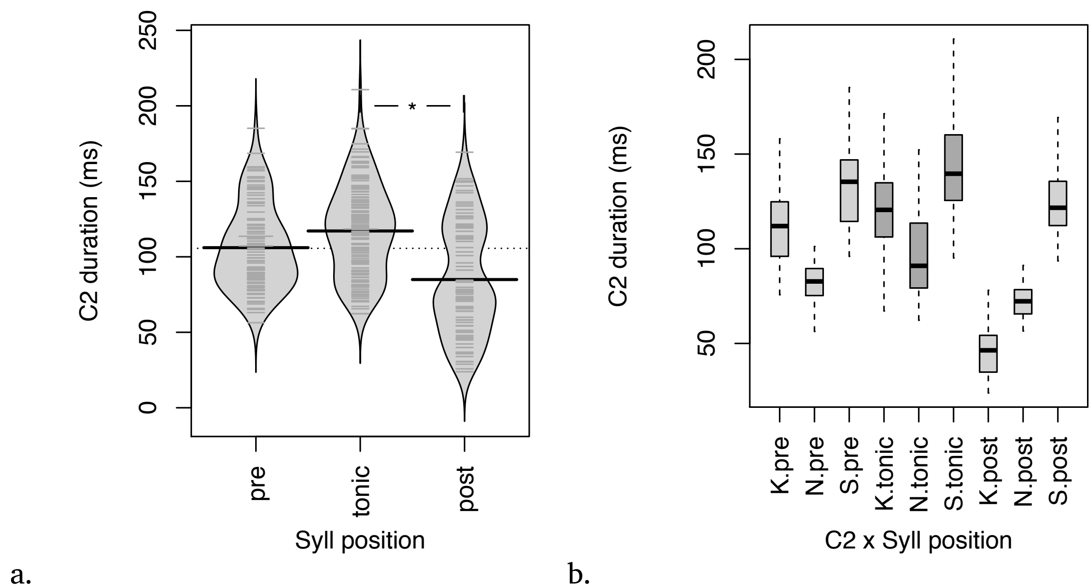


Figure 5.8: Following consonant duration distributions for speaker MC (a) by syllable position and (b) by following consonant and syllable position

after a post-tonic syllable 45 ms shorter (CI = [-59, -31]; t = -6.2; p(df = 12) = 0.000). The consonant after a pre-tonic syllable is 12 ms shorter than the consonant after a tonic syllable, a difference that is just barely judged statistically significant (CI = [-24, 0.9]; t = -1.8; p(df = 12) = 0.047). The regression model about duration of the following consonant for speaker MO is shown in Appendix C Table C.9.

Likewise for speaker MC (Figure 5.8), syllable position is a highly statistically significant predictor of following consonant duration ($X^2 = 13$, p(2) = 0.002). The model estimates 114 ms as the duration of consonants after a tonic syllable, with consonants after a post-tonic syllable 24 ms shorter (CI = [-35, -13]; t = -4.5; p(df = 10) = 0.001). But the difference for consonants following pre-tonic syllables is negligible (CI = [-7.1, 7.2]; t = 0.0; p(df = 10) = 0.495). The regression model about duration of the following consonant for speaker MO is shown in Appendix C Table C.10.

The effect size of syllable position is again comparable to the effect size of segment type. The duration of [n] is 43 ms shorter than [s] for speaker MO, and 44 ms shorter than [s] for speaker MC. The breakdown of C2 duration by syllable position and C2 segment type (Figure 5.7b, 5.8b) indicates that the duration differences associated with syllable position are small for [n] and [s] but large for [k].

5.3.6 Vowel quality

Next we test whether the unstressed vowels have more reduced vowel quality than the stressed vowels. From the cross-linguistic trends summarized in Table 5.1, there are two distinct hypotheses to consider. If vowel quality is associated with stress in Nieves Mixtec, this association might be either vowel centralization in unstressed syllables, as in English (Cho & Keating 2009), or vowel raising in unstressed syllables, as in Bulgarian (Pettersson & Wood 1987; Wood & Pettersson 1988). In terms of F1, the acoustic correlate of vowel height, we would expect less extreme values in unstressed vowels in the case of unstressed vowel centralization, and in the case of unstressed vowel raising, we would expect lower F1 values in unstressed vowels. Because the statistical interaction between vowel type and syllable position is crucial to distinguishing between these two hypotheses—and the sample is well-balanced between /a/ and /i/ vowel types in each syllable position—the regression models for F1 include a vowel type by syllable position interaction term (V × SYLL). The F1 results shown in Figures 5.9, 5.10 show that both speakers exhibit unstressed vowel centralization.

For speaker MO (Figure 5.9), the main effect of syllable position is not statistically significant, but including the interaction between syllable position and vowel type, syllable position is a highly statistically significant predictor of F1 ($X^2 = 34.1$, $p(4) = 0.000$). As shown in Figure 5.9b, the F1 value of [i] is higher in pre-tonic and post-tonic positions than in tonic position (that is, having a lower vowel quality), while the F1 value of [a] is higher in pre-tonic and post-tonic positions than in tonic position (that is, having a higher vowel quality). As a result, the F1 values of [i] and [a] are 6.2 ST (CI = [-7.9, -4.4]; $t = -7.1$; $p(df = 10) = 0.000$) closer together in pre-tonic position than in tonic position and 4.3 ST (CI = [-6.4, -2.2]; $t = -3.94$; $p(df = 10) = 0.001$) closer together in post-tonic position than in tonic position. This indicates that the vowel qualities of [i] and [a] are centralized in unstressed positions. The F1 regression model for speaker MO is shown in Appendix C Table C.11.

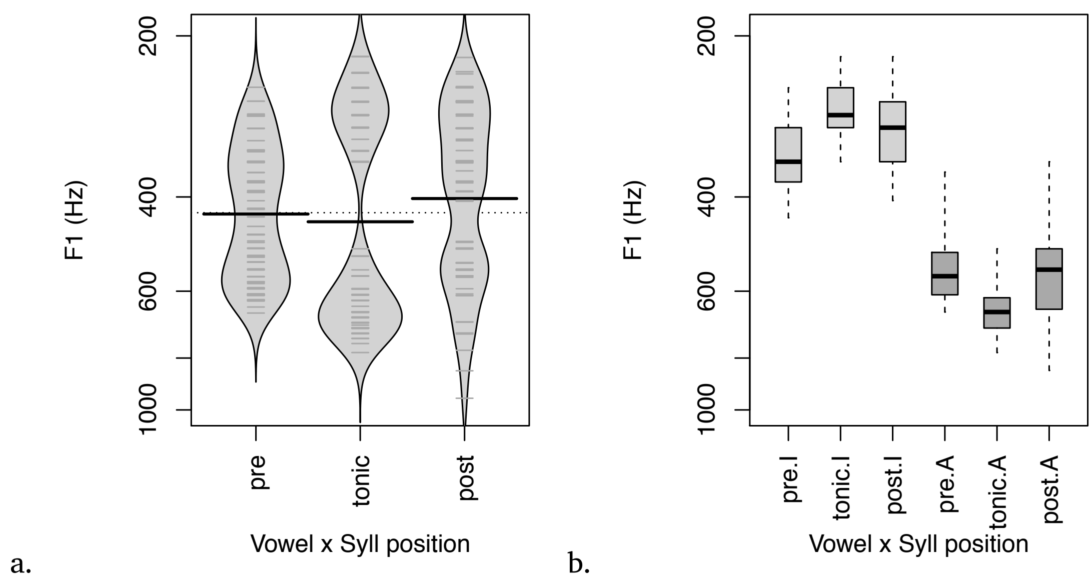


Figure 5.9: Vowel quality distributions for speaker MO (a) by syllable position and (b) by vowel type and syllable position. The F1 axis is inverted to correspond to vowel height.

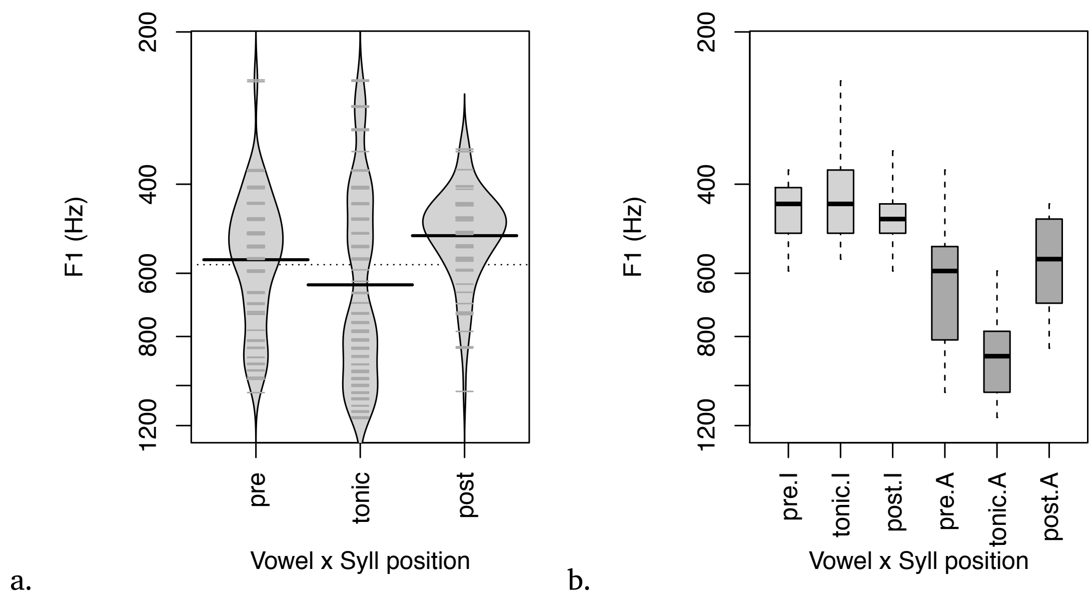
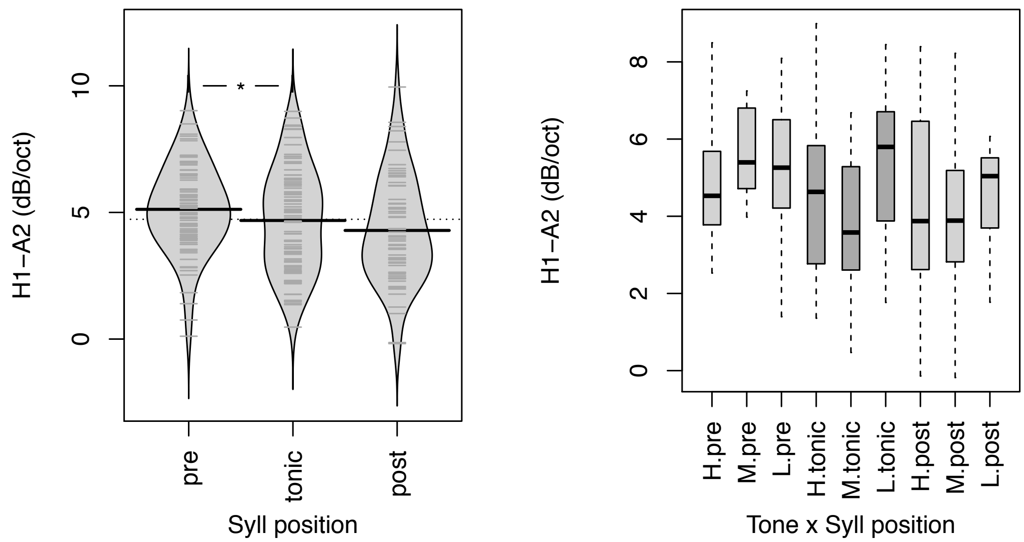


Figure 5.10: Vowel quality distributions for speaker MC (a) by syllable position and (b) by vowel type and syllable position. The F1 axis is inverted to correspond to vowel height.

For speaker MC (Figure 5.10), the overall effect of syllable position is again a highly statistically significant predictor of F1 ($X^2 = 26.2$, p(4) = 0.000). As shown in Figure 5.10b, the F1 value of [i] is relatively consistent across syllable positions, while the F1 value of [a] is much lower (that is, with higher vowel quality) in pre-tonic and post-tonic position than in tonic position. The F1 values of [i] and [a] are 5.0 ST (CI = [-7.4, -2.5]; t = -3.88; p(df = 8) = 0.002) closer together in pre-tonic position than in tonic position and 8.3 ST (CI = [-10.5, -6.2]; t = -7.70; p(df = 8) = 0.000) closer together in post-tonic position than in tonic position. Because the F1 values [a] are so much lower in pre-tonic and post-tonic positions than in tonic position, the overall F1 values are 1.5 ST lower (CI = [-2.8, -0.2]; t = -2.23; p(df = 8) = 0.028) in pre-tonic position than in tonic position and 2.2 ST lower (CI = [-3.4, -1.0]; t = -3.58; p(df = 8) = 0.004) in post-tonic position than in tonic position. However, a re-leveled model (with [i] as the base level of a treatment contrast) shows that the F1 values of [i] are numerically 1.0 ST higher (CI = [-1.0, 3.0]; t = -1.0; p(df = 8) = 0.174) in pre-tonic position and 2.0 ST higher (CI = [0.4, 3.6]; t = -2.5; p(df = 8) = 0.019) in post-tonic position. This indicates that the vowel qualities of [i] and [a] are both centralized in unstressed positions. Even though the centralization of [i] is subtle and the centralization of [a] is a major change, these results are more consistent with the vowel centralization hypothesis than the vowel raising hypothesis. The F0 regression model for speaker MC is shown in Appendix C Table C.12.

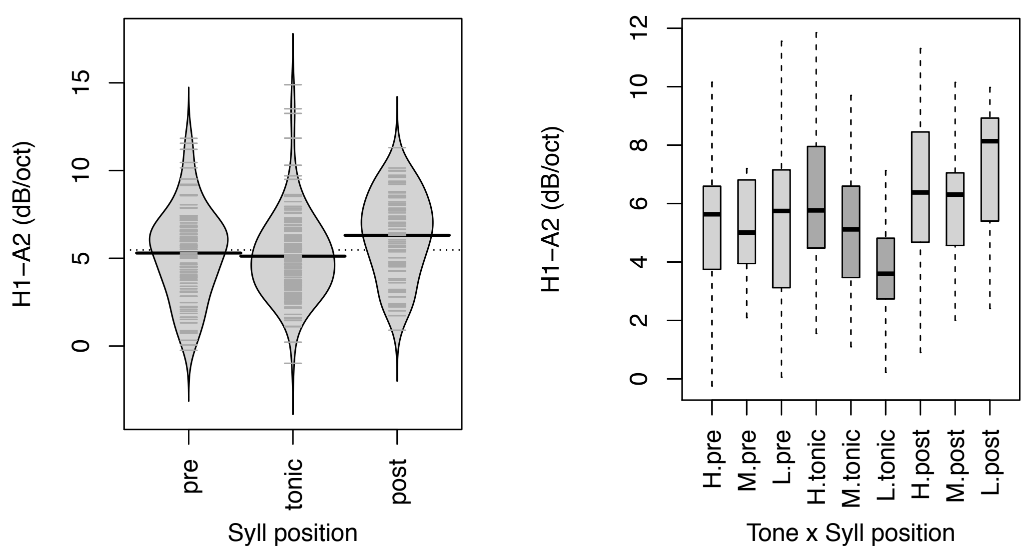
5.3.7 Mid-band spectral tilt

Next we test whether the unstressed vowels have a steeper mid-band spectral tilt (H1-A2) than the stressed vowels. From the cross-linguistic trends summarized in Table 5.1, we expect that if there is an association between mid-band spectral tilt and stress, stressed vowels will have lower spectral tilt values, as lower mid-band spectral tilt values indicate higher intensities in the frequency range of vowel formants. The results for mid-band spectral tilt, shown in Figures 5.11 and 5.12, indicate that pre-tonic vowels do have steeper spectral tilts than tonic vowels for speaker MO, but no statistically significant differences were found for speaker MC.



a. b.

Figure 5.11: Mid-band spectral tilt distributions for speaker MO (a) by syllable position and (b) by tone type and syllable position



a. b.

Figure 5.12: Mid-band spectral tilt distributions for speaker MC (a) by syllable position and (b) by tone type and syllable position

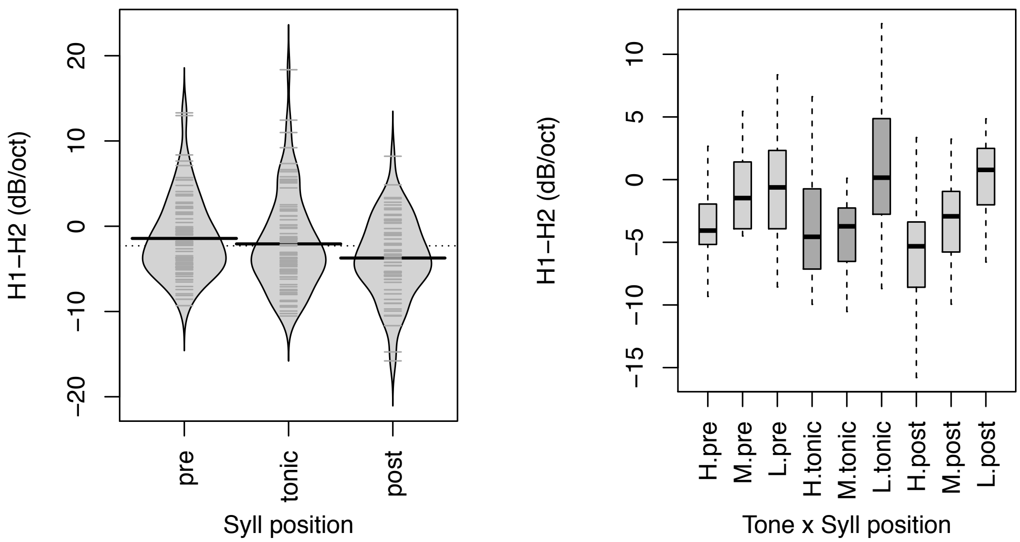
For speaker MO (Figure 5.11), syllable position is judged to be a statistically significant predictor of H1-A2 ($X^2 = 7$, p(2) = 0.036). The tonic vowels have a central H1-A2 value of 4.3 dB, and the pre-tonic vowels have a central H1-A2 value that is 0.9 dB higher (CI = [0.2, 1.6]; t = 2.7; p(df = 12) = 0.010), indicating lower intensity in the vowel formants of pre-tonic vowels. The post-tonic vowels are not statistically significantly different than the tonic vowels (CI = [-0.5, 0.6]; t = 0.1; p(df = 12) = 0.459). The size of the pre-tonic vowel effect is comparable to the largest of the control factors, the effect of tone, where L tones have a central H1-A2 value 1.0 dB higher than H tones, as shown in Figure 5.11b. The H1-A2 regression model for speaker MO is shown in Appendix C Table C.13.

For speaker MC (Table C.14), syllable position as a predictor of H1-A2 is marginally statistically significant ($X^2 = 6$, p(2) = 0.063). The tonic vowels have a central H1-A2 value of 5.3 dB, and neither the pre-tonic vowels (CI = [-1.1, -0.7]; t = -0.4; p(df = 10) = 0.331) nor the post-tonic vowels (CI = [-0.3, 2.1]; t = 1.5; p(df = 10) = 0.084) are statistically significantly different. The size of these effects are smaller than the largest of the control factor effects, that of tone as shown in Figure 5.12b, where L tones have a central H1-A2 value 1.2 dB lower than H tones. The H1-A2 regression model for speaker MC is shown in Appendix C Table C.14.

5.3.8 Low-band spectral tilt

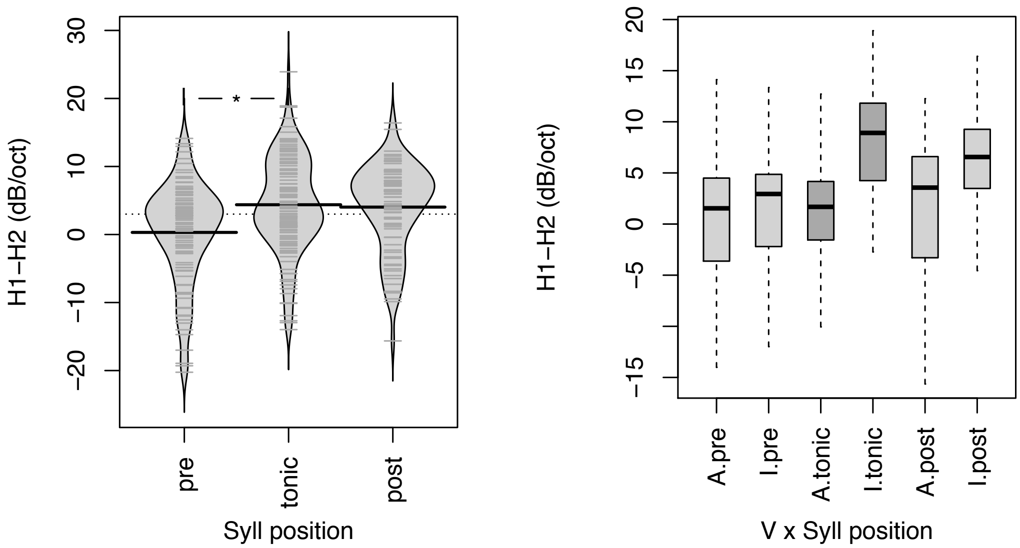
Next we test whether the stressed vowels have lower low-band spectral tilt (H1-H2) than the unstressed vowels. From the cross-linguistic trends summarized in Table 5.1, we expect that if there is an association between low-band spectral tilt and stress, the stressed vowels will have lower spectral tilt values than unstressed vowels. The results for low-band spectral tilt, shown in Figures 5.13, 5.14, indicate that pre-tonic vowels actually have lower spectral tilt values than tonic vowels for speaker MC, while no statistically significant differences are found for speaker MO.

For speaker MO (Figure 5.13), syllable position is not a statistically significant predictor of H1-H2 ($X^2 = 2$, p(2) = 0.340). The tonic vowels have a central H1-H2 of



a. b.

Figure 5.13: Low-band spectral tilt distributions for speaker MO (a) by syllable position and (b) by tone type and syllable position



a. b.

Figure 5.14: Low-band spectral tilt distributions for speaker MC (a) by syllable position and (b) by vowel type and syllable position

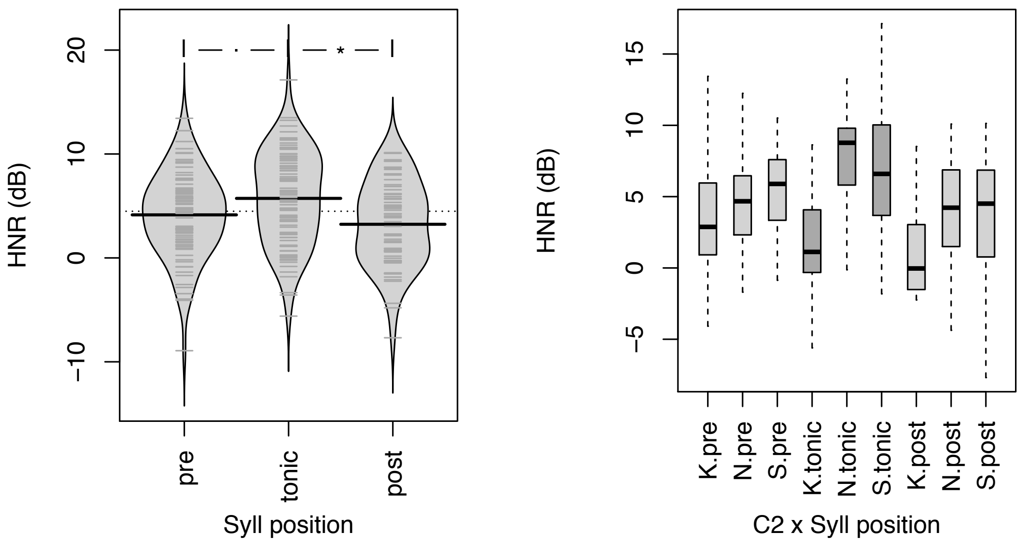
-2.6 dB, and the pre-tonic vowels (CI = [-0.6, 2.7]; t = 1.3; p(df = 12) = 0.118) and post-tonic vowels (CI = [-1.9, 1.3]; t = -0.4; p(df = 12) = 0.363) are not statistically significantly different. The largest effects in the model of H1-H2 for speaker MO are those associated with tone, where L tones have a central H1-H2 value 4.4 dB higher than that of H tones, as shown in Figure 5.13b. The H1-H2 regression model for speaker MO is shown in Appendix C Table C.15.

In contrast, for speaker MC (Figure 5.14), syllable position is a statistically significant predictor of H1-H2 ($X^2 = 11$, p(2) = 0.005). The tonic vowels have a central H1-H2 of 4.3 dB, and the pre-tonic vowels have a central H1-H2 that is 3.6 dB lower (CI = [-5.6, -1.6]; t = -3.5; p(df = 10) = 0.003), while the H1-H2 values of post-tonic vowels are not statistically significantly different (CI = [-3.2, 0.8]; t = -1.2; p(df = 10) = 0.129). These effects suggest that pre-tonic vowels are breathier than tonic vowels. The effect size associated with the difference between pre-tonic vowels and tonic vowels is comparable to the largest of the control factors effects, associated with the difference in vowel type. The central H1-H2 value for [i] is 3.8 dB higher than that of [a], as shown in Figure 5.14b. The H1-H2 measure used in this study attempts to reverse the filtering effect of vowels (Iseli et al. 2007), which should remove any correlation between vowel quality and H1-H2, but the correction term is difficult to estimate for high vowels, particularly for higher pitch voices. The H1-H2 regression model for speaker MC is shown in Appendix C Table C.16.

5.3.9 Harmonics-to-Noise Ratio

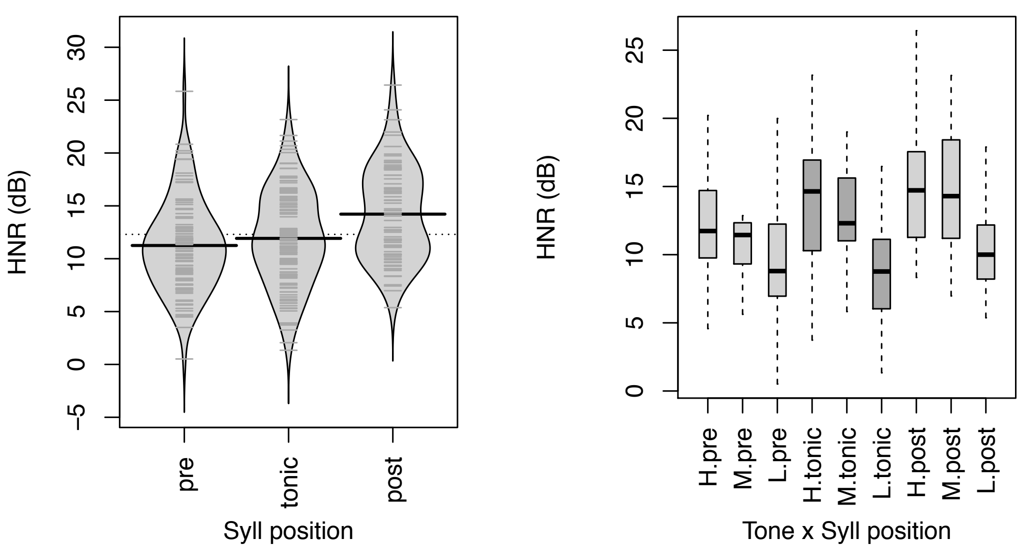
Next we test whether stressed vowels have higher HNR periodicity than unstressed vowels. From the cross-linguistic trends summarized in Table 5.1, we expect that if HNR is associated with stress, the stressed vowels will show higher HNR values than unstressed vowels. The results for HNR, shown in Figures 5.15, 5.16 indicate that tonic vowels have higher HNR periodicity than pre-tonic and post-tonic vowels for speaker MO but not for speaker MC.

For speaker MO (Figure 5.15), syllable position is a highly statistically significant predictor of HNR ($X^2 = 17$, p(2) = 0.000). The tonic vowels have a central HNR of



a. b.

Figure 5.15: Harmonics-to-Noise Ratio distributions for speaker MO (a) by syllable position and (b) by following consonant and syllable position



a. b.

Figure 5.16: Harmonics-to-Noise Ratio distributions for speaker MC (a) by syllable position and (b) by tone type and syllable position

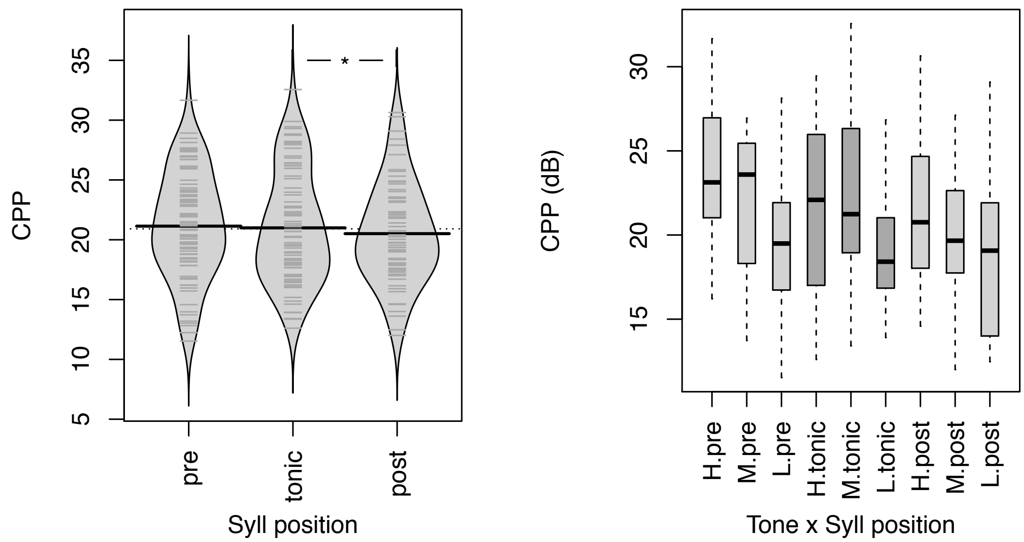
5.7 dB, and the pre-tonic vowels have a central HNR 1.5 dB lower (CI = [-3.1, 0.1]; t = -1.8; p(df = 12) = 0.050), while the post-tonic vowels have a central HNR 3.3 dB lower (CI = -4.6, -2.0]; t = -5.0; p(df = 12) = 0.000). These effects indicate that tonic vowels are more periodic than pre-tonic and post-tonic vowels. The size of these effects is smaller than the largest of the control factor effects, that of following consonant as shown in Figure 5.15b, where vowels before [n] have a central HNR 3.6 dB higher than vowels before [k]. The HNR regression model for speaker MO is shown in Appendix C Table C.17.

For speaker MC (Figure 5.16), syllable position is not a statistically significant predictor of HNR ($X^2 = 2.3$, p(2) = 0.309). The tonic vowels have a central HNR value of 12.2 dB, and the HNR values of pre-tonic (CI = [-2.0, 0.8]; t = -0.9; p(df = 10) = 0.204) and post-tonic (CI = [-0.7, 2.2]; t = 1.1; p(df = 10) = 0.157) vowels are not statistically significantly different. The size of these effects is much smaller than the largest of the control factor effects, that of tone shown in Figure 5.16b, where H tones have a central HNR value 4.2 dB higher than L tones. The HNR regression model for speaker MC is shown in Appendix C Table C.18.

5.3.10 Cepstral Peak Prominence

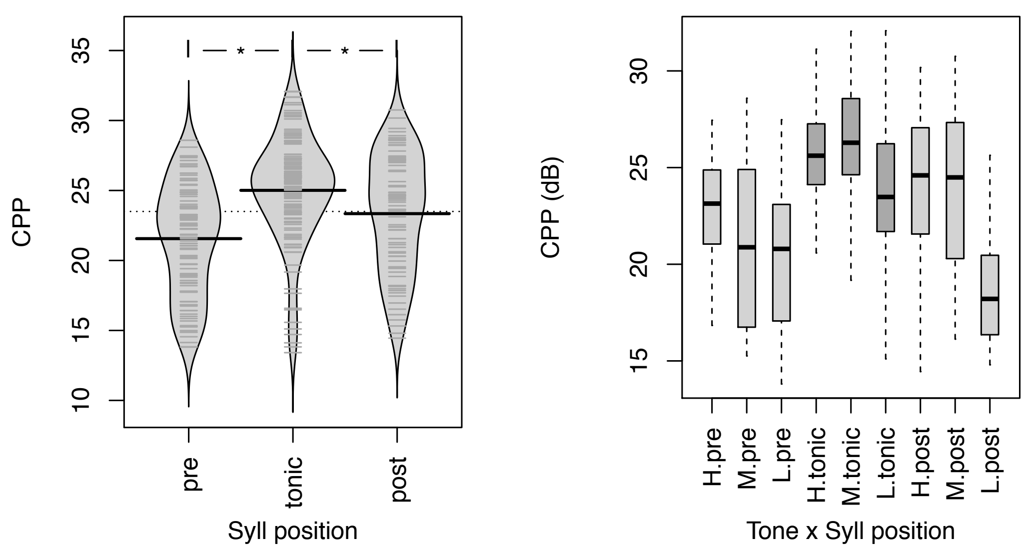
Next we test whether stressed vowels have higher CPP periodicity than unstressed vowels. From the cross-linguistic trends summarized in Table 5.1, we expect that if CPP is associated with stress, stressed vowels will have higher CPP values than unstressed vowels. The results for CPP, shown in Figures 5.17, 5.18, indicate that stressed vowels generally do have higher CPP periodicity than unstressed vowels, though no difference was found between pre-tonic and tonic vowels for speaker MO.

For speaker MO (Figure 5.17), syllable position is a statistically significant predictor of CPP ($X^2 = 7.6$, p(2) = 0.023), but the association with syllable position is limited to the difference between tonic and post-tonic vowels. The central value for tonic vowels is 21.4 dB, and the central value for post-tonic vowels is 1.7 dB lower (CI = [-2.9, -0.5]; t = -2.7; p(df = 12) = 0.009), while the difference between tonic vowels and pre-tonic vowels is negligible (CI = [-1.3, 1.4]; t = 0.1; p(df = 12) = 0.470). These effects indicate that



a. b.

Figure 5.17: Cepstral Peak Prominence distributions for speaker MO (a) by syllable position and (b) by tone type and syllable position



a. b.

Figure 5.18: Cepstral Peak Prominence distributions for speaker MC (a) by syllable position and (b) by tone type and syllable position

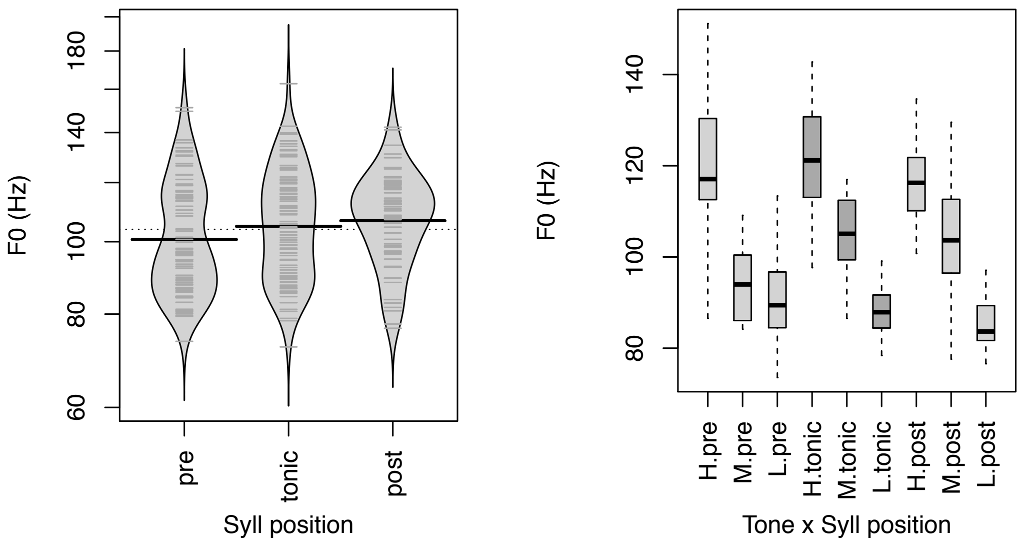
tonic vowels are more periodic than post-tonic vowels. These effects are much smaller than the largest of the control factor effects, that of tone shown in Figure 5.17b, where H tones have a central CPP value 3.2 dB higher than L tones. The CPP regression model for speaker MO is shown in Appendix C Table C.19.

For speaker MC (Figure 5.18), syllable position is a highly statistically significant predictor of CPP ($X^2 = 26$, p(2) = 0.000). The central value of tonic vowels is 24.8 dB, and the central value for pre-tonic vowels is 3.8 dB lower (CI = [-4.7, -2.9]; t = -8.3; p(df = 10) = 0.000), and the central value for post-tonic vowels is 1.5 dB lower (CI = [-2.5, -0.5]; t = -2.9; p(df = 10) = 0.009). These effects indicate that tonic vowels are more periodic than pre-tonic and post-tonic vowels. These effects are comparable to the largest of the control factor effects, that of tone shown in Figure 5.18b, where the H tones have a central CPP value 2.4 dB higher than L tones. The CPP regression model for speaker MC is shown in Appendix C Table C.20.

5.3.11 Fundamental frequency

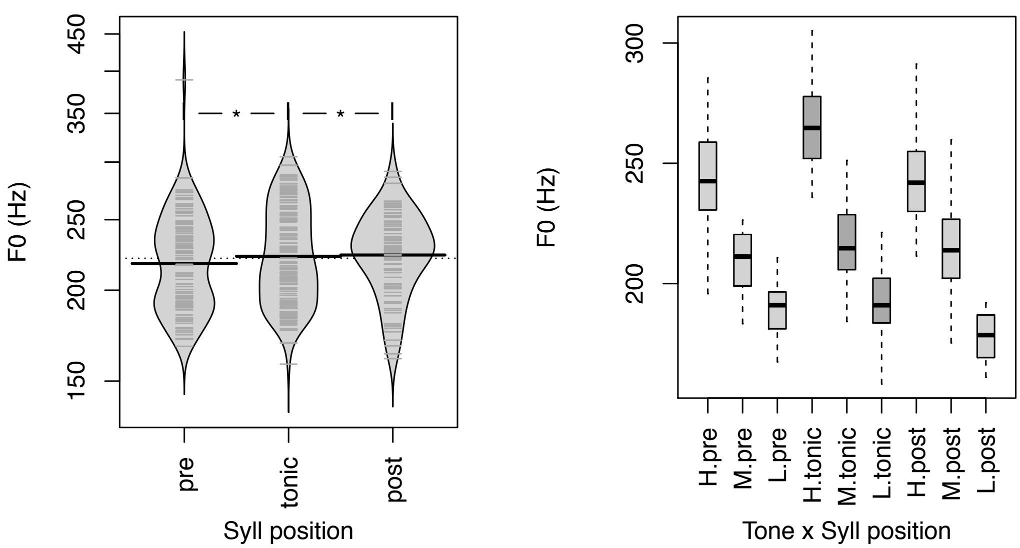
Next we test whether stressed vowels exhibit pitch raising or pitch expansion compared to unstressed vowels. From the cross-linguistic trends summarized in Table 5.1, we expect that if F0 is associated with stress (or phrasal accent), the F0 of tonic vowels would either be higher overall (pitch raising) or have higher highs and lower lows (pitch expansion). To better distinguish between pitch raising and pitch expansion, we consider a regression model with parameters for an interaction between syllable position and tone (SYLL $\times$ T), as well as the simpler model without that interaction. Because of gaps in the design matrix, the interaction between syllable position and tone cannot be included in the random effects, which makes the estimates of the interaction fixed effect less reliable and exaggerates their statistical significance. However, the parameter estimates still help illuminate the phenomena. The results for F0, shown in Figure 5.19, 5.20 indicate pitch raising in tonic syllables for speaker MC but no association between F0 and stress for speaker MO.

For speaker MO (Figure 5.19), syllable position is not a statistically significant pre-



a. b.

Figure 5.19: Fundamental frequency distributions for speaker MO (a) by syllable position and (b) by tone type and syllable position



a. b.

Figure 5.20: Fundamental frequency distributions for speaker MC (a) by syllable position and (b) by tone type and syllable position

dictor of F0 ($X^2 = 1.5$, p(2) = 0.473). Pre-tonic syllables (CI = [-0.7, 0.7]; t = 0.0; p(df = 12) = 0.490), and post-tonic syllables (CI = [-1.1, 0.2]; t = -1.3; p(df = 12) = 0.116) have central F0 values that are not statistically significantly different than tonic syllables. These negligible differences are much smaller than the difference 5.2 ST between H and L tones shown in Figure 5.19b. The F0 regression model for speaker MO is shown in Appendix C Table C.21. In the expanded model that includes an interaction between syllable position and tone, as in the case of the simpler model, syllable position is again not a statistically significant predictor of F0 ($X^2 = 9$, p(6) = 0.172). The F0 regression model with the interaction terms is shown in Appendix C Table C.22. So speaker MO shows neither pitch raising nor pitch expansion in the tonic syllable.

However, for speaker MC (Figure 5.20), syllable position is a highly statistically significant predictor of F0 ($X^2 = 23$, p(2) = 0.000). Pre-tonic syllables have a central F0 value 0.8 ST lower than tonic syllables (CI = [-1.2, -0.4]; t = -4.2; p(df = 10) = 0.001), and post-tonic syllables have a central F0 value 1.3 ST lower than tonic syllables (CI = [-1.9, -0.7]; t = -4.4; p(df = 10) = 0.001). These differences are still much smaller than the 4.8 ST difference between H and L tones shown in Figure 5.20b. The F0 regression model for speaker MC is shown in Appendix C Table C.23. In the expanded model with an interaction between syllable position and tone, syllable position with its interaction with tone is a highly statistically significant predictor of F0 ($X^2 = 45$, p(6) = 0.000). The F0 regression model with the interaction terms is shown in Appendix C Table C.24. The interaction terms suggest pitch raising in tonic position. In pre-tonic position relative to tonic position, the F0 of L tones is lowered by 0.3 ST, the F0 of M tones is lowered by 0.8 ST, and the F0 of H tones is lowered by 1.6 ST. So even though the tones are more spread out in tonic position than in pre-tonic position, all tones have higher F0 in tonic position than in pre-tonic position. In post-tonic position, the F0 of L tones is lowered by 2.1 ST, the F0 of M tones is lowered by 1.5 ST relative to tonic position, and the F0 of H tones is lowered 1.8 ST. So the F0 of each tone in tonic position is more-or-less equally raised relative to post-tonic position. These results indicate that the tones in tonic position exhibit pitch raising relative to both pre-tonic and post-tonic positions.

Table 5.5: Association between stress and each acoustic measure and speaker. '+' indicates distinguishing tonic from both pre-tonic and post-tonic syllables; '✓' indicates just one of these.

	Speaker	
Acoustic Property	MO	MC
Vowel Duration	+	+
Intensity	✓	+
Consonant Duration	✓	✓
Vowel Quality	+	+
H1–A2	✓	X
H1–H2	X	✓
HNR	✓	X
CPP	✓	+
F0	X	✓

5.4 Discussion

In sum, the discriminant analysis (§5.3.1) highlighted segmental durations as key indicators of stress, and the regression analyses (§5.3.2–§5.3.11) confirmed this finding while also showing that a few other measures are important. The associations between stress and acoustic properties are summarized in Table 5.5.

Both vowel duration (§5.3.2) and vowel quality (§5.3.6) distinguish the tonic syllable from both the pre-tonic and post-tonic syllables for both speakers. The vowels in tonic syllables have longer durations than pre-tonic and post-tonic syllables, and the vowels in tonic syllables have more peripheral vowel height than the pre-tonic and post-tonic syllables.

In addition, vowel intensity (§5.3.3), onset duration (§5.3.4), following consonant duration (§5.3.5), and CPP periodicity (§5.3.10) are found to distinguish tonic syllables from either pre-tonic or post-tonic syllables for both speakers. For speaker MO, greater intensity was found to distinguish tonic from post-tonic syllables, while for speaker MC, greater intensity was found to distinguish tonic from both pre-tonic and post-tonic syllables. Among the consonant durations (§5.3.4, §5.3.5), the pre-tonic onsets have shorter durations than the tonic onsets, and the enclitic consonants have shorter durations than the root consonants, but only small or negligible differences were found between the initial and medial consonants in the root, from either the perspective of syllable onsets or the perspective of consonants following the target syllables. Greater CPP periodicity (§5.3.10) distinguished tonic syllables from both pre-tonic and post-tonic syllables for speaker MC but only distinguished tonic from post-tonic syllables for speaker MO.

Finally, the spectral tilt measures, HNR periodicity, and F0 showed effects for one or the other speaker but not both speakers. Low-band spectral tilt (§5.3.8) was found to be unrelated to prosodic position for speaker MO, but for speaker MC, greater low-band spectral tilt did distinguish pre-tonic from tonic syllables. In contrast, greater mid-band spectral tilt (§5.3.7) was found to distinguish pre-tonic syllables from tonic syllables for speaker MO, but it was unrelated to syllable position for speaker MC. Similarly, greater HNR periodicity (§5.3.9) did distinguish tonic syllables form pre-tonic and post-tonic syllables for speaker MO but not for speaker MC. The F0 analysis (§5.3.11) found that speaker MO showed no association between F0 and syllable position, while for speaker MC, there was an association that suggests pitch raising in the tonic syllable.

The variation between speakers observed here might be characteristic of phonological variation within the speech community, and the number of speakers included in this study is insufficient to attempt an analysis of speaker differences. On the other hand, the variation observed here might also be due to different speaking styles in the elicited translation task itself. As previously noted, the study design can not distinguish between effects of word stress and effects of phrasal accent that are localized to stressed syllables, and it is not even clear yet what phrasal domains are involved in the prosody of Nieves Mixtec. Thus it is possible that different speakers have used different phrasing and so different prominence types, besides the differences that might exist in how stress or other prosodic prominence is realized phonetically. The study design also did not independently control for the position of the syllable within the word or the position of the syllable within the phrase. It is possible that some differences between speakers are due to different distributions of syllables within words or phrases in the data sample. [3] The

[3]Regression analyses of the effect on vowel duration and onset duration for speaker MO, contrasting just the two extremes of syllables that are utterance-initial and syllables that are word-internal, found no reliable effect on onset duration and only slightly longer vowel duration in

effects of word boundaries and phrasal prosody merit further investigation.

Despite the between speaker differences in how tonic syllables differed from pre-tonic and post-tonic syllables, the results are consistent with findings from other languages on the realization of stress contrasts. The directions of the effects found here all point towards the claimed tonic syllable as the most prominent syllable. The longer vowel durations consistently found in the tonic syllable are a widely reported correlate of stress (e.g. Remijsen & van Heuven 2005; de Jong 2004; Ortega-Llebaria & Prieto 2007). The longer consonant durations in root consonants are comparable to findings in other languages of longer consonants in stressed syllables (e.g. Arvaniti 1994; Everett 1998; van Santen & Shih 2000). The vowel height centralization observed in unstressed syllables is comparable to the vowel quality reduction found in many other languages (e.g. van Bergem 1993; Remijsen & van Heuven 2005; Cho & Keating 2009). The overall intensity differences and mid-band spectral tilt differences, where found here, favor the tonic syllable as the loudest of the three syllables, another characteristic of stress and phrasal accent (e.g. Heldner 2003; Ortega-Llebaria & Prieto 2007). The differences in periodicity measures suggest that the tonic syllables have more modal voice or less spectral noise than the other syllables, similar to results reported for Tongan (Garellek & White 2015). And the pitch raising found for speaker MC is comparable to pitch raising in prominent positions reported in other tone languages (e.g. Jin 1996; Chávez-Peón 2008). Though the phonetic correlates of stress somewhat differed between speakers, these findings confirm the stress analysis presented in the previous chapter, while expanding the phonetic typology of stress summarized in §2.3.

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utterance-initial syllables than in word-internal syllables.

Chapter 6

Tone phonology

6.1 Introduction

This chapter provides a phonological description of Nieves Mixtec tone. All phonologically described languages within the large Otomanguean language stock (including Mixtec languages) have been described as having tone systems (van der Hulst, Rice, & Wetzels 2006:256). In addition, many Otomanguean languages exhibit 'laryngeal complexity' (Silverman 1997), defined as the presence of contrastive phonation types in addition to contrastive tone. This includes Mixtec languages, which are well-known for having dense tone systems and complex tone phonologies, besides contrastive glottalization (Josserand 1983; Dürr 1987; Macaulay & Salmons 1995). Moreover, the tone systems in Mixtec have a high functional load, distinguishing lexical classes and verbal inflections, besides the phonemic contrasts essential to lexical tone systems. The tone system of Nieves Mixtec is thus central to the language structure as well as being important for cross-linguistic study of word prosody.

6.1.1 Overview of Mixtec tone systems

In order to better contextualize both what can be established about the Nieves Mixtec tone system and the questions that are raised but not answered within the scope of this dissertation, it is necessary to examine the substantial literature on the tone systems of other Mixtec varieties. Here I summarize trends established by Dürr (1987) and McKendry (2013:107–129) using comparative data, while comparison of Nieves Mixtec with selected Mixtec tone systems is provided in section §6.4 after the description of the Nieves Mixtec tone system.

Nieves Mixtec belongs to a set of central Mixtec languages—called "Area A" by Dürr and "Group A" by McKendry—which show variation around one tone system prototype, while several peripheral varieties in the south and east ("Area B" or "Group B") have tone systems that are inverted compared to Group A tone systems. The difference in terminology is based on differing views as to whether "B" varieties can be delimited by a geographic region. The tonal systems of many varieties have not been described, but as far as existing documentation shows, the "B" varieties do not constitute a genetic clade, nor do they occupy a contiguous region. The distinction cuts across the dialect groups proposed by Josserand (1983), with the Group A varieties occupying most of the Mixteca region and Group B varieties lying along the periphery, alongside Group A varieties in Alta and Costa regions. It is thus only a small improvement to call B varieties a group rather than an area, but I nevertheless follow the terminology of McKendry. In both Group A and Group B, the tonal phonologies generally involve a tripartite system of underlying low (L), mid (M), and high (H) tones. However, several Group A varieties have developed a fourth level between L and M,[1] written 'Λ' here following McKendry (2013), and a few Group B varieties have been analyzed with just two basic tone levels.[2] In Group A varieties, the H tone, which is reconstructed in Proto-Mixtec as a morpheme-final glottal stop,

[1]These include at least Santo Domingo Nuxaá (NUX) (McKendry 2013), San Esteban Atatlahuca (ATA) (Mak 1953; R. M. Alexander 1980), Xochapa which is affiliated with Alcozauca (ALC) (Stark et al. 2003) and Yoloxochitl (YOL) (DiCanio et al. 2012).

[2]These are San Juan Coatzospan (COA) (E. V. Pike & Small 1974; Gerfen & Denisowski 2001) with two levels (L and H) plus downstep of H tone, and San Juan Diuxi (DIU) (Daly 1978) and Santa María Peñoles (PÑL) (Daly 1977) with two levels (L and H) plus modification (comparable but not equivalent to downstep). Note, however, that E. V. Pike and Oram (1976) analyzed the Diuxi system as two tone levels plus lexical stress, and Daly and Hyman (2007) reanalyzed the Peñoles system as a three-level tone system (L, ∅ and H) with unspecified [M]. Herrera Zendejas (2009) also describes the system in Ayutla de los Libres (AYU, in neither Group A nor Group B) as involving just two levels, but Pankratz and Pike (1967) describes it as a three-level system with limited distribution of M tone.

Table 6.1: Comparison of tones in cognate words for five Mixtec varieties, with Proto-Mixtec (PM) reconstructed forms, adapted from McKendry (2013: 107–129)

		Group A				Group B			
PM	Gloss	Nux		Mig	Alc	Pñl		Ayu	
*L.L	comb	L	kūkà	kūkà	kʷìkà	H.H	kúká	M.L	βīkà
*L.L	priest	L	ðūtù	sūtù	sùtù	H.H+L	ðútú`	M.L	sūtù
*L.Lʔ	snake	L+H	kōò´	kōò´	kòó	H.H+L	kóó`	M.Lˀ	kōòˀ
*L.Lʔ	cloud	L+H	βīkò´	βīkò	βìkó	H.H+L	βíkó`	M.Lˀ	βīkòˀ
*M.M	house	M	βēˀē	βēˀē	βēˀē	M	βēˀē	L.L	βìˀè
*M.M	one	M	īī$_n$	ɨ̄ɨ̄$_n$	ɨ̄ɨ̄$_n$	M	ɨ̄ɨ̄$_n$	L.L	ìì$_n$
*M.Mʔ	festival	M+H	βīkō´	βīkō´	βīkó	M+L	βīkō`	L.Mˀ	βìkōˀ
*M.Mʔ	mouth	M+H	jūˀū´	jūˀū´	jūˀú	M+L	jūˀū`	L.Mˀ	jùˀūˀ
*L.M	adobe	L+M	^{n}dōˀò¯	^{n}dòˀō	^{n}dòˀō	H.M	^{n}dóˀō	L.L	^{n}dòˀò
*L.M	pot	L+M	kīðì¯	kɨ̀sɨ̄	kìsī	H.M	kɨ́ðɨ̄	L.L	kìsì
*M.L	deer	ML	īðū̀	īsù	īsū	M.H	īðú	L.L	ìsù
*M.L	flower	ML	ītā̀	ītà	ītā	M.H	ītá	L.L	ìtà

is the most phonologically marked, and M tone is least marked. McKendry (2013) further shows that for the six tone patterns that are reconstructed for Proto-Mixtec roots, a few geographically dispersed varieties within Group A even require the same synchronic underlying tonal specifications, while they differ in their tonal association patterns. These similarities are summarized in Table 6.1,[3] with three Group A varieties that show close correspondences: Santo Domingo Nuxaa (Nux) in the Eastern Alta dialect group, San Miguel el Grande which is affiliated with Chalcatongo (Chl) in the Western Alta dialect group, and Xochapa, affiliated with Alcozauca (Alc) in the Guerrero dialect group. As described in §6.2, the tone system of Ixpantepec Nieves is also a Group A system, though it slightly differs from the underlying tones of the systems in Table 6.1. In contrast, in Group B varieties, represented in the table by Santa Maria Peñoles (Pñl), the tones are inverted, such that the L tone of Group A corresponds to H tone in Group B, and the H tone of Group A corresponds variously to L tone or downstep in Group B. Group B va-

[3]The transcriptions here are taken from McKendry (2013) with minimal adaptation towards the conventions used in the rest of this dissertation. Tones that usually associate to the host morpheme are transcribed on the appropriate vowel, e.g. /á/ H tone, /ā/ M tone, /à/ L tone. Tones that usually associate to a following morpheme are transcribed as floating tones over white space, e.g. / ´/ +H tone, / ¯/ +M tone, / `/ +L tone. In the specification of the tone patterns, a plus ('+H') indicates a floating tone, and I use a period ('L.M'), the conventional indication of syllable boundaries, to separate the tones associated to each mora, even though the boundary between morae generally does not correspond to a syllable boundary in CVV stems (§4.4.1). The subscript <n> indicates a nasalized morpheme.

rieties have comparatively low density tone systems, such as Peñoles Mixtec, which has nine tone patterns in bimoraic stems, while the tonal density of Group A systems span from the ten tone patterns of Santo Domingo Nuxaá Mixtec to more than 20 tone patterns in Yoloxochitl Mixtec (YOL) (DiCanio et al. 2012). Finally, the Mixtec of Ayutla (AYU) is not considered to belong to either group, as it maintains the morpheme-final glottal stop and shows more complicated correspondence with respect to the other tones. In Ayutla Mixtec, the rising *L.M tone pattern, the falling *M.L tone pattern and the level *M.M tone pattern of Proto-Mixtec all neutralized to L.L, and the other level tone patterns changed to rising and falling tone patterns L.Mˀ, M.L, and M.Lˀ.

6.1.2 Themes and claims

The central questions and claims of the description of Nieves Mixtec tone—as well as the comparisons with other Mixtec tone systems—are structured around the themes in (6.1).

(6.1) a. The derivation of lexical tone specifications (sequences of [H], [M] and [L] tones) from underlying tone (marked /H/ and /L/ tones and unmarked ∅).

b. The post-lexical derivation of phonetic tone targets (levels and contours) from lexical tone specifications.

c. The morphological and prosodic domains which sponsor underlying tone (morphemes), bear lexical tone (morae), and license tone processes (stems, clitics, feet, prosodic words or prosodic phrases).

In regard to (6.1a), the description presented here shows that Nieves Mixtec lexical tone specifications are based on a three-level system, where the [M] level is less marked than the other levels. This difference in markedness is shown by the absence of tone processes triggered by [M] tone and by its susceptibility to tone changes, in both the lexical phonology (6.1a) and the post-lexical phonology (6.1b). In contrast, L and H tones can both trigger tone processes, and they undergo tone changes in more restricted environments. In regard to (6.1c), the distribution of tone in morphemes of different prosodic types (e.g.

bimoraic stems, monomoraic functional morphemes, and non-moraic tonal morphemes) indicates that a morpheme can sponsor one tone per mora, plus an additional +H or +L floating tone, which is underlyingly unassociated to any mora. Finally, this description, like the reviewed literature on tone processes in other Mixtec varieties, provides evidence that tonal processes are influenced by prosodic or morphological domain type, but this work ultimately remains agnostic as to what the licensing domains of the tonal processes are.

The structure of the chapter is as follows. Section §6.2 describes the distribution of tone and some tone processes in bimoraic stems. Section §6.3 then describes the distribution of tone in monomoraic functional morphemes and some tone processes that involve functional morphemes. Section §6.4 summarizes descriptions of several Mixtec tone systems and compares them with the Nieves Mixtec tone system, focusing on two tone systems of the Western Alta dialect group—San Miguel el Grande and San Esteban Atatlahuca—which closely resemble that of Nieves and have been extensively described. Finally, §6.5 summarizes the chapter.

6.2 Tone in bimoraic stems

In this section, we examine the tone system of Ixpantepec Nieves Mixtec within bimoraic stems, including the tonal inventory as well as aspects of the phonetic implementation. As proposed for most Mixtec varieties (reviewed in §6.4), here I adopt an analysis in which lexical tones in Nieves Mixtec are specified as sequences of low (L), mid (M) and high (H) targets. The evidence presented in this section demonstrates that L and H tones are underlyingly specified and phonologically active. The observed tonal processes, discussed in §6.2.1 and §6.2.3, can be described via the association and dissociation of L and H tones to morae, and some L and H tones are best analyzed as floating tones, which are underlyingly unassociated to any mora. The role of M tone in the tone distribution and processes indicates that it is less marked. In the lexical phonology, there are no floating M tones, and M tone can be described as the absence of L or H tone. But in the post-lexical phonology, M tone can block tone processes and, in restricted circumstances, share a mora with L tone. In the analysis pursued here, I treat M tone as underlyingly unspecified but having a default specification in the lexical surface form, so that it is not unspecified in the post-lexical phonology.

As discussed in §4.2, the canonical bimoraic stem, known as a *couplet*, is a natural unit for analysis of tone and stress in content words across Mixtec varieties, so this section focuses on the tone system in couplets. In contrast, function words and affixes are canonically monomoraic, and tone processes in functional morphemes are described in section §6.3. The distribution of tone in couplets is described in §6.2.1, and then §6.2.2 describes a few ways that couplet tone patterns are restricted in certain lexical classes. Finally, §6.2.3 describes some tone processes observed in couplets.

6.2.1 Couplet tone pattern inventory

Couplets can be either monosyllabic with a long vowel ((C)VV) or disyllabic with short vowels ((C)VCV). All nine possible pairs of basic tones are attested in these couplet types. Example (C)VV couplets with these tone patterns are shown in (6.2–6.4), with phonetic transcriptions according to typical production as isolated utterances.

(6.2)	a. H.H: kuéé [kʷe˥e˥] /kʷéé/ ‘slow’	b. M.H: vií [vi˧i˥] /vií/ ‘clean’	c. L.H: tyi̱í [tʲi˩i˥] /tʲìí/ ‘numb’ (v.)
(6.3)	a. H.M: jíin [xĩ˥ĩ˧] /xíi$_n$/ ‘different’	b. M.M: iin [ĩ˧ĩ˧] /ii$_n$/ ‘one’	c. L.M: ve̱e [ve˩e˧] /vèe/ ‘heavy’
(6.4)	a. H.L: kuíi̱n [kʷĩ˥ĩ˩] /kʷíì$_n$/ ‘skinny’	b. M.L: nii̱ [nĩ˧ĩ˩] /niì/ ‘corn ear’	c. L.L: i̱i̱n [ĩ˧ĩ˩] /ìì$_n$/ ‘nine’

These same tone patterns are shown in (C)VCV couplets in (6.5–6.7).

(6.5)	a. H.H: jíkó	b. M.H: ijá	c. L.H: chi̲kí
	[xi˥ko˥]	[i˧xa˥]	[tʃi˩ki˦]
	/xíkó/	/ixá/	/tʃìkí/
	‘tall’	‘overmorrow’	‘cactus pear’

(6.6)	a. H.M: sáko	b. M.M: tyuku	c. L.M: ki̲ki
	[sa˥ko˧]	[t^{j}u˧ku˧]	[ki˩ki˨]
	/sáko/	/t^{j}uku/	/kìki/
	‘opossum’	‘again’	‘sew’

(6.7)	a. H.L: ndyíka̲	b. M.L: xiko̲	c. L.L: yu̲ku̲
	[^{n}d^{j}i˥ka˩]	[ʃi˧ko˩]	[ʒu˧ku˩]
	/^{n}d^{j}íkà/	/ʃikò/	/ʒùkù/
	‘wide’	‘smell’ (n.)	‘grass’

In addition, seven tone patterns with final floating tone (indicated by “+”) have been identified: H.L+H, M.L+H, L.L+H, M.M+L, H.H+L, M.H+L, L.H+L. These are exemplified in CVV couplets in (6.8–6.10).

(6.8)	a. H.H+L: léé	b. M.H+L: ñuú	c. L.H+L: tyi̲ín
	[le˥e˥]	[ɲũ˧ũ˥]	[t^{j}ĩ˩ĩ˦]
	/léé`/	/ɲuú`/	/t^{j}ìí$_{n}$`/
	‘baby’	‘night’	‘mouse’

(6.9)	a. H.M+L:	b. M.M+L: ñuu	c. L.M+L:
	<unattested>	[ɲũ˧ũ˧]	<unattested>
		/ɲuu`/	
		‘town’	

(6.10)	a. H.L+H: kuíi̲	b. M.L+H: nuu̲	c. L.L+H: ni̲i̲
	[k^{w}i˥i˩]	[nũ˧ũ˧˩]	[nĩ˨ĩ˧˩]
	/k^{w}îì´/	/nuù´/	/nìì´/
	‘green’	‘face’	‘salt’

The same tone patterns in (6.8–6.10) are found in CVCV couplets as in (6.11–6.13).

(6.11)	a. H.H+L: kóchí	b. M.H+L: kasí	c. L.H+L: ndyu̲xú
	[ko˥tʃi˥]	[ka˧si˥]	[^{n}d^{j}u˩ʃu˦]
	/kótʃí`/	/kasí`/	/^{n}d^{j}ùʃú`/
	‘pig’	‘eat (sweet)’	‘vain’

Table 6.2: The underlying couplet tone patterns in Nieves Mixtec and their corresponding surface tones in isolation

	Target Type		
Trigger Type	Raised	Non-raised	
Raising {	[H.L] /H.L+H/	[M.L] /M.L+H/	[L.L] /L.L+H/
Non-triggering {	[H.H] /H.H/	[M.H] /M.H/	[L.H] /L.H/
	[H.M] /H.M/	[M.M] /M.M/	[L.M] /L.M/
Lowering {	[H.L] /H.L/	[M.L] /M.L/	[L.L] /L.L/
	[H.H] /H.H+L/	[M.H] /M.H+L/	[L.H] /L.H+L/
		[M.M] /M.M+L/	

(6.12) a. H.M+L: <unattested>
b. M.M+L: landyi [la˧ⁿdʲi˧] /laⁿdʲi`/ 'navel'
c. L.M+L: <unattested>

(6.13) a. H.L+H: káni̲ [kã˥nĩ˩] /kánì´/ 'long.SG'
b. M.L+H: yuku̲ [ʒu˧ku˩] /ʒūkù´/ 'hill'
c. L.L+H: ji̲ko̲ [xi˧ko˩] /xìkò´/ 'neck'

Note that in the tone patterns identified thus far, the only floating tone found after L tone is +H, and the only floating tone found after M tone or H tone is +L.[4] The tone patterns exemplified in (6.2–6.13) are summarized in Table 6.2, organized according to their behavior in tone sandhi (phonological tone processes). The layout of the table is chosen to be comparable to the tone pattern tables shown in §6.4 for other Mixtec varieties.

As shown in the phonetic transcriptions here, the floating tones generally do not

[4]These gaps are partially explained by etymology. As discussed in §6.4, floating +H tone in Group A Mixtec varieties (including Nieves Mixtec) is traced to a final flottal stop in Proto-Mixtec. The tones *L and *M on the last mora of these couplets in Proto-Mixtec are maintained in Alta and Costa varieties within Group A, but these tones changed to L in most Baja varieties (Dürr 1987). The distribution of floating +L might also be explained through diachronic processes, since comparative work on Western Alta varieties (Hollenbach 2003; McKendry 2013) suggests the floating +L tone is generated when L tone is delinked from the final mora of the couplet. In these varieties, the highly active H tone readily delinks L tone, while M tone is much less active, and L tones scarcely interact with each other. On the other hand, the patterns H.M+L and L.M+L, indicated as <unattested> in (6.9, 6.12) are uncommon in other varieties but still etymologically expected. For example, the cognates of /tʲìna/ 'dog' show evidence of a floating +L tone in San Esteban Atatlahuca Mixtec (ATA) (Mak 1953) and Santo Domingo Nuxaa Mixtec (NUX) (McKendry 2013:160), and the cognate in San Miguel el Grande Mixtec (CHL) (K. L. Pike 1948) has a final L tone. But I did not find evidence of a floating +L tone on this word in Nieves Mixtec.

affect the surface form in utterance-final position. In words with the tone patterns H.L+H (6.8b, 6.8b), M.L+H (6.9b, 6.12b) and L.L+H (6.10b, 6.11b), the floating +H tone may create a slightly rising contour on the last mora of the utterance, though this effect is variable. However, in many other contexts, the floating tone associates to either the preceding mora or the following mora, dramatically affecting the pitch contour. For example, when a L-tone enclitic attaches to a couplet that has a floating +H tone, the +H tone associates to the preceding mora. The couplets that have floating +H tones, such as (6.8) and (6.11), have a L tone in the final mora, so this process results in a monomoraic LH contour in the final mora of the couplet, as shown in (6.14).

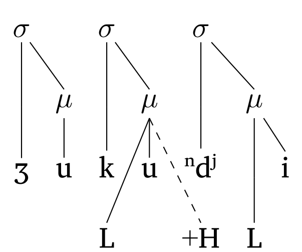
(6.14)	a. nuu̱ ndyi̱	b. ni̱i̱ ndyi̱	c. yuku̱ ndyi̱	d. ji̱ko̱ ndyi̱
	[nũ˧ũ˩˥^{n}d^{j}i˩]	[nĩ˧ĩ˩˥^{n}d^{j}i˩]	[ʒu˧ku˩˥^{n}d^{j}i˩]	[xi˧ko˩˥^{n}d^{j}i˩]
	/nuù´=^{n}d^{j}ì/	/nìì´=^{n}d^{j}ì/	/ʒūkù´=^{n}d^{j}ì/	/xìkò´=^{n}d^{j}ì/
	face=1P.EX	salt=1P.EX	hill=1P.EX	neck=1P.EX
	'our faces'	'our salt'	'our hill'	'our necks'

In contrast, when an M-tone enclitic attaches to these couplets, the floating +H tone associates to the enclitic, as shown in (6.15).

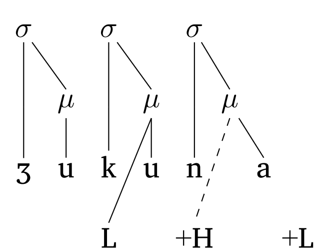
(6.15)	a. nuu̱ na	b. ni̱i̱ na	c. yuku̱ na	d. ji̱ko̱ na
	[nũ˧ũ˩nã˥]	[nĩ˧ĩ˩nã˥]	[ʒu˧ku˩nã˥]	[xi˧ko˩nã˥]
	/nuù´=na`/	/nìì´=na`/	/ʒūkù´=na`/	/xìkò´=na`/
	face=3P	salt=3P	hill=3P	neck=3P
	'their faces'	'their salt'	'their hill'	'their necks'

The floating tone replaces the M tone of the enclitic, producing a simple H surface tone. These processes will be analyzed in section §6.2.3, but their autosegmental representations are shown in (6.16) for concreteness.

(6.16) a.



b.



In (6.16a), corresponding to (6.14c), the enclitic has a linked L tone, and so the floating +H of the couplet associates back to the final mora of the couplet. However, in (6.16b), corresponding to (6.15c), the mora of the (default M tone) enclitic is not pre-associated to a tone, as the enclitic only has a floating +L tone. This permits the floating +H of the couplet to associate to the mora of the enclitic, and the (utterance final) floating +L tone fails to associate.

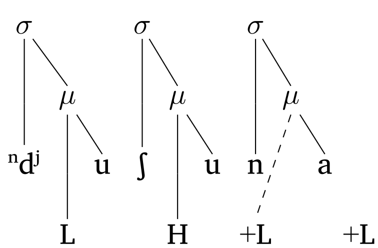
The effects of the floating +L tone are more nuanced than the effects of the floating +H tone, but one such effect is observable when an M-tone enclitic attaches to a couplet with a floating +L tone, as shown in (6.17).

(6.17)

a.	b.	c.	d.
léé na	tyi̲ín na	ndyu̲xú na	kóchí na
[le˥e˥nã˩]	[tʲĩ˩ĩ˧nã˩]	[^{n}dʲu˩ʃu˧nã˩]	[ko˥tʃi˥nã˩]
/léé\`=na\`/	/tʲìí$_{n}$\`=na\`/	/^{n}dʲùʃú\`=na\`/	/kótʃí\`=na\`/
baby=3P	mouse=3P	vain=3P	pig=3P
‘their baby’	‘their mouse’	‘they’re vain’	‘their pig’

In these words, the floating +L tone associates to the enclitic, replacing the M tone. The autosegmental representation of the process in (6.17c) is shown in (6.18) for concreteness.

(6.18)



Here in (6.18), as in (6.16b), the mora of the M-tone enclitic is not pre-associated to any tone, and so the floating +L tone of the couplet is permitted to associate to that mora, realizing a [L] surface tone rather than the default [M] tone.

As assumed in the autosegmental representations in (6.16, 6.18) and explicated in the following sections, the distribution of underlying tone and the tonal processes indicate that M tone is unspecified in the underlying form, being instead the absence of an associated L or H tone. Three arguments for this conclusion are provided in (6.19).

(6.19)

a. Tonal processes (as in (6.14–6.18), but also those presented in sections §6.2.3 and §6.3) can be described via the association and spreading of L and H tones to morae. In contrast, M tone does not spread.

b. L and H tones can be floating tones, both in the underlying lexical form as in (6.8–6.13), and in grammatical tone processes (discussed in §6.3). There are no floating M tones.

c. Though in isolation form only one tone target is licensed per mora, L and H tones can share a mora in other contexts, creating monomoraic LH contours (as in (6.14–6.15), also discussed in §6.3) as well as monomoraic HL contours (discussed in §6.3). Monomoraic contours involving M tone are not attested.

In other words, because L and H are marked phonological values, they can spread, exist independently of a moraic host, and share a mora. But M tone is realized in the absence of L or H tone.

6.2.2 Tone trends of lexical categories

The tone pattern inventories of the distinct lexical classes differ substantially. The following observations are based on a wordlist containing 110 plain CVV roots, 90 glottalized CVˀV roots, and 170 plain CVCV roots. A few differences are quite apparent even in this small list of roots. Other differences, especially related to floating tones, may be just as substantial but less noticeable.

First, none of the verb roots have initial H tone. Verbs composed of a single root have initial M tone, as in (6.20), or initial L tone, as in (6.21), in their basic (potential) verb form.

(6.20)	a.	naá [nã˧ã˦] /naá/ fight	b.	nuu [nũ˧ũ˧] /nuu/ descend	c.	kaa̱ [ka˧a˩] /kaà/ stretch

(6.21)	a.	tyi̱í [tʲi˩i˦] /tʲìí/ numben	b.	tyi̱in [tʲĩ˩ĩ˧] /tʲìi$_{n}$/ get_stuck	c.	sa̱a̱ [sa˧a˩] /sàà/ arrive

As described in §6.3.2, imperfective verb forms are derived by replacing the stem-initial tone with a H tone. As a result, the only bimoraic verbs with an initial H tone are imperfective verb forms.[5] However, multi-morphemic verbs that are derived from adjectives or nouns may have a H tone on the initial mora of the root. The verbs in (6.22, 6.23) are derived from adjectives.

(6.22)	a. kundyáa	b. kukwé'é	c. kujíkó
	[ku˧^{n}d^{j}a˥a˧]	[ku˧k^{w}e˥ʔe˥]	[ku˧xi˥ko˥]
	/ku–^{n}d^{j}áa/	/ku–k^{w}é^{ʔ}é/	/ku–xíkó`/
	INCH–adhered	INCH–mad	INCH–high
	'will be on (wall)'	'will get mad'	'will get high'

(6.23)	a. chindyáa	b. ndyukwé'é	c. ndyujíkó
	[ʧi˧^{n}d^{j}a˥a˧]	[^{n}d^{j}u˧k^{w}e˥ʔe˥]	[^{n}d^{j}u˧xi˥ko˥]
	/ʧi–^{n}d^{j}áa/	/^{n}d^{j}u–k^{w}é^{ʔ}é/	/^{n}d^{j}u–xíkó/
	put–adhered	INCH–mad	INCH–high
	'will stick on (TR)'	'will get mad'	'will get tall'

The H tone in the root-initial position of the verbs in (6.22, 6.23) are part of the underlying specification of the adjective root. The verbs in (6.24) are derived from nouns.

(6.24)	a. kuchíín	b. kunúu	c. chinúu	d. chisá'á
	[ku˧ʧĩ˥ĩ˥]	[ku˧nũ˥ũ˧]	[ʧi˧nũ˥ũ˧]	[ʧi˧sá˥ʔá˥]
	/ku–ʧíí$_{n}$`/	/ku–núu	/ʧi–núu/	/ʧi–sá^{ʔ}á/
	INCH–nail	INCH–face	put–face	put–foot
	'will scratch'	'will be on'	'will place on'	'will trample'

The H tone in the root-initial position of (6.24a) is part of the underlying specification of the noun. However, the root-initial H tone in (6.24b–d) comes from the verb derivation. The corresponding independent nouns (/nuù´/ 'face' and /sà^{ʔ}à´/ 'foot') do not have an initial H tone, but the tone is also changed in verb compounds formed with these roots, as in (6.25).

(6.25)	a. kava núu	b. kata sá'á
	[ka˧va˧nũ˥ũ˧]	[ka˧ta˧sa˥ʔa˥]
	/kava–núu/	/kata–sá^{ʔ}á/
	turn–face	IR:sing–foot
	'will spin around'	'will dance'

Similarly, floating +H tones are common in noun roots, but rare in verb roots. Among 85 roots with floating +H tones in the sample wordlist, 74 are nouns, six are ad-

[5] There is one known exception. The basic 'go' verb has L.L tone pattern in perfective (/nì = sà^{ʔ}à$_{n}$/), imperfective (/k^{w}à^{ʔ}à$_{n}$/) and potential (/kù^{ʔ}ù$_{n}$/) forms, but H.H tone pattern in imperative form (/k^{w}á^{ʔ}á$_{n}$/) and H.L tone pattern in habitual form (/sáʔà$_{n}$/).

jectives, three are verbs, and two are of other lexical categories. Examples of noun and adjective roots with floating +H tones were shown above in §6.2.1. The three verbs with floating +H tones are shown in (6.26).

(6.26)	a.	ko̲o̲	b.	kuma̲ni̲	c.	nandyee̲
		[ko˨o˩˨]		[ku˧mã˨nĩ˩˨]		[na˧^{n}d^{j}e˧e˩˨]
		/kòò´/		/ku–mànì´/		/na–^{n}d^{j}eè´/
		NEG.EXIST		INCH–want		REP–strengthen
		‘there isn’t’		‘lack’		‘rest’

The negative existential (6.26a) is categorized as a verb, but it is grammatically exceptional. The other two verbs (6.26b, c) have prefixes that are typically associated with verbal roots, but the possibility remains that these roots should be recategorized as adjectival or nominal roots.

Third, most numeral roots have L.L tone pattern. Nieves Mixtec uses a mixed decimal-vigesimal number system. Numbers 1 to 10, as well as 15 and 20, are monomorphemic numerals. Numbers 11 to 14 are composed of the numeral 10 plus numerals one to four. Numbers 16 to 19 are composed of the numeral 15 plus numerals one to four. Numbers larger than 20 are composed of multiples of 20 plus numbers one to 19, as in (6.27).

(6.27)	a.	o̲ko̲	u̲su̲	e̲ve̲
		[ʔo˨ko˩	ʔu˨su˩	ʔe˨ve˩]
		/òkò	ùsù	èvè/
		twenty	ten	two
		‘thirty-two’		
		<OO MIN0019:7:28.8>		

b.	e̲ve̲	xiko	sa̲’u̲n	ko̲mi̲
	[ʔe˨ve˩	ʃi˧ko˧	sã̰˨ṵ̃˩	kõ˩mĩ˩]
	/èvè	ʃiko	sà^{ʔ}ù$_{n}$	kòmì´/
	two	of.twenty	fifteen	four
	‘fifty-nine’			
	<OO MIN0019:12:50.0>			

The 11 numerals with L.L tone pattern are shown in (6.28–6.30).

(6.28)	a.	e̲ve̲	b.	u̲ni̲	c.	u̲’u̲n	d.	i̲ño̲
		[ʔe˨ve˩]		[ʔũ˨nĩ˩]		[ʔũ˨ʔũ˩]		[ʔĩ˨ɲõ˩]
		/èvè/		/ùnì/		/ù^{ʔ}ù$_{n}$/		/ìɲò/
		two		three		five		six

(6.29)	a. u̲sa̲	b. u̲na̲	c. i̲i̲n
	[ʔu˧sa˩]	[ʔũ˧nã˩]	[ʔĩ˧ĩ˩]
	/ùsà/	/ùnà/	/ìì$_{n}$/
	seven	eight	nine

(6.30)	a. u̲su̲	b. sa̲'u̲n	c. o̲ko̲
	[ʔu˧su˩]	[sã˧ʔũ˩]	[ʔo˧ko˩]
	/ùsù/	/sàˀù$_{n}$/	/òkò/
	ten	fifteen	twenty

The only three native numerals with some other tone pattern are shown in (6.31).

(6.31)	a. ko̲mi̲	b. iin	c. xiko
	[kõ˧mĩ˩˧]	[ʔĩ˧ĩ˧]	[ʃi˧ko˧]
	/kòmì´/	/ii$_{n}$/	/ʃiko/
	four	one	of.twenty

The numeral /kòmì´/ 'four' (6.31a) has L.L+H tone pattern, differing from the other number words only in having a floating +H tone. The numeral /ii$_{n}$/ 'one' (6.31b) and the combining vigesimal base /ʃiko/ (6.31c) have M.M tone pattern.

Finally, H.H and H.H+L patterns are quite common in adjectives. In some cases, the H.H+L tone pattern of an adjective can be attributed to a semi-productive derivational tone change, as many adjective roots have associated noun roots with lower tones. In many of the adjective-noun pairs, the adjective has H.H+L tone pattern, and the corresponding noun has L.M, L.L, L.L+H or M.L+H tone pattern, as in (6.32–6.34).

(6.32)	a. níí	vs.	ni̲i̲	b. yúú	vs.	yu̲u̲
	[nĩ˥ĩ˥]		[nĩ˧ĩ˩]	[ʒu˥u˥]		[ʒu˧u˩]
	/níí`/		/nìì´/	/ʒúú`/		/ʒùù´/
	bloody		blood	solid		stone

(6.33)	a. kué'é	vs.	kue̲'e̲	b. tú'ún	vs.	tu̲'un
	[kʷe˥ʔe˥]		[kʷe˧ʔe˩]	[tũ˥ʔũ˥]		[tũ˩ʔũ˧]
	/kʷéˀé`/		/kʷèˀè/	/túˀú$_{n}$`/		/tùˀu$_{n}$/
	injured		sickness	gossipy		word

(6.34)	a.	lú^{n}dʲú	vs.	lu̠ndyu̠	b.	yúkú	vs.	yuku̠
		[lu˥^{n}dʲu˥]		[lu˧^{n}dʲu˩]		[ʒu˥ku˥]		[ʒu˧ku˩˧]
		/lú^{n}dʲú`/		/lù^{n}dʲù/		/ʒúkú`/		/ʒukù´/
		stocky		stump		wild		mountain

In a few cases, as in (6.35), the adjective has L.H+L tone pattern instead.

(6.35)	a.	tu̠ún	vs.	tu̠un	b.	xa̠’án	vs.	xa̠’an
		[tũ˩ũ˦]		[tũ˩ũ˧]		[ʃã˩ʔã˦]		[ʃã˩ʔã˧]
		/tùú$_{n}$/		/tùu$_{n}$/		/ʃàˀá`$_{n}$/		/ʃàˀa$_{n}$/
		black		coal		greasy		lard

These correspondences are only semi-productive, since for many adjectives with H.H(+L) tone pattern, no corresponding noun can be identified.

The various tone trends associated with lexical categories contribute to a high functional load of tone in Nieves Mixtec. The tone trends in verbs suggest a contraint in the lexicon against initial H tone in verb roots, which is needed to realize contrasts in grammatical aspect. The tone trends in adjectives suggest a tonal process involved in morphological derivation. And the tone trends in nouns and numerals suggest that some similar lexical constraint or former tonal process influenced the tone distribution in those lexical classes. Some functions of tone in inflectional morphology are discussed in §6.3, but tone changes involved in morphological derivation are beyond the scope of this dissertation.

6.2.3 Tone processes in couplets

This section presents aspects of the conditions of sandhi attested in the juxtaposition of two couplets. The focus here is on the evidence for distinguishing different trigger classes of couplet tone patterns, as a full description of the contexts and consequences of tone sandhi is beyond the scope of this dissertation. Two couplets may be juxtaposed either within a phonological phrase or within a phonological word as in a compound, and (as in San Esteban Atatlahuca, discussed in §6.4.1) these prosodic domains license different sandhi effects. In addition, there is variation dependent on speaker and speech rate. These issues are left for future research.

As indicated in Table 6.2, I distinguish three types of triggering behavior of the initial couplet. Non-triggering couplets leave the following morpheme with its basic tone pattern. Lowering couplets may cause the pitch of the following morpheme to be lower than in the basic pattern. Finally, raising couplets are so designated because, in some contexts, they may cause the pitch of the following morpheme to be higher than in its basic pattern. However, in other contexts, raising couplets may lower the pitch of the following morpheme.

6.2.3.1 Non-triggering couplets

Except for a few subtle differences, the basic tones (the surface tones in isolation), as in (6.36), are the same as the surface tones in phrase-initial position, as in (6.37), and after non-triggering couplets, as in (6.38).

(6.36) a. yá’á
[ʒa˥ʔa˥]
/ʒáˀá`/
tan
<MC MIN0464:8:57.0>

b. ve’e
[ve˧ʔe˧]
/veˀe/
house
<MC MIN0041:0:17.2>

(6.37) a. yá’á rí
[ʒa˥ʔa˥=ɾi˩]
/ʒáˀá`=tʲí/
tan=3.ZO
‘it is yellowish’
<FO MIN0761>

b. ve’e vii
[ve˧ʔe˧ vi˧i˥]
/veˀe vií/
house clean
‘the clean house’
<MC MIN0399:3:44.8>

(6.38) a. chélē yá’á
[tʃe˥le˦ ʒa˥ʔa˥]
/tʃéle ʒáˀá`/
rooster tan
‘a tan rooster’

b. ma̱’ní vē’ē
[mã̱˩nĩ˦ve˧ʔe˧]
/màˀní=veˀe/
center=house
‘between the houses’

For comparison with data in later subsections which show tone changes, a few more examples are presented in (6.39–6.42) showing basic tone patterns after non-triggering couplets.

(6.39)	a.	ma̲'ní léé	b.	tyi̲chí vání	c.	sìto kóchí
		[mã̰˩nĩ˦le˥e˥]		[tʲi˩tʃi˦ va˥li˥]		[si˩to˨ ko˥tʃi˥]
		/màˀní=léé`/		/tʲìtʃí válí`/		/sìto kótʃí`/
		center=baby		avocado little.PL		bed pig
		'between the babies'		'little avocados'		'a pig's bed'

(6.40)	a.	nda̲kú iyá	b.	ndyi̲chi katyí	c.	ku̲ñu katyí
		[^{n}da˩ku˦ i˧ʒa˥]		[^{n}dʲi˩tʃi˨ ka˧tʲi˦]		[kũ˩ɲũ˨ ka˧tyi˦]
		/^{n}dàkú iʒá/		/^{n}dʲìtʃi katʲí/		/kùɲu kātʲí/
		stew viscous		bean bland		meat bland
		'thick stew'		'bland beans'		'bland meat'

(6.41)	a.	tyi̲si laa	b.	si̲to uju	c.	tyi̲na kini
		[tʲi˩si˨ la˧a˧]		[si˩to˨ u˧hu˧]		[tʲĩ˩nã˨ kĩ˧nĩ˧]
		/tʲìsi laa`/		/sìto uxu`/		/tʲìna kini/
		belly bird		bed deer		dog ugly
		'a bird's belly'		'a deer's bed'		'a mean dog'

(6.42)	a.	tyi̲chí i'a̲	b.	ndyi̲chi satyi̲	c.	ku̲ñu satyi̲
		[tʲi˩tʃi˦ i˧ʔa˩]		[^{n}dʲi˩tʃi˨ sa˧tʲi˩]		[kũ˩ɲũ˨ sa˧tʲi˩]
		/tʲìtʃí iˀà/		/^{n}dʲìtʃi satʲì/		/kùɲu satʲì/
		avocado salty		bean spicy		meat spicy
		'salty avocado'		'spicy beans'		'spicy meat'

The couplets with [H.H] basic tone, as in (6.39), [M.H] basic tone, as in (6.40), [M.M] basic tone, as in (6.41), and [M.L] basic tone, as in (6.42), are all susceptible to tone sandhi in other contexts, but after non-triggering couplets, no sandhi is observed.

6.2.3.2 Lowering couplets

The phonological tone change which is both least restricted prosodically and most perceptible replaces the first of two H tones by a spreading L tone. For example, the quantifier /kʷàˀà/ 'many' causes a [L] initial tone to surface on /náná/ 'mother' in (6.43) whereas the basic [H] tone is shown in (6.44).

(6.43) kwa̱’a̱ na̱ná ni̱ kanana na
[kʷa˨ʔa˩ nã˩nã˦ nĩ˨ka˩nã˧nã˧]
/kʷàˀà náná nì = ka = nana = na`/
many mom PFV = PL = ascend = 3P
‘many mothers went up (a hill)’

< MC MIN0478:14:26.1 >

(6.44) náná na ni̱ kakana na
[nã˥nã˥nã˥˨ nĩ˨ka˩kã˧nã˧nã˧]
/náná = na` nì = ka = kana = na`/
mom = 3P PFV = PL = exit = 3P
‘their mothers left’

< MC MIN0478:12:45.3 >

Similarly in (6.45), the noun /tʃítò/ ‘cat’ pushes a [L] tone onto the first mora of /ʒáˀá/ ‘tan’, in place of what would otherwise be a [H] tone.

(6.45) kītyí chíto̱ ya̱’á tyi̱
[ki˧tʲi˥ = tʃi˥to˨ ʒa˩ʔa˦ɾi˨]
/kitʲí = tʃítò ʒáʔá` = tʲí/
DEF.ZO = cat tan = 3.ZO
‘the cat is tan’

< FO MIN0761 >

This occurs even though the sandhi in (6.45) is crossing a major syntactic boundary, between a preposed (topicalized) subject and its predicate. Similarly, the lowering sandhi can cross the word boundary between a verb and its following subject (i.e. in the canonical position). In (6.46), the final [L] on /kú-na-kaà/ ‘be located’ adds a [L] tone in place of the initial basic [H] tone of /tásá/, as shown in (6.47).

(6.46) ndyáa kɨ́nɨ́kaa̱ tásá
[ⁿdʲa˥a˦ kə̃˥nə̃˥ka˧a˩ ta˩sa˦]
/ⁿdʲáa ´\ku–na–kaà tásá`/
where IPFV\INCH-REP-sit cup
‘where is the cup?’

< MC MIN0157:7:47.3 >

(6.47) jo̱'ō tásá
[xo˩ʔo˧ ta˥sa˥]
/xòˀo tásá/
ear cup
'cup handle'

<MC MIN0042:28:07.4>

Notably, this tone lowering process does not occur if the following H tone is followed by a M or L tone, as in (6.48).

(6.48)
a. kólo̱ ná'no
[ko˥lo˧ nã˥ʔnõ˧]
/kólò náˀno/
turkey big.PL
'big turkeys'

<FO MIN0760>

b. kityí u̱ni̱ yó'o
[ki˧tʲi˦ ũ˧nĩ˩ ʒo˥ʔo˧]
/kitʲí ùnì ʒóˀo/
DEF.ZO three PROX.1
'these three animals'

<OO MIN1072>

c. e̱ve̱ chíto̱
[e˧ve˩ tʃi˥to˩]
/èvè tʃítò/
two cat
'two cats'

<OO MIN0176>

And except for one case discussed below in (6.68, 6.69), this tone lowering process does not affect M tone, as shown in (6.49).

(6.49)
a. kólo̱ katyí
[ko˥lo˧ ka˧tʲi˦]
[kólò katʲí]
turkey bland
'bland turkey'

<OO MIN0859>

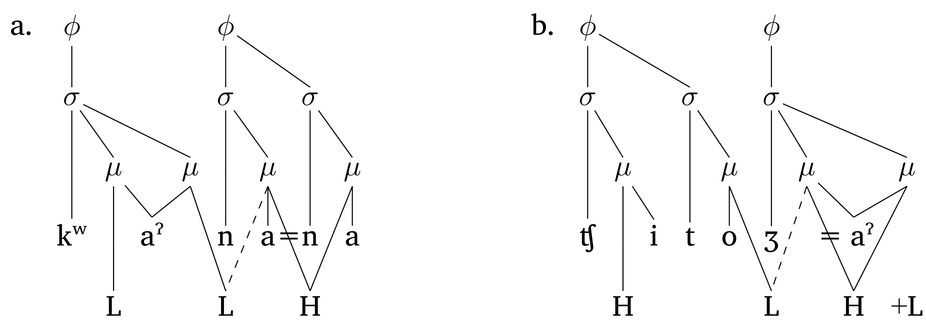
b. u̱su̱ iin
[u˧su˩ ĩ˧ĩ˧]
/ùsù ii_n/
ten one
'eleven'

<FC MIN0869>

c. e̱ve̱ yito̱
[e˧ve˩ ʒi˧to˩]
/èvè ʒitò´/
two wood
'two trees'

<FO MIN0734>

I analyze the lowering of H tone as the spreading of the final L tone from the trigger and the retraction of the H tone, with an autosegmental representation as in (6.50).

(6.50)


The diagram in (6.50a) shows the crucial feet of (6.43), and the diagram in (6.50b) shows the crucial feet of (6.45). In each case, the final L tone of the initial couplet spreads by associating to the initial mora of the second couplet, and the pre-associated H tone of that mora delinks to avoid sharing the mora with the L tone. Note that I assume that the H tone is pre-associated to both morae and that only a multiple-linked H will delink instead of sharing a mora with L tone. This assumption provides a local mechanism for capturing the observation of LH monomoraic contours elsewhere and the generalization that this displacement of H tone by L tone only occurs when the following mora also bears H tone.

The examples shown thus far all have [L] basic tone on the final mora of the trigger, but similar effects are observed with triggers that have [H] or [M] on the final mora. These triggers are the lowering couplets that are analyzed as having a floating +L tone. For example, the plural diminutive /válí`/ often has [L.H] surface tone pattern after couplets with floating +L tone, as in (6.51, 6.52).

(6.51)	a.	b.	c.
	ilo válí ndyi̲	kóchí válí	pátó válí
	[i˧lo˧va˩i˦ⁿdʲi˩]	[ko˥tʃi˥va˩li˦]	[pa˥to˥va˩li˦]
	/ilo`–válí`=ⁿdʲì/	/kótʃí`–válí`	/pátó`–válí`
	rabbit–little.PL=1.EX	pig–little.PL	duck–little.PL
	‘our little rabbits’	‘piglets’	‘ducklings’
	<OO MIN1198>	<OO MIN0841>	<OO MIN0841>

(6.52)	a.	b.	c.
	sityi válí	uju válí	laa válí
	[si˧tʲi˧va˩li˦]	[u˧hu˧va˩li˦]	[la˧a˧va˩li˦]
	/sitʲi`–válí`/	/uxu`–válí`/	/laa`–válí`/
	tripe–little.PL	deer–little.PL	bird–little.PL
	‘little tripe’	‘little deer’	‘little birds’
	<FC MIN1205>	<FC MIN1205>	<FC MIN1204>

This lowering effect is also observed on other modifiers, as in (6.53, 6.54).

(6.53)	a.	b.	c.
	laa léé	kóchí léé	ndásá le̲é
	[la˧a˧ le˩e˦]	[ko˥tʃi˥ le˩e˦]	[ⁿda˥sa˥ le˩e˦]
	/laa` léé`/	/kótʃí` léé`/	/ⁿdásá` léé`/
	bird baby	pig baby	chachalaca baby
	‘baby bird’	‘baby pig’	‘baby chachalaca’
	<FC MIN1204>	<FC MIN1203>	<FC MIN1203>

(6.54) a. ilo píndó
[i˧lo˧ pi˩^{n}do˥]
/ilo` pí$^{n}$dó`/
rabbit speckled
'a speckled rabbit'

<FC MIN1201>

b. ilo kúsú
[i˧lo˧ ku˩su˥]
/ilo` kúsú/
rabbit white
'a white rabbit'

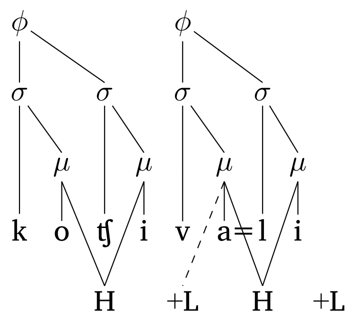
<FC MIN1201>

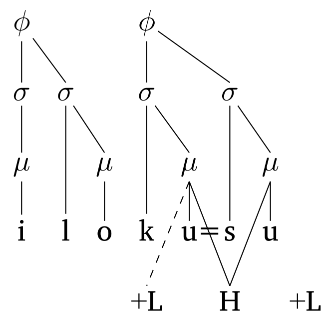
c. ita kuáán
[i˧ta˧k^{w}ã˩ã˩˥]
/ita`–k$^{w}$áá$_{n}$`/
flower–yellow
'marigold'

<FC MIN1201>

The lowering effects triggered by +L tone couplets are more variable than the effects triggered by L basic tone, with variation observed between speakers and across contexts.

Autosegmental representations of the lowering process caused by floating +L tone are shown in (6.55).

(6.55) a. 

b. 

The autosegmental diagram in (6.55a) represents the tone processes of (6.51b), and the diagram in (6.55b) represents the tone processes of (6.53c). In each case, the floating +L tone sponsored by the initial couplet associates to the initial mora of the second couplet, and the pre-associated H tone of that mora delinks. The process is the same as in (6.50), except that the tone that associates across the morpheme boundary is a floating +L tone here, rather than a pre-associated spreading L tone in (6.50).

6.2.3.3 Raising couplets

A second pattern of tone change affects [M] tones, raising them to [H] after raising triggers. The examples in (6.56) show [M] tone raising in attributive adjectives /kini/ 'bad' and /livi/ 'pretty', while on corresponding predicate adjectives in (6.57), the basic tones are observed.

(6.56) a. iin ko̲o̲ kini
[ĩ˧ĩ˧ ko˧o˩ kĩ˥nĩ˧]
/iiₙ kòò´ kini/
one snake bad
‘a mean snake’

<FO MIN0820>

b. ndyixi̲ lívi
[ⁿdʲi˧ʃi˩ li˥vi˧]
/ⁿdʲiʃì´ livi/
corn_ear pretty
‘a pretty ear of corn’

<OO MIN0774>

(6.57) a. iin ko̲o̲ kini káa
[ĩ˧ĩ˧ ko˧o˩ kĩ˧nĩ˧ ka˥a˦]
/iiₙ kòò´ kini ´\kaa/
one snake bad IPFV\STAT
‘a snake that is ugly’

<FO MIN0820>

b. ndyixi̲ livi káa a̲n
[ⁿdʲi˧ʃi˩ li˧vi˧ ka˥ã˧]
/ⁿdʲiʃì´ livi ´\kaa=àₙ
corn_ear pretty IPFV\STAT=3.N
‘the ear of corn is pretty’

<OO MIN0773>

Similarly, each of the modifiers in (6.58) has an initial surface [H] tone rather than the basic [M] tone, because the nouns in initial position are raising triggers.

(6.58) a. viko̲ chelo̲
[vi˧ko˩ tʃe˥lo˧]
/vikò´ tʃelò/
party calf
‘the calf’s party’

<MC MIN0674>

b. ndyi̲vi̲ laa
[ⁿdʲi˧vi˩ la˥a˦]
/ⁿdʲìvì´ laa`/
egg bird
‘the bird’s egg’

<MC MIN0698>

c. yusa̲ satyi̲
[ʒu˧sa˩ sa˥tʲi˩]
/ʒusà´ satʲì/
dough spicy
‘spicy dough’

<MC MIN0717>

As mentioned in §6.2.1, all the raising couplets have L tone on the last mora. But having L tone on the last mora of the couplet is not sufficient to trigger raising, as shown in (6.59).

(6.59) a. u̲su̲ iin
[u˧su˩ ĩ˧ĩ˧]
/ùsù iiₙ/
ten one
‘eleven’

<FC MIN0869>

b. e̲ve̲ yito̲
[e˧ve˩ ʒi˧to˩˧]
/èvè ʒitò´/
two wood
‘two trees’

<FO MIN0734>

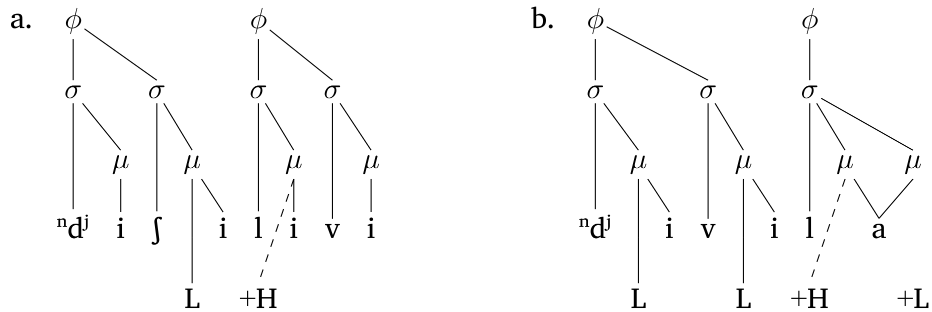
c. chíto̲ kini
[tʃi˥to˩ kĩ˧nĩ˧]
/tʃítò kini/
cat bad
‘mean cat’

<FO MIN0819>

The nouns in trigger position in (6.59) have a final L tone, but they do not trigger raising on the adjective.

The tone raising process is analyzed as the effect of final floating +H tones on the raising triggers. Autosegmental representations of this tone process are shown in 6.60.

(6.60)



The diagram in (6.60a) corresponds to (6.56b), and the diagram in (6.60b) corresponds to (6.58b). In these examples, the floating +H tone sponsored by the first couplet associates to the first mora of the second couplet, which has no underlyingly associated tone.

Raising triggers have two more possible effects. In some cases, especially when hyperarticulated, the final [L] of a raising couplet changes to a sharp [LH] rise, instead of or in addition to raising the tone of the following couplet. For example, in the locative phrases in (6.61) and the noun phrases in (6.62), there is a sharp rise on the initial couplet, with basic tones observed on the second couplet.

(6.61)

	a.	b.	c.
	nuu̲ ndyi̲vi̲	yu’u̲ ku̲ñu	sa̲’a̲ tyi̲na
	[nũ˧ũ˧˦^{n}dʲi˧vi˩˨]	[ʒu˧ʔu˧˦kũ˩ɲũ˧]	[sa˧ʔa˧˥tʲĩ˩nã˧]
	/nuù´=^{n}dʲìvì´/	/ʒuˀù´=kùɲu/	/sàˀà´=tʲìna]
	face=egg	lip=meat	foot=dog
	‘on the egg’	‘alongside the meat’	‘around the dog’
	<MC MIN0683>	<MC MIN0646>	<MC MIN0605>

(6.62)

	a.	b.	c.
	yivi̲ tyi̲na	yusa̲ tu̲ún	yusa̲ satyi̲
	[ʒi˧vi˧˥ tʲĩ˩nã˧]	[ʒu˧sa˧˥ tũ˩ũ˦]	[ʒu˧sa˧˥ sa˧tʲi˩]
	/ʒivì´ tʲìna/	/ʒusà´ tùú$_{n}$/	/ʒusà´ satʲì/
	mat dog	dough black	dough spicy
	‘dog’s mat’	‘black dough’	‘spicy dough’
	<MC MIN0644>	<MC MIN0720>	<MC MIN0717>

In the locative phrases in (6.63) and the noun phrases in (6.64), there is both a sharp rise on the initial couplet and raising on the second couplet.

(6.63)

a. nuu̲ ve'e
[nũ˧ũ˧˦ve˥ʔe˧]
/nuù´=ve^{ʔ}e/
face=house
'on the house'

<MC MIN0618>

b. yuu̲ yasi̲
[ʒu˧u˧˦ʒa˥si˨]
/ʒuù´=ʒasì´/
lip=gourd
'at the gourd's mouth'

<MC MIN0684>

(6.64)

a. ndyayi̲ i'a̲
[^{n}d^{j}a˧ji˧˦ i˥ʔa˨]
/^{n}d^{j}aʒì´ iʔà/
mole salty
'salty mole'

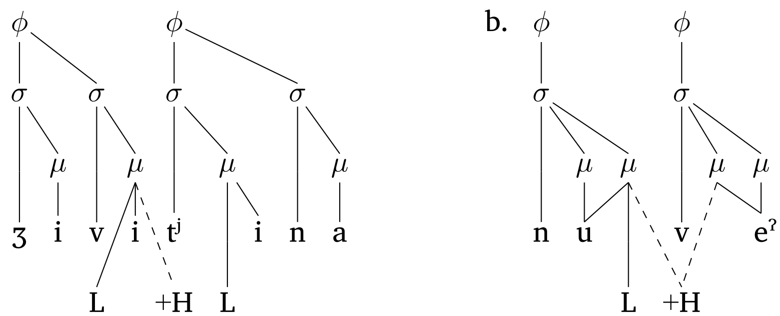
<MC MIN0716>

b. ndyixi̲ satyi̲
[^{n}d^{j}i˧ʃi˧˦ sa˥t^{j}i˨]
/^{n}d^{j}iʃì´ sat^{j}ì/
corn_ear spicy
'spicy corn'

<MC MIN0717>

The autosegmental representations of this raising process are shown in (6.65).

(6.65) a. b.



The diagram in (6.65a) corresponds to (6.62a), and the diagram in (6.65b) corresponds to (6.63a). In (6.65a), the floating +H tone sponsored by the first couplet associates back to the last mora of that couplet, and it is not able to associate to the first mora of the second couplet because the L tone is already associated to it. The monomoraic LH contour is permitted while the monomoraic HL contour—which would be created if the floating +H tone and the pre-associated L tone shared the mora—is more restricted. In (6.65b), the floating +H tone associates back to the last mora of that couplet as well as associating to the unoccupied first mora of the second couplet.

Finally, raising triggers can cause lowering of [H.H] and [M.H] couplets, producing [L.H] surface tone patterns. Lowering of [H.H] couplets is shown in (6.66, 6.67).

(6.66) a. nuu̲ le̲é
[nũ˧ũ˩le˩e˥]
/nuù´=léé`/
face=baby
'towards the baby'

<MC MIN0603>

b. yu'u̲ kóchí
[ʒu˧ʔu˩ko˩ʧi˥]
/ʒuˀù´=kóʧí`/
lip=pig
'alongside the pig'

<MC MIN0653>

c. sa̲'a̲ kóchí
[sa˩ʔa˩ko˩ʧi˥]
/sàˀà´=kóʧí`/
foot=pig
'at the foot of the pig'

<MC MIN0653>

(6.67) a. viko̲ ko̲chí
[vi˧ko˩ ko˩ʧi˥]
/vikò´ kóʧí`/
party pig
'the pig's party'

<MC MIN0687>

b. yavi̲ kóchí
[ʒa˧vi˩ ko˩ʧi˥]
/ʒavì´ kóʧí`/
hole pig
'the pig's hole'

<MC MIN0687>

This lowering of H tone by raising couplets closely resembles the tone change caused by lowering couplets. Lowering of [M.H] couplets is shown in (6.68, 6.69).

(6.68) a. ndyixi̲ iyá
[ⁿdʲi˧ʃi˩ i˩ʒa˥]
/ⁿdʲiʃì´ iʒá/
corn$_e$ar sour
'sour corn'

b. ndyi̲vi̲ iyá
[ⁿdʲi˧vi˩ i˩ʒa˥]
/ⁿdʲìvì´ iʒá/
egg sour
'sour egg'

<MC MIN0718>

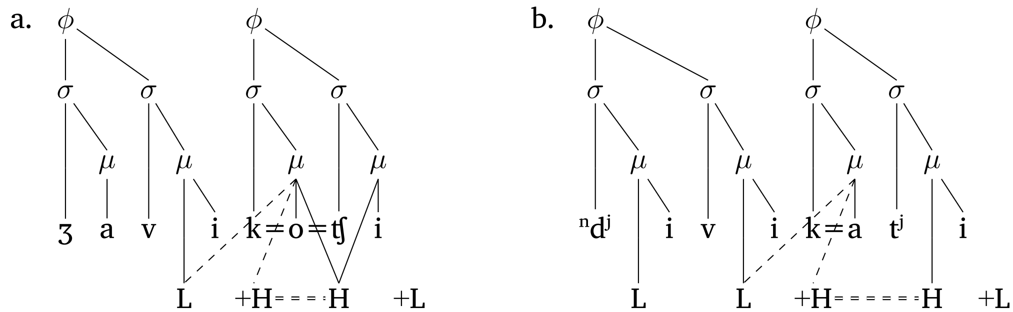
(6.69) a. ndyixi̲ katyí
[ⁿdʲi˧ʃi˩ ka˩tʲi˥]
/ⁿdʲiʃì katʲí/
corn_ear mild
'mild corn'

b. ndyi̲vi̲ ka̲tyí
[ⁿdʲi˧vi˩ ka˩tʲi˥]
/ⁿdʲìvì´ katʲí/
egg mild
'mild eggs'

<MC MIN0719>

Autosegmental representations of these processes are shown in (6.70).

(6.70)



The diagram in (6.70a) corresponds to the H tone lowering in (6.67b), and the diagram in (6.70b) corresponds to the M tone lowering in (6.69b). In the case of the H tone lowering in (6.70a), the floating +H tone merges with the H tone of the second couplet, producing the configuration found in the input to the H tone lowering examples previously examined in (6.50). As in those examples, the L tone that is pre-associated to the initial couplet then spreads onto the first mora of the second couplet, and the H tone of the second couplet retracts from that mora rather than share it with the L tone. The cases of lowering of the initial mora of [M.H] couplets to [L] tone, represented in (6.70b) are analyzed as telescoping of the raising and lowering processes already described. The raising trigger first raises the initial M tone to H tone. The floating +H tone sponsored by the first couplet associates to the first mora of the second couplet, and the adjacent H tones merge, creating a H.H tone pattern. Then the L tone on the final mora of the trigger displaces the H from the first mora of the second couplet. The L tone from the first couplet associates to the first mora of the second couplet, and the H tone of that mora delinks to avoid sharing the mora with the L tone. The association of the H tone to the unspecified mora and subsequent dissociation from that mora are necessary to distinguish this case of L tone spreading onto a couplet with basic [M] tone from the general case (6.49), where L tone does not affect M tone in couplets.

6.2.4 Summary

In sum, the distribution of tone in couplets and the sandhi processes found in the interaction between couplets show that the three levels of lexical tone arise from marked

H and L tones and underlyingly unmarked default M tone. Couplets host one of these three on each mora, and all nine combinations of basic tones are attested. In addition, couplets with a final L may sponsor a floating +H tone and couplets with a final M or H tone may sponsor a floating +L tone. Besides this co-occurrence restriction on floating tones, there are tonal restrictions within lexical categories.

The stipulation of floating tones is necessary to explain otherwise arbitrary differences in sandhi triggering behavior. Grouped according to triggering behavior, couplets are categorized as non-triggering couplets, raising triggers, or lowering triggers. The couplets with a floating +H tone are raising triggers, the couplets with a final L tone or a floating +L tone are lowering triggers, and the other couplets are non-triggering. The sandhi processes can then be explained through autosegmental rules of tone association and dissociation.

6.3 Tone in functional morphemes

This section describes tone representation and tone processes in functional morphemes, focusing on pronominal enclitics and verbal proclitics. The contrast between the functional morphemes and the couplets serves as key evidence that the mora is the tone-bearing unit. As described in the previous section, the bimoraic stems sponsor up to three tones. In contrast, the evidence presented in this section shows that monomoraic clitics sponsor up to two tones, and non-moraic tonal morphemes sponsor just one tone. Thus, the morphemes of different moraicity together support the generalization that a morpheme can sponsor one tone per mora plus one floating tone. In addition, different patterns of tonal association are observed in clitics than in couplets, indicating that different morphological or prosodic domains within the word license different tonal processes.

6.3.1 Enclitics

As is the case in other Mixtec varieties, Nieves Mixtec has a large number of pronominal enclitics, as well as several enclitics with other grammatical functions. The pronominal enclitics are listed in Table 6.3. As shown in the table, I distinguish between CV enclitics and vocalic enclitics. The vocalic enclitics can cause shortening of a preceding long vowel or elision of a preceding short vowel, while CV enclitics do not. This prosodic reduction generates complicated surface tone contours that are beyond the scope of this dissertation. I focus here on the pronominal CV enclitics.

Table 6.3: Pronominal enclitics grouped by basic tone and syllable structure

CV	H+L	[nĩ˥] 2S.FRM	M+L	[ɾa˧] 3M	L	[ⁿdʲi˩] 1P.EX
	H+L	[ⁿdo˥] 2P	M+L	[nã˧] 3P		
	H	[ɲã˥] 3SF	M+L	[ɲã˧] 3.N		
	H	[tʲi˥] 3.ZO	M	[si˧] 3S.FRM		
	H	[ɾa˥] 3.LQ				
	H	[to˥] 3.WD				
V	H+L	[ũ˥] 2S.FAM	M+L	[ã˧] 3.N	L	[i˩] 1S
	H	[e˥] 1P.IN	M	[ã˧] 3SF		

Among CV enclitics, the three-way contrast among [H], [M] and [L] tone is reliably observed when the host word is a non-triggering couplet, so the tone appearing in these environments is considered basic and serves as the preliminary hypothesis of the underlying tones of these clitics. An environment that is particularly well-suited to demonstrate the basic tones of the pronominal enclitics is the emphatic demonstrative /mèē/ (6.71–6.73), as it is grammatically and semantically compatible with all of the pronominal enclitics, except for the CV allomorph of the neuter enclitic.[6]

(6.71)

a. me̱endyi̱
[mẽ˩ẽ˧ⁿdʲi˩]
/mèē = ⁿdʲì/
EMPH = 1P.EX
'we' (EX)

b. me̱ení
[mẽ˩ẽ˧nĩ˥]
/mèē = ní/
EMPH = 2S.FRM
'you' (FRM)

c. me̱endó
[mẽ˩ẽ˧ⁿdo˥]
/mèē = ⁿdó/
EMPH = 2P
'you all'

(6.72)

a. me̱era
[mẽ˩ẽ˧ɾa˧]
/mèe = ra/
EMPH = 3M
'he'

b. me̱eñá
[mẽ˩ẽ˧ɲã˥]
/mèē = ɲá/
EMPH = 3SF
'she'

c. me̱esi
[mẽ˩ẽ˧si˧]
/mèē = sī/
EMPH = 3S.FRM
'(s)he' (FRM)

[6]The neuter enclitic, like the feminine enclitic, have both CV and V allomorphs [ɲã ∼ ã]. The CV and V forms are often interchangeable with no discernible semantic or pragmatic difference, but in this case they are not interchangeable.

(6.73) a. me̱ena
[mẽ˩ẽ˧nã˧]
/mèē = nā/
EMPH = 3P
'they'

b. me̱erá
[mẽ˩ẽ˧ɾa˥]
/mèē = rá/
EMPH = 3.LQ
'it' (liquid)

c. me̱erí
[mẽ˩ẽ˧ɾi˥]
/mèē = rí/
EMPH = 3.ZO
'it' (animal)

d. me̱etó
[mẽ˩ẽ˧to˥]
/mèē = tó/
EMPH = 3.WD
'it' (wood)

The majority of the CV pronominal enclitics have [H] basic tone, while there is just one [L] tone CV pronominal enclitic, /ⁿdʲì/ '1P.EX'. I have also indicated hypothesized floating tones in Table 6.3. There is no evidence of any enclitic sponsoring a floating +H, while lowering effects attributable to a floating +L tone have been observed after the enclitics marked with floating tone.[7] The vocalic pronominal enclitics are shown in (6.74, 6.75) for comparison.

(6.74) a. me̱i̱
[mẽ˧ĩ˧]
/mèe = ì/
EMPH = 1S
'I'

b. me̱é
[mẽ˩ẽ˥]
/mèe = é/
EMPH = 1P.IN
'we all'

c. me̱ú
[mẽ˩ũ˥]
/mèe = $ú_n$/
EMPH = 2S
'you' (FAM)

(6.75) a. me̱a
[mẽ˩ã˧]
/mèe = a_n/
EMPH = 3SF
'she'

b. me̱a
[mẽ˩ã˧]
/mèe = a_n/
EMPH = 3.N
'it'

As indicated, the vocalic enclitics cause the long vowel of the host to reduce to a short vowel.

There are at least two sandhi processes that affect the surface tone on individual CV enclitics—the lowering of M-tone and H-tone enclitics by a spreading L tone and the raising of M-tone enclitics by the association of a floating +H tone. M-tone enclitics are lowered to [L] after a host word that has a L tone on the final mora. The contrast is shown by the minimal pairs in (6.76, 6.77).

[7] According to the pedagogical grammar of Alacatlatzala (ALA) Mixtec (Zylstra 2012), which has a pronominal system very similar to the Nieves Mixtec system, all unperturbed enclitics with H or M basic tone exhibit lowering effects on an immediately following M-tone enclitic, and unperturbed enclitics with H basic tone also cause lowering effects on an immediately following H-tone enclitic. A systematic investigation of interactions between enclitics is beyond the scope of this dissertation.

(6.76) a. síka na
[si˥ka˧nã˧]
/síkā = nā/
IPFV\RE:walk = 3P
‘they are walking’

<MC MIN0479:6:02.5>

b. síka̲ na
[si˥ka˧nã˩]
/síkà = na/
IPFV\RE:request = 3P
‘they are asking’

<MC MIN0479:5:57.7>

(6.77) a. kuni ra
[kũ˧nĩ˧ɾa˧]
/kuni = ra/
IR:see = 3M
‘he will see’

<OO MIN0331:1:20.3>

b. kuni̲ ra
[kũ˧nĩ˧ɾa˩]
/kunì = ra/
want = 3M
“he will want’

<OO MIN0331:0:23.3>

The verbs in (6.76a, 6.77a) have [M] tone on their final morae, so the enclitics /= na`/ ‘they’ and /= ɾa`/ ‘he’ also have [M] tone. But in (6.76b, 6.77b), the verbs have [L] tone on their final morae, so the enclitics also have [L] tone. Enclitics with [H] basic tone may also be lowered to [L] in these environments, as shown in (6.78, 6.79).

(6.78) a. chi̲núu ndó
[tʃi˩nũ˥ũ˧^{n}do˥]
/`\tʃi–núu = ^{n}dó/
PFV\put–face = 2P
‘you put it on top’

<MC MIN0338:8:50.0>

b. nuu̲ ndó
[nũ˧ũ˨^{n}do˩]
/nuù = ^{n}dó/
face = 2P
‘to you all’

<OO MIN0174:1:04.2>

(6.79) a. ni̲ tyi̲i rí
[nĩ˧t^{j}i˩i˧ɾi˥]
/nì = t^{j}ìi = t^{j}í/
PFV = freeze = 3.ZO
‘it froze’

<MC MIN0398:5:49.5>

b. ni̲ si̲kaa̲ kuíi̲ rí
[nĩ˧si˩ka˧a˩ k^{w}i˥i˧ɾi˩]
nì = sì–kāà k^{w}íì´ = t^{j}í
PFV = HAB–STAT green = 3.ZO
‘it was green’

<MC MIN0336:8:09.1>

The verbs in (6.78a, 6.79a) again have [M] tone on their final morae, leaving the enclitics with their basic [H] tones. But in (6.78b, 6.79b), the enclitics are hosted by raising couplets, which have a [L] tone on their final morae and then a floating +H tone. The [L] tone spreads onto the enclitic, deleting both H tones. In other cases, in the same tonal context, the H tone is displaced but not deleted, as in (6.80).

(6.80) a. nuu̱ ndó
[nũ˧ũ˧ⁿdo˩˥]
/nuù = ⁿdó/
face = 2P
'to you all'

<OO MIN0353:0:05.4>

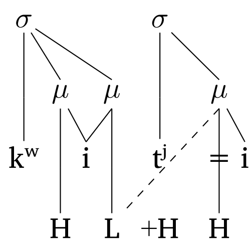
b. ndyukuíi̱ rí
[ⁿdʲi˧kʷi˥i˧ɾi˩˥]
/ⁿdʲu–kʷîˊ = tʲí/
INCH–green = 3.ZO
'it may turn green'

<MC MIN0336:22:39.5>

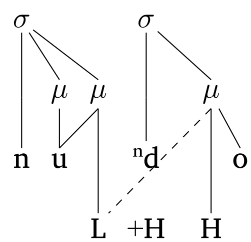
In these examples, the [L] tone associates to the enclitic, and shares the mora with the H tone, producing a sharp rising contour on the enclitic. The lowering of M-tone enclitics by a preceding [L] as in (6.76, 6.77), is quite consistent, while the lowering of H-tone enclitics as in (6.78–6.80) is variable.

Autosegmental diagrams of this process are shown in (6.81).

(6.81) a.



b.



The diagram in (6.81a) represents the tone processes in (6.79b), where the tone of the enclitic is replaced, and the diagram in (6.81b) represents the tone process in (6.80a), where the H tone of the enclitic is not deleted. In both cases, the final L tone of the couplet spreads by associating to the mora of the enclitic. In (6.81a), the H tone of the enclitic delinks, whereas in (6.81b) it does not.

In contrast to the lowering of H-tone enclitics that are hosted by raising couplets as in (6.78–6.80), M-tone enclitics are raised by raising couplets, just as M-initial couplets are raised by raising couplets. This raising effect is shown in (6.82, 6.83).

(6.82) a. nuu̱ ra
[nũ˧ũ˩ɾa˦]
/nuùˊ = ra/
face = 3M
'to him'

<MC MIN0576:1:51.9>

b. nuu̱ na
[nũ˧ũ˩nã˦]
/nuùˊ = na/
face = 3P
'to them'

<MC MIN0475:10:15.1>

c. nuu̱ si
[nũ˧ũ˩si˦]
/nuùˊ = si/
face = 3S.FRM
'to him'

<FO MIN0734>

(6.83) a. ni̱i̱ na
[nĩ˧ĩ˩nã˦]
/nìì´=na`/
salt=3P
'their salt'

b. yuku̱ na
[ʒu˧ku˩nã˦]
/ʒūkù´=na`/
hill=3P
'their hill'

c. ji̱ko̱ na
[xi˨ko˩nã˦]
/xìkò´=na`/
neck=3P
'their necks'

Hosted by raising couplets as in (6.82, 6.83), the M-tone enclitics /=ɾa/, /=na/ and /=si/ have pitches that are higher than when hosted by either non-triggering couplets or lowering couplets, as in (6.76, 6.77).

When the raising couplets are hosts to a L-tone enclitic, the enclitic remains unchanged, while the host tone is raised, as in (6.84).

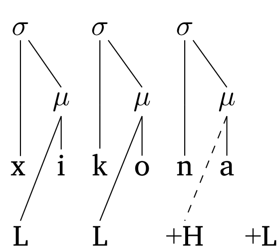
(6.84) a. nuu̱ ndyi̱
[nũ˧ũ˧˦=$^{n}d^{j}$i˩]
/nuù´=$^{n}d^{j}$ì/
face=1P.EX
'to us, not you'

<OO MIN0195:5:49.9>

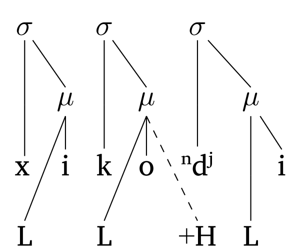
b. ji̱ko̱ ndyi̱
[xi˨ko˨˦$^{n}d^{j}$i˩]
/xìkò´=$^{n}d^{j}$ì/
neck=1P.EX
'our necks'

The autosegmental representations of these processes are shown in (6.85).

(6.85) a.



b.



The diagram in (6.85a) corresponds to (6.83c), while the diagram in (6.85b) corresponds to (6.84b). In (6.85a), the mora of the enclitic is not pre-associated to any tone, and so the floating +H sponsored by the couplet is permitted to associate to that mora. But in (6.85b), the enclitic already has a L tone, and the floating +H tone of the couplet associates back to the last mora of the couplet to create a LH monomoraic contour.

6.3.2 Proclitics

In order to demonstrate tonal processes observed in the pretonic domain, I describe here four proclitics,[8] marking verbal aspect and negation: perfective, imperfective, counterfactual and negative potential. These proclitics trigger tone changes in tonal contexts that ordinarily do not undergo tone changes.

The most productive exponent of perfective aspect is the proclitic /nì/, which bears a L tone. The perfective aspect is contrasted with the unmarked potential aspect in (6.86, 6.87).

(6.86) a. sa'a̲n an
[sã˧ʔã˩]
/saˀà$_n$ = a$_n$/
smell = 3.N
'it will stink'

<OO MIN0340>

b. ni̲ sa'a̲n an
[nĩ˩sã˧ʔã˩]
/nì = saˀà$_n$ = a$_n$/
PFV = smell = 3.N
'it stank'

<OO MIN0340>

(6.87) a. ki̲ki ra
[ki˩ki˧ɾa˧]
/kìki = ɾa/
sew = 3M
'he will sew'

<OO MIN0340>

b. ni̲ ki̲ki ra
[nĩ˧ki˩ki˧ɾa˧]
/nì = kìki = ɾa/
PFV = sew = 3M
'he sewed'

<OO MIN0340>

When the perfective clitic occurs with simplex verbs as in (6.86b, 6.87b), there are no further tonal effects. But most verbal prefixes have default M tone, which surfaces in potential aspect forms as in (6.88).

[8]There is disagreement in the literature on Mixtec morphology about whether verbal aspect and negation should be considered prefixes or proclitics. K. L. Pike (1948), describing San Miguel el Grande Mixtec, treated most pre-verbal functional morphemes as proclitics, and many of the descriptions of other Mixtec varieties followed suit. Macaulay (1996) treats negation, optative and prohibitive as proclitics in Chalcatongo Mixtec, and the other aspectual markers are treated as prefixes. McKendry (2013) treats all the markers of verbal negation and aspect as prefixes in Santo Domingo Nuxaa Mixtec. I follow a more traditional categorization, leaving a systematic analysis of the morphological domains in Nieves Mixtec for future work.

(6.88)	a. nakani ra̲	b. kujíkó ra	c. chindyáa ra
	[nã˧kã˧nĩ˧ɾa˧]	[ku˧xi˥ko˥ɾa˧]	[tʃi˧ⁿdʲa˥a˧ɾa˧]
	/na–kani = ɾa/	/ku–xíkó = ɾa/	/tʃi–ⁿdʲáa = ɾa/
	REP–hit = 3M	INCH–high = 3M	put–adhered = 3M
	'he will count'	'he will get tall'	'he will stick in on'

A verb with one of these M-tone prefixes has multiple possible realizations of perfective aspect. First, the L tone of the proclitic /nì/ may spread onto the prefix, as in (6.89).

(6.89)	a. ni̲ kakānī rā	b. ni̲ nandyi̲ko̲-ra̲	c. ni̲ kusíká na̲
	[nĩ˧ka˩kã˧nĩ˧ɾa˧]	[nĩ˧nã˩ⁿdʲi˩ko˩ɾa˩]	[nĩ˧ku˩si˧ka˥nã˧]
	/nì = ka–kani = ɾa/	/nì=na–ⁿdʲìkò=ɾa/	/nì = ku–síká = na`/
	PFV=PL–hit=3M	PFV=REP–follow=3M	PFV = INCH–far = 3P
	'they hit (something)'	'he followed'	'they went away'
	<MO MIN0955>	<MC MIN0976>	<MO MIN0969>

In these contexts, the L tone may dissociate from the perfective proclitic, changing it from [L] to [M] tone as in (6.90).

(6.90)	a. ni̲ kanana ra	b. ni̲ ndaka'a̲n ra̲	c. ni̲ ndyusa̲tyi̲ ra̲
	[nĩ˧ka˩nã˧nã˧ɾa˧]	[nĩ˧ⁿda˩kã˧ʔã˩ɾa˩]	[nĩ˧ⁿdʲu˩sa˩tʲi˩ɾa˩]
	/nì = ka–nana = ɾa/	/nì=ⁿda–kaˀa$_{n}$=ɾa/	/nì = ⁿdʲu–sàtʲì = ɾá/
	PFV=PL–go_up=3M	PFV=REP–talk=3M	PFV=INCH–spicy=3.LQ
	'they went up'	'he spoke again'	'it (sauce) got spicy'
	<MC MIN1010>	<MO MIN0951>	<MO MIN0953>

The segmental part of the proclitic /ni/ can also elide altogether, leaving only the L tone as a marker of aspect, as in (6.91).

(6.91)	a. chi̲núu ndó	b. ka̲kani ra	c. na̲sino̲ ra̲
	[tʃi˩nu˥u˥ⁿdo˥]	[ka˩kã˧nĩ˧ɾa˧]	[nã˩sĩ˧nõ˩ɾa˩]
	/`\tʃi–núu = ⁿdó/	/`\ka–kani = ɾa/	/`\na–sinù = ɾa/
	PFV\put–face = 2P	PFV\PL–hit = 3M	PFV\REP–descend=3M
	'you put it on top'	'they hit (something)'	'he went back down'
	<MC MIN0338>	<MC MIN0535>	<MC MIN0971>

In contrast to the lowering caused by a floating +L tone sponsored by a couplet, which is variable and most easily observed in H.H couplets, the floating +L tone of the perfective is reliably realized, and it targets an individual M-tone mora.

Imperfectives are formed by replacing the initial tone of the verb with a H tone. The imperfective and potential forms of bimoraic verbs with underlying initial M tone are contrasted in (6.92–6.94).

(6.92) a. kasí ra
[ka˧si˦ɾa˧]
/kasí = ɾa/
eat.sweet = 3M
‘he will eat’

b. sásí ra
[sa˥si˥ɾa˧]
/´\sasí = ra/
IPFV\eat.sweet = 3M
‘he is eating’

(6.93) a. kueen ra
[kʷẽ˧ẽ˧ɾa˧]
/kʷee$_{n}$ = ɾa
IR:buy = 3M
‘he will buy’

b. séen ra
[sẽ˥ẽ˧ɾa˧]
/´\see$_{n}$ = ɾa/
IPFV\RE:buy = 3M
‘he is buying’

(6.94) a. ndyayi̲ na
[ⁿdʲa˧ji˨nã˩]
/ⁿdʲaʒì = na/
shake = 3P
‘they will shake’

b. ndyáyi̲ na
[ⁿdʲa˥ji˨nã˩]
/´\ⁿdʲaʒì = na/
IPFV\shake = 3P
‘they are shaking’

Regardless of the tone of the second mora, the initial M tone is replaced by the H tone. The imperfective forms of bimoraic verbs with underlying initial L tone are contrasted with their potential forms in (6.95–6.96).

(6.95) a. xi̲kó na
[ʃi˩ko˦na˧]
/ʃìkó = na/
sell = 3P
‘they will sell’

b. xíkó na
[ʃi˥ko˥nã˧]
/´\xìkó = na/
IPFV\sell = 3P
‘they are selling’

(6.96) a. ki̲ki ra
[ki˩ki˨ɾa˧]
/kìki = ɾa/
sew = 3M
‘he will sew’

b. kíki na
[ki˥ki˦na˧]
/´\kìki = na/
IPFV\sew = 3P
‘they are sewing’

<OO MIN0340>

Whether the initial mora of the verbs is underlyingly M as in (6.92–6.94) or L as in (6.95, 6.96), the underlying tone is replaced. The tone is not displaced onto the next mora, and the downstep effect of the initial L tone on the adjacent H tone in (6.95a) or M tone in (6.96a) is canceled in (6.95b, 6.96b) by the +H tone of the imperfective. In verbs that have an initial M-tone prefix, the tone of the prefix is replaced by the +H tone of the imperfective morpheme, as in (6.97).

(6.97) a. ndyúsa̱tyi̱ rá
[ⁿdʲu˥sa˧tʲi˩ɾa˧˥]
/´\ⁿdʲu–sàtʲì = ɾá/
IPFV\INCH–spicy=3.LQ
'it's getting spicy'

<MO MIN0953>

b. ndáne'e ra
[ⁿda˥nẽ˧ʔẽ˧ɾa˧]
/´\ⁿda–neˀe = ɾa/
IPFV\REP–carry=3M
'he is holding it'

<MO MIN0951>

c. kásika ra
[ka˥si˧ka˧ɾa]
/´\ka–sika = ɾa/
IPFV\PL–RE:walk=3M
'they are walking'

<MO MIN0955>

Verbal negation is marked by one of two particles which bear [L] basic tone plus a floating +H tone, which causes raising on the following vowel. The counterfactual /kò´=/ is used with perfective and imperfective verb forms. In perfective verbs, as in (6.98, 6.99), the counterfactual requires the segmental allomorph of the perfective proclitic /nì/.

(6.98) a. ni̱ ka'a yaa
[nĩ˩ka˧ʔa˧ ja˧a˧]
/nì = kaˀa ʒaa/
PFV = play music
'there was music'

<OO MIN0340>

b. ko̱ ni̱ ka'a yaa
[ko˩nĩ˧ka˧ʔa˧ ja˧a˧]
/kò´ = nì = kaˀa ʒaa/
NEG.RE = PFV = play music
'there wasn't music'

<OO MIN0340>

(6.99) a. ni̱ saku ra
[nĩ˩sa˧ku˧ɾa˧]
/nì = saku = ɾa/
PFV = RE:cry = 3M
'he cried'

<MC MIN0339>

b. ko̱ ni̱ saku na
[ko˩nĩ˧sa˧ku˧na˧]
/kò´ = nì = saku = na/
NEG.RE = PFV = RE:cry = 3P
'they didn't cry'

<MC MIN0339>

The floating +H tone of the counterfactual replaces the L tone of the perfective proclitic. In imperfective verbs, as in (6.100, 6.101), the floating +H tone of the counterfactual and the floating +H tone of the imperfective fuse, and only one mora is raised to [H] tone.

(6.100) a. ká'a yaa
[ka˥ʔa˧ ja˧a˧]
/´\kaˀa ʒaa/
IPFV\play music
'there is music'

<OO MIN0340>

b. ko̱ ká'a yaa
[ko˩ka˥ʔa˧ ja˧a˧]
/kò´ = ´\kaˀa ʒaa/
NEG.RE = IPFV\play music
'there wasn't music'

<OO MIN0340>

(6.101) a. sáku na
[sa˥ku˦nã˧]
/´\saku = ɾa/
IPFV\ = RE:cry = 3M
‘they are crying’

<MC MIN0339>

b. ko̱ sáku na
[ko˩sa˥ku˧nã˧]
/kò´= ´\saku = na/
NEG.RE = IPFV\RE:cry = 3P
‘they aren’t crying’

<MC MIN0339>

Potential verb forms are instead negated by the proclitic /ù$_n$´=/. The affirmative and negative forms of potential verbs are contrasted in (6.102–6.104).

(6.102) a. kuaku na
[kʷa˧ku˧nã˧]
/kʷaku = na/
IR:cry = 3P
‘they will cry’

<MC MIN0339>

b. u̱n kuaku na
[ũ˩kʷa˥ku˧nã˧]
/ù$_n$´= kʷaku = na/
NEG.IR = IR:cry = 3P
‘they won’t cry’

<MC MIN0339>

(6.103) a. kua̱ku̱ na
[kʷa˨ku˩nã˩]
/kʷàkù = na/
IR:laugh = 3P
‘they will laugh’

b. u̱n kua̱ku̱ na
[ũ˩kʷa˥ku˨nã˩]
/ù$_n$´= kʷàkù = na/
NEG.IR = IR:cry = 3P
‘they won’t laugh’

(6.104) a. kundye’e̱ ra
[ku˧^{n}dʲe˧ʔe˩ɾa˩]
/ku–^{n}dʲeʔè = ɾa/
IR–watch = 3M
‘he will watch’

<MC MIN0339>

b. u̱n kundye’e̱ ra
[ũ˩ku˥^{n}dʲe˧ʔe˩ɾa˩]
/ù$_n$´= ku–^{n}dʲeʔè = ɾa/
NEG.IR = IR–watch = 3M
‘he will not watch’

<MC MIN0339>

Just like the floating +H tones of the imperfective and the counterfactual, the floating +H of the negative potential proclitic replaces the following tone, whether it is M tone as in (6.102b) or L tone as in (6.103b).

6.3.3 Summary

In sum, both enclitics as targets of tone change and proclitics as triggers of tone change license different processes than couplets do, though there are similarities.

In both enclitics and couplets, a floating +H tone will associate to a M-tone mora.

However, a floating +H tone is prevented from associating to a L-tone enclitic, and instead the +H tone associates back to the last mora of the sponsoring morpheme. In couplets, the +H tone can raise the pitch of a L.L couplet, and otherwise delete or associate back to the last mora of the sponsoring morpheme. In both enclitics and couplets, a L tone may spread onto a H-tone mora. However, when the target is an enclitic, the spreading may occur regardless of the following context, whereas when the target is a couplet, the L tone may spread onto the H-tone mora only if the following mora also bears H tone. In addition, L tone may spread onto a M-tone enclitic. This is comparable to the downstep of M tone after L tone, which is observed in couplets, but the spreading of L tone onto M-tone enclitics is categorical, not merely a phonetic effect.

The data from proclitics show other divergences from the tone changes seen elsewhere. The L tone of the perfective spreads onto M-tone morae, which resembles the spreading of L tone on to M-tone enclitics, but it is not a tone change that can target couplets. The floating +L tone of the tonal allomorph of the perfective also associates consistently to the prefix vowel, whereas +L tones sponsored by couplets trigger highly variable processes. The floating +H tones of the imperfective and negative proclitics also are more dominant than the +H tones sponsored by couplets. The floating +H tones of the proclitics replace either M and L tones, regardless of the following context, while the floating +H tones sponsored by couplets can only associate to a mora occupied by an L tone if it is the first mora of a L.L couplet. The differences could spring from morphological differences, such as the higher functional load of tone in grammatical morphemes, or prosodic differences such as pre-tonic, tonic and post-tonic domains.

6.4 Survey of tone systems of Mixtec varieties

This section motivates the analytic approach taken in this chapter through reanalysis of two previously studied Mixtec varieties and recontextualizes the description of Nieves Mixtec tone within the documented diversity of Mixtec tone systems. Previous tone description and analysis of Mixtec varieties in the Western Alta region have been more extensive than in other dialect groups, and the tone system of Nieves Mixtec closely resembles the tone systems of Western Alta. For these reasons, the discussion here focuses on the tone systems of Western Alta, particularly San Miguel el Grande Mixtec, which is associated with Chalcatongo Mixtec (CHL), and the neighboring variety of San Esteban Atatlahuca Mixtec (ATA). After examining these systems, brief comparisons are made to three more Group A systems—Alcozauca (ALC), San Juan Colorado (COL), and Santo Domingo Nuxaá (NUX)—and three systems outside group A—Ayutla de los Libres (AYU), Santa Maria Peñoles (PÑL), and San Juan Coatzospan (COA). The locations of these varieties are shown in the map in Figure 6.1. I summarize existing tone analyses for the selected varieties, and I revise analyses of a few Group A varieties to highlight the similarities and differences with Nieves Mixtec.

For each tone system, I continue the approach used in the description of the Nieves Mixtec tone system, examining the tone patterns per mora within couplets, then the tone sandhi observed in couplets, and finally the tone sandhi observed in clitics and triggered by clitics. To the extent that existing descriptions allow, I identify what formal resources are required to (i) specify the inventory of underlying tone patterns, with special attention to floating tones, (ii) describe the surface tones that result from tone processes, and (iii) distinguish the domain types, trigger types, and target types. As a set of primarily descriptive works, the Mixtec tone literature depends heavily on arbitrary classes of trigger and target types to describe tone changes, though a few descriptions hint at a deeper analysis (e.g. K. L. Pike 1948; Mak 1953; Pankratz & Pike 1967), and some include extensive analytic work (e.g. Tranel 1995; Daly & Hyman 2007; McKendry 2013). These analytic works propose differences in underlying tone specifications to explain much of the sandhi behavior, so that the observed tonal processes can be analyzed as phonologically natural even if the tonal classes are still semantically and syntactically arbitrary. Like the analysis presented in the preceding sections for Nieves Mixtec, analyses of other Mixtec varieties have made extensive use of floating tones, tones that are considered unassociated with any particular mora in the underlying representation. Furthermore, because of the descriptive utility of the couplet across Mixtec varieties (as discussed in §4.2), the original

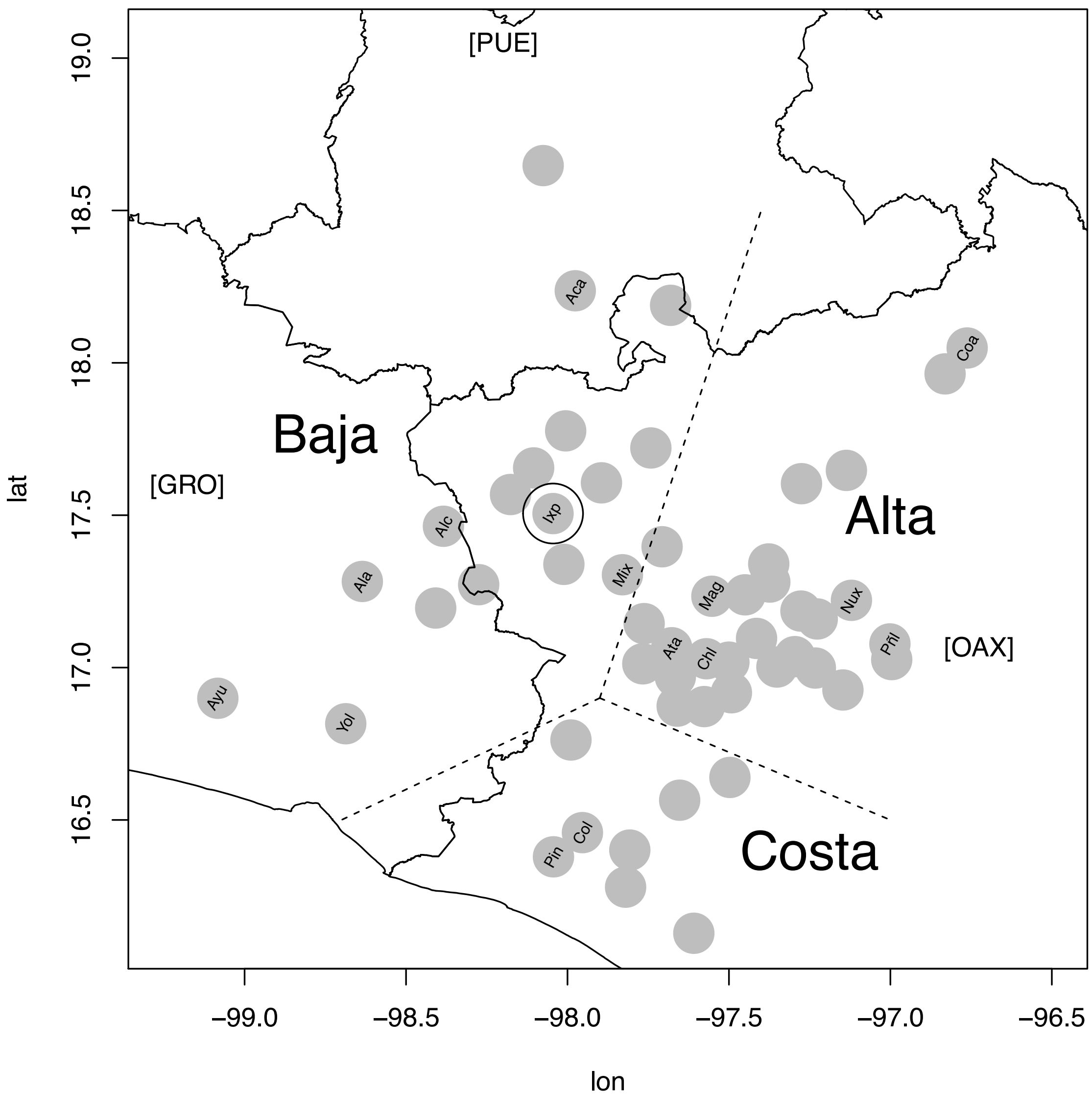


Figure 6.1: The location of Ixpantepec Nieves (IXP) and of other Mixtec varieties. Except for Ixpantepec Nieves and San Jorge Nuchita (NCH), each gray circle represents the central location of one ISO language, and the labeled circles are the varieties whose tone systems are mentioned in this section.

descriptions are usually framed in terms of the tone classes of couplets and the tone sandhi observed in couplets. When the tone processes observed on monomoraic clitics and triggered by monomoraic clitics are discussed, these processes have been treated separately, in the same way that the description of Nieves Mixtec tone processes treated the tone sandhi of couplets in §6.2.3 separately from the tone processes of clitics in §6.3.

6.4.1 Western Alta

In the Western Alta region, we focus on two neighboring varieties, of San Miguel el Grande, affiliated with Chalcatongo (CHL), and San Esteban Atatlahuca (ATA). There are several other Mixtec varieties in the region with substantial description of the tone systems, but these are two of the varieties described in most detail. San Miguel el Grande was also the first system described (K. L. Pike 1948), and so the rest of the literature makes frequent comparisons to it. These two tone systems are particularly relevant for showing the analytical advantage of the hypothesized floating tones, as well as for showing the differences between the tone processes observed in couplets and the tone processes observed in clitics. The floating +H tone is particularly apparent in the tone system of San Miguel el Grande Mixtec, and the floating +L tone is particularly apparent in the tone system of San Esteban Atatlahuca. But according to the analyses I present here, both +H and +L floating tones are present in both varieties.

6.4.1.1 Couplets

In San Miguel el Grande Mixtec (K. L. Pike 1948; Mak 1950), there are three levels of tone, with no tone contours on a single mora,[9] and all binary combinations of tone levels except for [L.L] are attested in canonical bimoraic stems. This results in an inventory of eight surface tone patterns in bimoraic stems. However, the tone sandhi indicates further

[9]The early descriptions of Mixtec assumed disyllabic stems and no long vowels. Working prior to the integration of moraic theory into autosegmental theory (Trubetskoy 1958/1969; Goldsmith 1990), the descriptions express precursor concepts in terms of single syllables, single vowels, or single tonemes. I have translated these descriptions into the terminology of the moraic analysis adopted in more recent work and here.

distinctions in tonal patterns, as well as evidence that surface [H.L] and [M.H] have the same underlying tonal pattern, bringing to twelve the total count of underlying tonal patterns (McKendry 2013).

The most general sandhi process raises the tone of a single mora from [L] or [M] in the "basic" (i.e. isolation) form to [H] in the sandhi form (K. L. Pike 1948). This process is shown in (6.105), showing the analysis according to K. L. Pike (1948:56) and Goldsmith (1990:20–26) on consecutive lines.

(6.105)	a.	kee	su̲chí		b.	kee	su̲chí	
		[ke˧e˧	su˩tʃi˥]			[ke˧e˧	su˥tʃi˥]	
		/kee^{a}	sùtʃí^{b}/	(Pike)		/kee^{b}	sùtʃí^{b}/	(Pike)
		/kee	sùtʃí´/	(Goldsmith)		/kee´	sùtʃí´/	(Goldsmith)
		'the child will go away'				'the child will eat'		

The word /sùtʃí/ 'child' has L.H "basic tone" pattern, which appears in isolation and in contexts like (6.105a). But in contexts like (6.105b), it has H.H tone pattern. The tone raising is conditioned by the presence of preceding trigger morphemes, which were originally considered an arbitrary class. Morphemes were thus categorized by their basic tone pattern and whether they belonged to the non-triggering class of morphemes (Pike's "class (^{a})") or the raising class of morphemes (Pike's "class (^{b})"). Similarly, morphemes may be categorized as to whether they are susceptible to raising (called "unstable" by K. L. Pike (1948) but "non-raised" here) or already raised (called "stable" by K. L. Pike (1948) but "raised" here). However, later analyses reduced the phonological arbitrariness by hypothesizing that the triggering morphemes sponsor a final floating +H tone (Goldsmith 1990; Tranel 1995; McKendry 2013). These tone patterns and their sandhi behavior types are summarized in Table 6.4, showing underlying tones according to the analysis by McKendry (2013).

As shown in the table, the triggering behavior is only partially predictable from the surface tones of the triggering morpheme. Morphemes from the "basic" tone classes [H.H], [H.M], [M.M], [M.L], and [L.H] may trigger sandhi, while other morphemes from those same basic tone classes do not trigger sandhi. The sandhi behavior of couplets as targets is also puzzling. In bimoraic targets, it is usually the tone of the first mora that

Table 6.4: The underlying tone patterns in San Miguel el Grande (CHL) and their corresponding surface tones in isolation

Trigger Type	Target Type: Raised	Target Type: Non-raised	
Raising (^{b})	[H.H] /H.H+H/		[L.H] /L.H+H/
	[H.M] /H.M+H/	[M.M] /M.M+H/	
		[M.L] /M.L+H/	
Non-triggering (^{a})	[H.H] /H.H/		[L.H] /L.H/
	[H.M] /H.M/	[M.M] /M.M/	[L.M] /L.M/
	[H.L] /H.L/	[M.L] /M.L/	
	[M.H] /H(L)/		

changes—[M.M] targets are raised to [H.M], [L.H] targets are raised to [H.H], and [L.M] targets are raised to [H.M]. However, [M.H] stems and non-glottalized [M.L] stems with medial consonants (CVCV) are exceptional. CVV [M.L] stems and glottalized [M.L] stems change to [H.L] as expected, but plain (C)VCV [M.L] stems change to [M.H] rather than [H.L], as in (6.106) (K. L. Pike 1948:56).

(6.106) a. kee iso̱
[ke˧e˧ ʔi˧so˩]
/kee^{a} isò^{a}/
'the rabbit will go away'

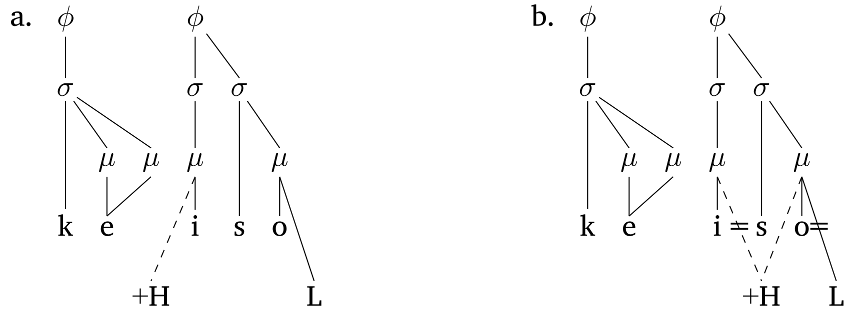
b. kee iso̱
[ke˧e˧ ʔi˧so˥]
/kee^{b} isó^{a}/
'the rabbit will eat'

In addition, [M.H] stems act as already raised, as they do not undergo the expected change to [H.H] after raising morphemes. Early analyses (Goldsmith 1990; Tranel 1995) struggle to deal with the data according to this description, but Hollenbach (2003) shows that the same exceptional sandhi case is found in the neighboring variety of Magdalena Peñasco (MAG), and in that variety, the independent [M.H] stems and the raised form of [M.L] stems carry a final floating /+L/ tone, evidenced in lowering sandhi. Evidence of a /+L/ tone for these stems in San Miguel el Grande Mixtec is limited,[10] but the data from Magdalena Peñasco Mixtec suggest an analysis in which the /+H/ tone of the trigger morpheme initially docks on the first mora of all /M.L/ stems, as in (6.107a), and this

[10] The best evidence of /+L/ tone in these stems is that [M.H] stems pattern with the 'non-triggering' [H.H] and [L.H] stems in causing lowering of H-tone enclitics, described in §6.4.1.2. Also, K. L. Pike (1948) mentions a 'unique perturbation' caused by /inì/ 'inside' on /beˀe/ 'house', changing it from basic [M.M] tones to [L.M] tones. The example utterance provided, shown in (6.1), is exactly the context where the raising of /inì/ 'inside', an /M.L/ stem, would create a floating +L that could then associate to /beˀe/ 'house'.

feeds a rule that shifts /H.L/ tones in plain CVCV stems to /M.H+L/, as in (6.107b).

(6.107)



In this analysis, the raising action of the floating +H tone is regular, and only the rightward shift of H.L tones in CVCV stems is exceptional. The ‘basic’ tone class of [M.H] is only found in plain CVCV stems, and so the same rule allows the analysis to unify the [M.H] tone class with the [H.L] tone class, with underlying /H.L/ tone. With the raising rule ordered before the tone shift, this explains why [M.H] stems do not undergo tone-raising–the underlying form is the already raised /H.L/ tone pattern.

Autosegmental analyses of this sandhi process, including the recent treatment by McKendry (2013), translate the lexical marking of raising morphemes uniformly into a floating /+H/ tone, treating all the raising effects as association of this floating tone to the following morpheme. However, the evidence that [M.H] morphemes sponsor a delinked /+L/ tone that causes few if any tone changes opens up an alternative analysis of [H.H] and [L.H] morphemes—the other morphemes that have [H] on the final mora. The effects triggered by [H.H] and [L.H] raising morphemes can be analyzed as spreading of the final /H/ tone rather than action of a floating tone, and the lack of raising after the non-

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(6.1)

te ni̱ jaa̱ tɨ̱	ini̱	beˀe	kaba tɨ̱
[te˧ni˩ha˧a˩tə˩	ʔi˧ni˥	be˩ʔe˧	ka˧ba˧tə˥]
/te = nì = haà = tə̀ ́	inì	beˀe	kaba ́ = tə̀ ́/
and = PFV = arrive = 3.ZO	inside	house	cliff = 3.ZO

‘and the animal (snake) arrived into the animal’s (rabbit’s) rock house’

Another effect of floating +L sponsored by a prefix is observed in a restricted set of verbs. Mak (1950) notes that the two andative auxiliary verbs /kwā/ ∼ /kʷāˀà$_{n}$/ and /kī/ ∼ /kīˀì$_{n}$/ change [M.M] verbs to [L.M], unless the verbs are themselves potential triggers in the raising sandhi system. Restated in the current autosegmental analysis, /M.M/ verbs permit the final +L tone of the andative to associate to the first mora, while /M.M+H/ verbs do not permit it. The sandhi does not depend on whether the monomoraic or bimoraic allomorphs of the andative are used, and no similar sandhi occurs with the tonally identical though non-glottalized venitive /kī/ ∼ /kīì/.

Table 6.5: Reanalysis of the underlying tone patterns in San Miguel el Grande (CHL)

Trigger Type	Target Type: Raised	Non-raised	
Raising	[H.H] /H.H/		[L.H] /L.H/
	[H.M] /H.M+H/	[M.M] /M.M+H/	
		[M.L] /M.L+H/	
Non-triggering	[H.H] /H.H+L/		[L.H] /L.H+L/
	[H.M] /H.M/	[M.M] /M.M/	[L.M] /L.M/
	[H.L] /H.L/	[M.L] /M.L/	
	[M.H] /H+L/		

triggering [H.H] and [L.H] morphemes is then explained by a floating /+L/ tone blocking the spread of the final /H/ tone. This reanalysis of the underlying tones is shown in Table 6.5. The further stipulation of inert floating /+L/ tones bears fruit in two ways: (i) it allows more coherent analysis of the tone sandhi found in clitics, discussed in §6.4.1.2, and (ii) the resulting inventory of tone patterns is more comparable to the tone patterns found in other Mixtec varieties. Besides the similarity between the tone pattern inventory in Table 6.5 and the tone pattern inventory found in Nieves Mixtec (Table 6.2), this inventory is more comparable to the ones found in other Group A varieties such as San Esteban Atatlahuca Mixtec (ATA), which we turn to now. San Esteban Atatlahuca Mixtec has not been previously analyzed with floating tones, though recent discussions of data from Atatlahuca Mixtec (Hollenbach 2003; McKendry 2013) have assumed that a floating tone analysis is appropriate.

In San Esteban Atatlahuca Mixtec (Mak 1953; R. M. Alexander 1980), there are four levels of surface tone, with the additional tone ([Λ]) having a pitch in between that of [L] and [M] tones. The [Λ] tone is frequent in sandhi contexts, and in some contexts it varies with [M], but it is also found contrasting with each of the other tones on the second mora of the stem, after [H] tone. Mak (1953) treats the tone patterns as having a single tone per vowel (i.e. mora) in basic form, but she describes two-toneme contours on a single vowel in sandhi contexts. In Mak's description, there are nine classes of surface tone, with the eight classes as found in San Miguel el Grande, plus [H.Λ], and R. M. Alexander (1980) adds one more, [L.MH]. But complex sandhi behavior indicates

Table 6.6: The underlying tone patterns in Atatlahuca (ATA) and their corresponding surface tones in isolation

Trigger Type	Target Type		
Raising	[H.H] /H.H/	[M.H] /M.H/	[L.H] /L.H/
			[L.MH] /L.MH/
Exceptional		[M.M] /M.M+H/	
		[M.L] /M.L+H/	
Non-triggering	[H.M] /H.M/	[M.M] /M.M/	[L.M] /L.M/
	[H.Λ] /H.LM/		
Lowering	[H.L] /H.L/	[M.L] /M.L/	
	[H.H] /H.H+L/		
	[H.M] /H.M+L/	[M.M] /M.M+L/	[L.M] /L.M+L/
	[H.Λ] /H.LM+L		

that there are at least 17 underlying tone patterns. These tone patterns and their sandhi behavior types are summarized in Table 6.6. The analysis adopted here assumes [Λ] tones are underlyingly /LM/ contours on a single mora, as in Santo Domingo Nuxaá (McKendry 2013). Note that unlike San Miguel Grande Mixtec and Nieves Mixtec, M tone can not be underspecified in this inventory, as the M tone shares a mora with L in the /LM/ contour tone and shares a mora with H in the /MH/ contour tone.

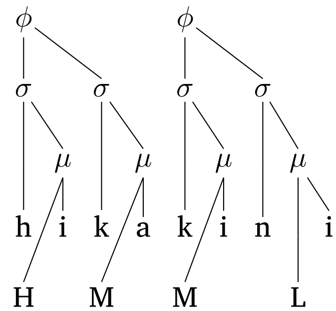
As in San Miguel el Grande Mixtec, the morphemes in Atatlahuca Mixtec may be divided between those which do not trigger sandhi and those which do, but the triggering category must be further divided to distinguish morphemes which consistently raise the tone pattern of the following morpheme, as in San Miguel el Grande Mixtec, from those which lower the tone pattern of the following morpheme. In addition, there are some morphemes which trigger raising sandhi only within exceptional domains, which I analyze as lexical sandhi domains. The behavior of the lowering morphemes ("type $(^{c})$" in the original description) led Mak to a proposal that presages a floating tone analysis:

> "This observation leads me to the hypothesis that $(^{c})$ morphemes are those which historically perhaps ended on a tone [L], whatever their present form, and that this low toneme now usually transfers itself to the following morpheme." (Mak 1953:92)

The analysis adopted here takes exactly this approach, grouping the lowering morphemes that do not have a final surface [L] tone with those that do have a final surface [L] tone by assigning a floating +L tone to those morphemes.

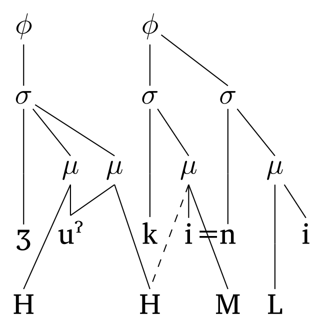
As shown in Table 6.6, I have analyzed the non-triggering morphemes as having underlying morpheme-final /M/ and raising morphemes having underlying morpheme-final /H/, while the lowering morphemes may either have morpheme-final /L/ or a floating /+L/ tone. The class of non-triggering morphemes come only from surface tone classes [H.M], [M.M], [L.M], and [H.ʌ], all with final M tone. This non-triggering environment is shown in (6.108) (R. M. Alexander 1980:14).[11]

(6.108) a. jíka kini̲
[hi˥ka˧ kĩ˧nĩ˩]
/´\hika kinì/
IPFV\RE.walk pig
'the pig walks'

b. 

The raising morphemes come only from surface tone classes [H.H], [M.H] and [L.H] classes, with final H tone. Raising of a following M tone is shown in (6.109) (R. M. Alexander 1980:14).

(6.109) a. yú'ú kini̲
[ʒu˥ʔu˥ kĩ˥nĩ˩]
/ʒúˀú kinì/
afraid pig
'the pig is afraid'

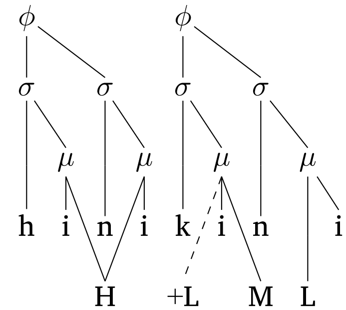
b. 

As shown in (6.109b), I analyze this as spreading of the H tone from the last mora of the first couplet onto the first mora of the second couplet, replacing the M tone. Besides two classes with final L tone ([H.L] and [M.L]), the lowering morphemes may come from surface tone classes [H.H], [H.M], [M.M], [L.M], and [H.ʌ]. These lowering morphemes without a final L basic tone are analyzed as having floating +L tones. Lowering of a fol-

[11] Transcription conventions are adapted from the original for consistency with data from other Mixtec varieties. These autosegmental diagrams show post-lexical or lexical tone processes, with the result of morphological tone processes included in the input.

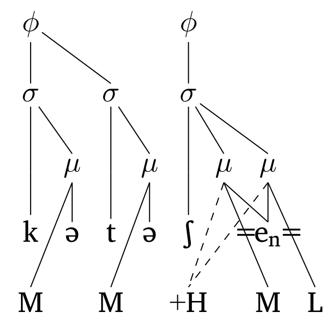
lowing M tone is exemplified in (6.110) (R. M. Alexander 1980:14).

(6.110) a. jíní kini̱
[hĩ˥nĩ˥ kĩ˧nĩ˩]
/híní` kinì/
IPFV.know pig
'the pig knows'

b. 

As shown in (6.110b), I consider this lowering as association of the floating +L tone onto the following morpheme, sharing the mora with the underlying M tone, to produce the surface [Λ] tone. Finally, the two exceptional tone classes with surface tone [M.M] and [M.L] behave differently in the post-lexical sandhi of phrasal domains (called "regular" by Mak and "automatic" by Alexander) and the lexical sandhi of word domains (called "special"). Raising of a following M tone in a word domain is shown in (6.111) (R. M. Alexander 1980:19).

(6.111) a. kɨtɨ xee̱n
[kə˧tə˧ʃẽ˥ẽ˥]
/kətə´–ʃeè$_{n}$/
animal–wild
'wild animal'

b. 

As shown, both morae of the target morpheme are raised to H tone in this case. Other tone patterns are raised differently, and when the trigger morpheme is of the [M.L] tone class, there may also be lowering in the first mora of the target morpheme, comparable to the lowering by raising triggers in Nieves Mixtec, shown in (6.66–6.69). The roots that have this exceptional triggering behavior are specifically those roots which are reconstructed as having a morpheme-final glottal stop in Proto-Mixtec (Table 6.1) and which have floating +H tones in Nieves Mixtec and San Miguel el Grande Mixtec. As shown in (6.111b), I assume here that these roots likewise bear a floating +H tone in Atatlahuca Mixtec, which associates onto the following morpheme in lexical sandhi but is deleted at word boundaries, as this raising process does not occur in phrasal domains.

Comparing tone pattern inventories across varieties, we can generalize that Ixpantepec Nieves Mixtec, San Miguel el Grande Mixtec and San Esteban Atatlahuca Mixtec have the same four sandhi trigger types, but with somewhat different triggering behavior in each variety. Couplets with a final M tone and no floating tone are non-triggering couplets in all three varieties. Couplets with a final H tone and no floating tone are non-triggering couplets in Nieves Mixtec, while they are raising triggers in San Miguel el Grande Mixtec and Atatlahuca Mixtec, as the final H tone can spread onto the following couplet. Couplets with a final L tone or with a floating +L tone are lowering triggers in Nieves Mixtec and Atatlahuca Mixtec, as the L tone may associate to the following couplet, while these couplets are generally non-triggering in San Miguel el Grande Mixtec. Finally, couplets with a floating +H tone can trigger raising in all three varieties, though their domains of application differ. In San Miguel el Grande Mixtec, the raising occurs in all environments, while in Nieves Mixtec the raising does not occur across major phrasal boundaries, and in Atatlahuca Mixtec, the raising by floating +H association only occurs within a word domain.

6.4.1.2 Clitics

As is generally the case in Mixtec, the tone sandhi of the clitics in San Miguel el Grande Mixtec and San Esteban Atatlahuca Mixtec is more difficult to analyze than the tone sandhi of couplets. According to K. L. Pike (1948), all monomoraic morphemes in San Miguel el Grande Mixtec are clitics, and the dichotomy between bimoraic couplets and monomoraic clitics is also used in the original description of San Esteban Atatlahuca Mixtec (Mak 1953).

In San Miguel el Grande Mixtec, the tonal alternations found in proclitics and triggered by proclitics can be unified with the raising sandhi found in couplets, as proclitics require the same formal tools as the couplets. Proclitics are divisible between morphemes that never trigger sandhi and morphemes that always trigger raising on a susceptible following morpheme, and the raising is consistent with association of a floating +H tone.

Table 6.7: San Miguel el Grande (CHL) Mixtec enclitics with their underlying tones and corresponding surface tones when leaning on a non-raising [M.M] word

	Target Type		
Trigger Type	Raised	Non-raised	
Raising	/H/ [ró] 2.FAM	/M+H/ [ɲā] 3F.FRM	/L+H/ [tə̀] 3ZO
	/H/ [ʒó] 1IN		/L+H/ [ʒà] 3DIV
Non-triggering	/H+L/ [ná] 1EX.FRM	/M/ [ðē] 3M.FRM	/L/ [rì] 1.EX.FAM
	/H+L/ [ní] 2.FRM	/M/ [ī] 3.FAM	

However, the sandhi behavior of enclitics requires further stipulations. As shown in Table 6.7, the enclitics of San Miguel el Grande Mixtec may still be divided between triggering and non-triggering morphemes and between raised morphemes and non-raised morphemes. But the results of sandhi go beyond raising L-tone or M-tone morae to [H] tone. The non-raised raising enclitics (with 'basic' tones [L] or [M]) will trigger raising on a following morpheme if they are not targets of sandhi, but when they are themselves targets of raising sandhi, they have [H] surface tone and will not trigger raising on a following morpheme. Pike treats the loss of triggering ability as an arbitrary effect of raising, but McKendry (2013) analyses it as deletion of all the enclitic's underlying tones when the floating +H of the preceding morpheme associates to the enclitic. But McKendry also provides an argument for the necessity of a specified M tone in San Miguel el Grande Mixtec, so we can equivalently consider the enclitic's base L or M tone delinked and only the +H tone of the enclitic deleted. The delinked L or M tone would then provide the mechanism to prevent the linked H tone from spreading.

Furthermore, the other two triggering enclitics ([ró] 2.FAM and [ʒó] 1IN) act as triggers regardless of the preceding morpheme, but they may have surface tone [H], [M] or [L] depending on the tone class of the preceding morpheme. In Pike's original analysis, [ró] 2.FAM and [ʒó] 1IN have [L] 'basic' tone and an abstract class marking distinguishes them from the other raising enclitics with 'basic' [L] tone ([tə] 3ZO and [ʒà] 3DIV). In that analysis, the observed behaviors are phonologically arbitrary. However, McKendry (2013) shows that an autosegmental analysis works well if we assume that the consistently raising enclitics bear underlying /H/ tone. The autosegmental analysis is made even more natural by the assumption that some 'non-triggering' couplets in San Miguel el Grande

Mixtec bear floating +L tones.

After raising morphemes, the surface tone of [ró] 2.FAM and [ʒó] 1IN is the same as the tone of the previous mora. This is analyzed as spreading of the tone of the previous mora, after deletion of the floating +H that would otherwise trigger raising. After non-triggering morphemes with final [L] tone, the surface tone of the enclitic is also [L], and this can again be treated as spreading of L tone with delinking of the enclitic's H tone. After non-triggering morphemes with final [M] tone, the enclitic surface tone is [H], the same as the underlying form. After non-triggering morphemes with final [H] tone, the enclitic surface tone is [L]. In Pike's description, this is the underlying ('basic') tone, and the various other possible surface tones require explanation. In McKendry's analysis, the surface [L] tone is caused by "dissimilation to avoid two adjacent High tones" (McKendry 2013:94), a process that is not observed elsewhere in the language. But my assumption that these 'non-triggering' morphemes bear a floating +L tone, reflected in the underlying forms in Table 6.5 and Table 6.7, makes the surface [L] tone on the enclitic a realization of the preceding morpheme's floating +L tone. The +L associates to the enclitic and delinks but does not delete the H tone of the enclitic, leaving it with the potential to trigger raising.

The sandhi found on pronominal enclitics in Atatlahuca Mixtec has fewer classes than the system found in San Miguel el Grande Mixtec, but it does not yield to a perspicuous autosegmental analysis. The enclitics of Atatlahuca Mixtec are shown in Table 6.8, arranged according to their classes of tone behavior. Two groups of enclitics with underlying /M/ and /L/ tones are recognizable. M-tone clitics have surface [M] tone after raising (/H/-final) and non-triggering (/M/-final) morphemes, and /Λ/ tone after lowering (/L/-final) morphemes. They act as non-triggering morphemes regardless of the previous morpheme. L-tone clitics have surface [H] tone after raising (/H/-final) morphemes, [L] tone or a [ML] contour tone after non-triggering (/M/-final) morphemes, and [L] tone after lowering (/L/-final) morphemes. They act as lowering morphemes regardless of the previous morpheme. However, there are two categories of apparently H-tone enclitics with different triggering behavior depending on the previous morpheme,

Table 6.8: San Esteban Atatlahuca (ATA) Mixtec enclitics with their underlying tones and corresponding surface tones when leaning on a non-raising [M.M] word

Trigger/Target Type

Raising 1	Raising 2	Non-triggering	Lowering
/H/ [ró] 2.FAM	/H+L/ [ná] 1EX.FRM	/M/ [ɲā] 3F.FRM	/L/ [tə̀] 3ZO
/H/ [ʒó] 1IN	/H+L/ [ní] 2.FRM	/M/ [ðē] 3M.FRM	/L/ [ʒà] 3DIV
		/M/ [ī] 3.FAM	/L/ [rì] 1.EX.FAM

shown in (6.112).

(6.112) a. The enclitics [ró] 2.FAM and [yó] 1IN, which I analyze as bearing /H/ tone

b. The enclitics [ná] 1EX.FRM and [ní] 2.FRM, which I analyze as bearing /H+L/ tone

Some mechanism is needed to distinguish the phonological behaviors of these two groups of enclitics. For convenience, I hypothesize the same underlying tones as their cognates in San Miguel el Grande Mixtec, but this analysis is not as phonologically motivated as in San Miguel el Grande Mixtec. After lowering morphemes, the clitics in (6.112a) have [L] surface tone and act as lowering triggers, while the enclitics in (6.112b) have [ʌH] surface tone and act as raising triggers. However, both groups of enclitics have [H] surface tone and act as raising triggers after non-triggering morphemes and have [H] surface tone and act as lowering triggers after raising morphemes. The behavior of these enclitics after lowering morphemes is consistent with association of the +L tone or spreading of the L tone onto the enclitic, and the presence or absence of a floating tone sponsored by the enclitic could provide a natural difference in behavior in that context. But then the behavior after raising and non-triggering morphemes must ignore that difference in underlying form to produce the correct raising or lowering behavior of the enclitics as triggers of sandhi. For example, after non-triggering morphemes, the floating +L tone of the enclitics in (6.112b) arbitrarily deletes so that the H tone may spread to produce raising on the following morpheme. Then after raising morphemes, the enclitics in (6.112a) arbitrarily gain a floating +L tone so that it may associate rightward to produce lowering on the following morpheme.

Comparing the tone behavior on enclitics in San Miguel el Grande Mixtec and San

Esteban Atatlahuca Mixtec with the tone behavior of couplets in these varieties, it is clear that couplets and enclitics license different tone processes, part of which is attributable to the bimoraic nature of couplets and monomoraic nature of enclitics. As in Nieves Mixtec, a morpheme may sponsor at most a single floating tone, so that the bimoraic couplets sponsor up to three tones and the monomoraic enclitics sponsor up to two tones. The enclitic sandhi of both of these Western Alta varieties also illustrates how the sandhi processes can largely be explained as phonologically natural consequences of autosegmental L, M, and H tones, with floating +L and +H tones in both varieties. And yet details remain that are not phonologically natural even under a floating tone analysis—like the triggering behavior of [H]-tone enclitics in Atatlahuca Mixtec.

6.4.2 Other Group A systems

The tone systems of other Group A varieties help illustrate the similarity of Group A tone systems, while demonstrating several aspects of Mixtec tone that are less apparent in the descriptions of the tone systems of San Miguel el Grande and San Esteban Atatlahuca. First, the tone sandhi can be either much more extensive or more restricted than found in Nieves Mixtec or Western Alta varieties. Second, alongside partial downstep of /M/ tones that produces [Λ] tones in several varieties, partial downstep of /H/ tones and partial upstep of /M/ tones is also found in some varieties. In addition, varieties that exhibit [Λ] tones, marked /M/ tone and monomoraic contours do not necessarily have larger inventories of tone patterns in couplets. But these differences to do not negate the similarity of Group A tone systems. They are still mostly tripartite tone systems with an easily perturbable M tone and highly active H and L tones.

6.4.2.1 Alcozauca

Xochapa Mixtec (Stark et al. 2003), which is affiliated with Alcozauca (ALC) in the Guerrero dialect group, has comparatively high surface tone density and very limited tone sandhi. There are four levels of surface tone plus monomoraic HL and LH contours. As in Atatlahuca Mixtec, the innovated tone level ([Λ]) can be shown to be derived from

Table 6.9: The bimoraic tone patterns in Xochapa (Alcozauca: ALC). Patterns in parentheses are found only in inflected couplets.

/H.H/	/M.H/	/L.H/
/HL.H	[Λ.H] /LM.H/	/LH.H/
/H.M/	/M.M/	/L.M/
(/HL.M/)	[Λ.Λ] /LM.M/	/LH.M/
/H.L/		/L.L/
(/HL.L/)	/M.HL/	

an underlying monomoraic LM contour. The higher tone density per mora does not lead to a higher inventory of couplet tone patterns, because the monomoraic contours have a limited distribution. The Xochapa dictionary (Stark et al. 2003) has bimoraic words with 16 tone patterns, shown in Table 6.9. However, two of these (with initial HL contour) are found only in inflected couplets, resulting in just 14 tone patterns in uninflected bimoraic stems. Though no sandhi interactions between couplets are reported, some tone sandhi is observed in enclitics, and the activity of floating +H tone characteristic of Group A tone systems is observed in the morphology.

The tonal system of Xochapa has an unusually high surface tone density and a high morphological load of tone, coinciding with a low number of phonological tone processes. High surface tone density and a low number of phonological tone processes are also found in Mixtepec (MIX) varieties (E. V. Pike & Ibach 1978; Paster 2005), while Yoloxochitl (YOL), which is in the same dialect group as Xochapa (Guerrero), has even higher tone density (DiCanio et al. 2012), coinciding with a similarly low number of phonological tone processes and high morphological load of tone (DiCanio and Amith, p.c.).

6.4.2.2 San Juan Colorado

The tone system of San Juan Colorado (COL) Mixtec (Stark & Johnson 1991), closely resembles that of San Miguel el Grande Mixtec, but with more extensive tone sandhi. There are three levels of tone, with no contours on single vowels permitted. All nine possible surface couplets are attested, and the sandhi patterns indicate 13 underlying tone patterns. These underlying tone patterns and their associated surface tones in isolation are shown in Table 6.10

Table 6.10: The underlying tone patterns in San Juan Colorado (Col) Mixtec and their corresponding surface tones in isolation

	Target Type		
Trigger Type	Raised	Non-raised	
Raising	[H.H] /H.H/	[M.H] /M.H/	[L.H] /L.H/
		[M.M] /M.M+H/	[L.M] /L.M+H/
			[L.L] /L.L+H/
Non-triggering	[H.M] /H.M/	[M.M] /M.M/	[L.M] /L.M/
Lowering	[H.L] /H.L/	[M.L] /M.L/	[L.L] /L.L/
	[M.H] /M.H+L/		

Table 6.11: The underlying tone patterns in Santo Domingo Nuxaa (Nux) Mixtec and their corresponding surface tones in isolation

	[M.H] /H/	[M.M] /M+H/	[M.L] /L+H/
[H.M] /HM/		[M.M] /M/	[M.Λ] /LM/
[H.L] /HL/	[M.H] /H+L/	[M.ML] /ML/	[M.L] /L/

The sandhi requires distinguishing subclasses for four of the surface tone classes ([M.H], [M.M], [L.M] and [L.L]). As in the case of Atatlahuca (Ata), the stems can be divided into three triggering categories that correspond with the final tone (or floating tone) of the stem, and target behavior categories which correspond roughly to the initial tone of the stem. In San Juan Colorado, however, these target categories gloss over considerable differences in resulting surface tones, and several tone sandhi processes are fed by other tone processes. A /H/ tone can spread without bound over a sequence of /M/ tones, and /L/ tone can spread into a sequence of /H/ tones. This leads to long reaction chains, such as spreading across several morphemes.

6.4.2.3 Santo Domingo Nuxaa

In Santo Domingo Nuxaá (Nux) Mixtec (McKendry 2013), there are four levels of surface tone, but the additional level [Λ] is easily analyzed as the realization of underlying /LM/ tones on a single mora. There are just six surface tone patterns in isolated bimoraic words, but patterns of tone sandhi indicate a total of 10 underlying tone patterns. These tone patterns are shown in Table 6.11 McKendry (2013) shows that both underlyingly specified M tone and default [M] tone are necessary to account for the tone sandhi.

The tone sandhi of Santo Domingo Nuxaá is quite extensive. The floating tones indicated in Table 6.11 can associate with few restrictions to replace default [M] tones, and in certain conditions, floating tones may delink the tone associated to the second mora of the target. In addition, morphemes without a floating tone may spread their final tone onto the following morpheme.

6.4.3 Systems outside Group A

The tone systems outside Group A—those of Group B and Ayutla—are noteable on the one hand for their commonalities with Group A varieties and on the other hand for their divergences. Like Group A varieties, they exhibit tone changes that can mostly be analyzed via the effects of autosegmental H and L tones, with a default unmarked M tone. And as with Group A varieties, bimoraic morphemes, monomoraic morphemes and tonal morphemes have distinct tone distributions and behaviors. But outside Group A the tone pattern inventory is generally smaller, the upstep and downstep processes are categorically larger, and the distribution of glottalization is more varied.

6.4.3.1 Ayutla de los Libres

The Mixtec of Ayutla has been studied extensively, but it is an outlier both geographically and phonologically. Ayutla retains morpheme-final glottal stops from Proto-Mixtec, which have been converted to tones in most of the other Mixtec languages.

In Ayutla de los Libres (AYU) Mixtec (Pankratz & Pike 1967), there is a three-level tone contrast, with only one underlying tone per mora. Of the nine possible tone sequences in bimoraic stems, only seven are attested, and only five are common: [H.L], [M.L], [L.L], [H.H], and [L.H]. Ayutla Mixtec differs from the varieties from other regions in that some morphemes have a lexically-specified final glottal stop, which surfaces phrase-finally but in other contexts is deleted, conditioning tone changes. As the glottal stop is attested with each of the five common tonal patterns, including the glottal stop in the tonal specification produces an inventory of 12 underlying patterns. The 5 common tonal patterns with and without glottal stop are shown in Table 6.12.

Table 6.12: The underlying tone patterns in Ayutla (AYU) Mixtec

	Target Type		
Trigger Type	Raised	Non-raised	
Checked	/H.Hʔ/		/L.Hʔ/
	/H.Lʔ/	/M.Lʔ/	/L.Lʔ/
Non-checked	/H.H/		/L.H/
	/H.L/	/M.L/	/L.L/

All triggering behavior is based on the basic/underlying forms rather than the trigger's surface tones. After morphemes that have final [Hʔ] in their basic form, a following [L] is changed to [M], while a following [M.L] is changed to [H.HL], with a falling contour on the second vowel. After morphemes that have a final [Lʔ] in their basic form, [M.L] stems show the same change, while [L.H] stems don't change, and [L.L] stems become [M.L] after [H.Lʔ], but [H.L] after [M.Lʔ] or [L.Lʔ]. With morphemes that don't have an underlying final glottal stop, a final [H] lowers a following [H] to [M] but raises a following [M] to [H], while the stem's basic form appears after a final [L]. Among [L]-initial stems, a subset behave as if they have a preceding floating /+H/, which may associate to either the preceding or following vowel, or to both, often creating contour tones.

The final glottals of Ayutla are considered a conservative feature, attributable to Proto-Mixtec (Josserand 1983), and the tonal effects of these glottals correspond to the floating /+H/ tone effects in Western Alta and floating /+L/ tone effects in Eastern Alta. But unlike the sandhi of Western Alta, the raising effect observed in Ayutla is not always raising to [H]. Though there are not very many tone changes to explain, the different treatment of [M.L], [L.L] and [L.H] couplets does not appear to be synchronically phonologically motivated. On the other hand, the small number of changes would make a formal account in terms of autosegmental rules tractable, even if not natural.

6.4.3.2 Santa María Peñoles

In Santa María Peñoles (SMP) (Daly 1977; Daly & Hyman 2007), the surface tone is better characterized as upstep and downstep than a specific number of surface tone levels. In an early description, Daly (1977) identified two tone categories, each of which had a

Table 6.13: The underlying tone patterns in Santa María Peñoles (SMP) Mixtec

Basic	/H.H/	/H.∅/	/∅.H/	/∅.∅/
Initial L	/+L H.H/	/+L H.∅/	/+L ∅.H/	/+L ∅.∅/
Final L	/H.H+L/			/∅.∅+L/

"modified" (lower) and "unmodified" (higher) allotone, but in a later treatment (Daly & Hyman 2007), these are reanalyzed as configurations of /H/, /∅/ (underspecified), and /L/ tones. These are the etymological inverses of the tonemes of Western Alta (/H/ → /L/, /L/ → /H/). The derivation of surface tones from these underlying specifications is quite involved. There are a total of ten attested tonal configurations in bimoraic stems, which are shown in Table 6.13.

In the later analysis, all /L/ tones are underlyingly unassociated, but they are forced by other tones to align with either the right or left edge of their sponsoring morpheme, and they associate to the right if possible. Docked /L/ is only licensed on stressed (root-initial) vowels, and /LH/ contours are permitted but /HL/ contours are not. The derivation of the surface tones includes the following rules:

(6.113) a. A /L/ tone is realized as a low level [L]

b. A sequence of /H/ tones upsteps each time

c. A /∅/ mora between /H/ tones causes downstep, and the first /H/ after a /∅/ mora lowers to [M]

d. A /∅/ mora or sequence of /∅/ morae is realized as [M] before /H/, and as a low fall elsewhere

Several rules are also specified to account for the tone changes. A /L/ tone is deleted when there are two adjacent /L/ tones at a morpheme boundary, when preceded by /H.H/ and followed by /∅.∅/ or a /∅.H/ verb, or when no suitable docking point is available, such as when prepausal. Ordinarily, a /L/ tone associated to a mora that bears an underlying /H/ will produce a rising contour tone, but certain morphemes, including aspect markers and quantifiers, delete this /H/. Other sandhi processes include several non-local changes. Low tone deletion applies to the second of two /L/ tones, ignoring any number of intervening /∅/ vowels. Low tone association also ignores /∅/ clitics. Finally, /H/

Table 6.14: The underlying tone patterns in San Juan Coatzospam (COA) Mixtec

Basic	/H.H/	/H.L/	/L.LH/	/L.L/
Initial Downstep	/!H.H/	/!H.L/	/!HL.H/	
Final Downstep	/H.H!/		/L.H!/	
Dual Downstep	/!H.H!/		/!HL.H!/	

tone spreading (across a morpheme boundary onto a /∅/ vowel) ignores any floating /L/. /H/ tone spreading is restricted to certain phrase types, while the others are general.

6.4.3.3 San Juan Coatzospam

In San Juan Coatzospam (COA) (E. V. Pike & Small 1974), there are only two levels of tone, but in addition, there is lexically-specified downstep, which can be aligned to either the beginning or the end of the morpheme, or moved to the middle of a bimoraic morpheme in certain tonal environments. The downstep only has an effect between /H/ tones, and one or more /L/ tones resets the [H] tone target. In isolation, the [L.L] and [H.H] tone patterns are acoustically indistinguishable (Gerfen & Denisowski 2001), and it is only in context that the level tones are phonetically low or high. The contours [LH] and [HL] are licensed on single morae. In total, there are 11 tone patterns in bimoraic stems, as shown in Table 6.14.

The tone sandhi of Coatzospam is not limited to downstep. There is extensive progressive sandhi, dependent on the basic tones and downstep specification of both the target and trigger, as well as the lexical category of the target. Clitic sandhi is treated separately, and similarly, it depends on the basic tones and downstep specification of both the target and trigger, as well as the lexical category of the trigger. The description of tone sandhi provided by E. V. Pike and Small (1974) is dependent on a large number of specific rules, which do not seem to be generalizable.

6.4.4 Summary

This section summarized the diversity of tone systems of Mixtec varieties, focusing on the formal mechanisms necessary to represent the complexity of underlying and surface tone patterns. Across Mixtec, the inventories of tone patterns are specified as sequences of /L/ and /H/ tones, with unmarked /M/ tone possible in some varieties and marked /M/ necessary in others. Beyond the three underlying tone levels, the surface tones involve some upstep and downstep processes as well as smoothing of monomoraic contours. In regard to the trigger types and target types, though the original descriptive works depend heavily on arbitrary distinctions within the surface tone classes, much of this seeming dependence on phonologically arbitrary classes can actually be accounted for instead with the hypothesized floating tones. Though doing so does not always provide a clear route to predicting the particular sandhi changes, and there may still be some dependence on prosodic domains, the phonological arbitrariness is substantially reduced. Another important distinction is between the tonal phonology of bimoraic couplets and that of monomoraic clitics. As the mora is the tone-bearing unit, the bimoraic couplets have a larger inventory of tone patterns. The monomoraic clitics have a smaller inventory of tone patterns, though their sandhi behavior is harder to explain through autosegmental tone rules.

The tone system described for Nieves Mixtec in §6.2 and §6.3 places Nieves Mixtec squarely within the diversity of Group A tone systems, standing apart from the Group B tone systems and Ayutla Mixtec. The tone phonology of Ayutla Mixtec is dominated by upstep and downstep, while Group B tone phonology is dominated by floating +L tone as in Peñoles Mixtec or downstep as in Coatzospam Mixtec, and Group A tone phonology is characterized by the activity of floating +H tone. Though Group A tone systems differ widely on the number of couplet tone patterns and how extensive the tone sandhi is, the tone systems of other Group A varieties are similar to that of Nieves Mixtec in the centrality of L, M, and H tones and their phonological roles. In all the Group A systems, H tone is most phonologically active while M tone is less so, even in varieties that do have a marked M tone. The tone inventory and tone sandhi of Nieves Mixtec is also of medium complexity relative to the other Group A systems. The couplet tone inventory in Table 6.2 shows 15 patterns. This count is greater than what is found in San Miguel el Grande Mixtec (12) and San Juan Colorado Mixtec (13), which have similarly been analyzed with unspecified M tone. It is also larger than what is found in Santo Domingo Nuxaa Mixtec (10) and Xochapa Mixtec (14), varieties where specified M is required to describe certain monomoraic contours and tonal processes. But the tone pattern count is still smaller than the inventories of Atatláhuca Mixtec (17), where specified M tone is required for monomoraic contours, or Yoloxóchitl Mixtec (more than 20; DiCanio et al. 2014), which has extensive monomoraic contours and four underlying tone levels. In regard to tone sandhi, Xochapa Mixtec (like Yoloxóchitl Mixtec) has much less tone sandhi than observed in Nieves Mixtec, while Santo Domingo Nuxaa Mixtec and San Juan Colorado Mixtec have extensive tone sandhi, well beyond what is observed in Nieves Mixtec.

6.5 Summary

This chapter described the tonal phonology of Nieves Mixtec. I showed that the distribution of tone and the tone processes support an analysis in which morae may bear H, M or L tone, where M tone is underlyingly unspecified, and each morpheme may sponsor a final floating +H or +L floating tone. Bimoraic couplets thus host up to two linked tones and one floating tone, while monomoraic clitics host just one linked tone and one floating tone, and tonal morphemes consist of just one floating tone. The tone processes in couplets are mostly reducible to two processes—floating +H tone replacing M tone, and L tone spreading to displace H tone. But the tones sponsored by proclitics are more dominant: floating +H tone may replace L tone in addition to M tone, and L tone may spread or associate to replace M tone. Among the tones sponsored by enclitics, the H tones and M tones are more susceptible to sandhi effects than the H tones and M tones of couplets, but L tones are less susceptible to sandhi effects than the L tones of couplets. These details show that the analysis of M tone as unspecified, though helpful, is insufficient to capture all the asymmetries among the tones. H tones and L tones have their own propensities to trigger and resist change, and the interactions among the tones are also affected by morphological and/or prosodic domains.

Chapter 7

Acoustics of tone

7.1 Introduction

This chapter presents three acoustic studies of tone patterns in couplets. These studies serve a dual purpose that is typological and dialectological. First, for the sake of expanding our understanding of the phonetic typology of word prosody, as reviewed in §2.3, it is important to document the acoustic realization of the complex tone system in Nieves Mixtec and its interactions with phonation type and prosodic structure. These studies are a first step towards placing the Nieves Mixtec tone system within the cross-linguistic variation. Second, for the sake of comparison with descriptions of other Mixtec tone systems, phonetic descriptions of the inventory of couplet tone patterns are particularly useful. The perceptual systems of both native speakers and linguists are tuned to the phonological contrasts of their own languages, making subphonemic properties difficult to assess within documentation methods that depend on impressionistic transcriptions and metalinguistic awareness of the language's phonological categories. Because of cross-linguistic differences in how pitch, duration, phonation and effort are used linguistically, properties of prosodic and tonal categories can be particularly elusive. For example, languages differ in tonal coarticulation effects—how tones influence the pitch contours of neighboring tones—, and it is often unclear to what extent tone transcriptions reflect coarticulation effects or (conscious or unconscious) efforts to remove coarticulation effects. These acoustic studies thus offer a tone system description that transcends the pitch perception and particular phonological analysis on which the categorization of tone patterns is based, to facilitate dialectological comparison or phonological reanalysis.

Several previous studies have described acoustic properties of other Mixtecan tone systems. These studies have addressed a variety of phenomena, including: how F0 contours depend on tonal context, such as tonal coarticulation and downstep; whether these changes result in contrast neutralization, reduction or maintenance; how couplet duration and contour timing depend on tone pattern; and how phonation type interacts with tone in F0 and spectral tilt. Meacham (1991) presents an analysis of the F0 contours and duration of the eight surface (basic) tone patterns in Chalcatongo Mixtec (CHL). The word list was balanced between CVV and CVCV couplets, with each of five vowel qualities equally represented. The findings included a much shorter duration for H.L couplets and a lower F0 for H tone after L tone. Gerfen and Denisowski (2001) investigated a claim made by E. V. Pike and Small (1974) that H.H and L.L tone patterns in Coatzospan Mixtec (COA) are indistinguishable in isolation. The word list included one CVV word and one CVCV word from each of these tone patterns plus the L.H tone pattern, and the words were recorded in isolation with six native speakers. Confirming the impressionistic description of neutralization, the results showed no difference between the F0 contours of H.H and L.L tone patterns, though each differed from the F0 contours of the L.H tone pattern. As part of a general overview of the phonetics of Ayutla Mixtec (AYU), Herrera Zendejas (2009) provides a brief study of downstep. In the associated phonological description, tones are either H or L, with no M tones. But in tone sequences of alternating H and L tones, the H tones have decreasing F0 values, creating a terracing effect within the intonation phrase. McKendry (2013) shows acoustic evidence of tone neutralization in Santo Domingo Nuxaa Mixtec (NUX), using morphologically complex words in naturalistic sentences. In addition to specified H, M, and L tones, there is a default tone D which has F0 levels indistinguishable from M tone. Moreover, when preceded by H tone and followed by H or M tone, the L tone is raised, so that its F0 level is also indistinguishable from M tone. One reason for distinguishing M tone from D tone is that L tone is not raised if it is followed by a D tone rather than a M tone. DiCanio et al. (2014) compare the alignment of F0 contours in CVV and CVCV couplets in Yoloxochitl Mixtec (YOL). The words included in the study were limited to plain couplets, representing 15 tone patterns that are well-represented in both monosyllabic and disyllabic couplets. The words were recorded in isolation with ten native speakers. The comparisons showed minimal differences in F0 levels and close alignment between F0 targets and morae. Finally, acoustic studies of Mixtec tone have avoided analysis of glottalized couplets and issues associated with the interaction between phonation type and tone, but these questions have been addressed in Itunyoso Triqui (DiCanio 2012a), another Mixtecan language. In Triqui, glottalization may occur either intervocalically or syllable-finally, which contrasts with modal vowels and syllable-final aspiration. DiCanio found that Triqui intervocalic glottalization and coda aspiration strongly affects F0 and spectral tilt, while coda glottalization does not. Coda aspiration also more strongly interacts with higher tones than with lower tones.

The studies described in this chapter discuss similar issues of tonal context dependence, contrast neutralization or maintenance, the duration and timing of couplet tone patterns, and the interaction between tone and phonation. The studies presented here are preceded by the description of the general design and elicitation procedures in §7.2. The first acoustic study in §7.3 describes the tonal coarticulation attested in plain CVCV stems and plain CVV stems, finding that tonal coarticulation is almost exclusively perseverative (carryover), with an asymmetry among the tones which echos the asymmetry in the tonal phonology. The following study in §7.4 compares the timing of CVCV and CVV stems, showing that observed duration differences are better attributed to higher prosody than to constraints of tone realization. The final study in §7.5 examines the interaction between tone and glottalization, showing that more glottalized phonation serves as a secondary cue of a lower tone category and that higher F0 serves as a secondary cue of glottalization.

7.2 General design and elicitation

The target words examined in these studies are chosen to reflect the phonological diversity within each tone pattern, within broad CV template categories. Among consonants, the sampling considers voicing and major (but not minor) place categories, as consonant voicing is known to interact with pitch (as discussed in §2.3), and consonants in the labial and dorsal places could be analyzed without an underlying voicing specification, as the consonant inventory (presented in §3.2.1) has only voiced labials and only voiceless dorsals. Among vowels, the sampling considers vowel quality but not nasality, as vowel quality is known to interact with pitch (as discussed in §2.3), but to the best of my knowledge, there are no reported effects of nasality on pitch.

The distributions of consonant type and vowel quality are not strictly matched across tone patterns, but the sample distribution is sufficiently nearly balanced to allow for statistical control of these effects in the regression analysis. As described in §6.2.2, there are distributional restrictions on tone patterns in particular lexical categories, making it particularly difficult to balance the sample for lexical category. The target words are mostly nouns and adjectives, while some verbs are included for tone patterns where few nouns or adjectives were available, and in a few cases, other lexical categories are included. As much as possible, the word consists of the bare bimoraic stem, but for some less common tone patterns, it was necessary to include a word with an additional prefix.

The target words are elicited both as individual words and as host to an M-tone enclitic, in order to clearly reveal any floating tone. Two M-tone enclitics (intensifier /=va/ and pronominal /=na`/) were used with each target word, except in cases where one or the other enclitic was semantically incompatible with the target word. The intensifier /=va/ is compatible with single adjectives and adverbs, as shown in (7.1).

(7.1)	a.	saa va [sa˧a˧va˧] /saa=va/ fast=INT ‘quite fast’	b.	jíkó va [xi˥ko˥va˧] /xíkó=va/ high=INT ‘very high’

However, verbs and nouns had to be elicited within slightly more complex phrases, as shown in (7.2).

(7.2)	a.	kasí va	b.	iin chéle va
		[ka˧si˥vã˩]		[ĩ˧ĩ˧ tʃe˥le˧va˧]
		/kasí`=va=a$_n$/		/ii$_n$ tʃéle=va/
		IR:eat.sweet=INT=3.N		one rooster=INT
		‘eat it (don’t play with it)’		‘only one rooster’

As in (7.2a), many verbs were produced with an overt argument enclitic, either /=na`/ 3P or /=a$_n$/ 3.N, which follows the intensifier. Nouns were elicited preceded by the numeral /ii$_n$/ ‘one’ as in (7.2b), and the intensifier modifies the quantified noun phrase. The pronoun /na`/ applies to third-person plural referents as well as referents that are cherished or sacred, without regard to number or animacy, such as babies, candles, flowers, and offerings. The polysemy of the pronoun allows considerable semantic flexibility, and the syntax allows the pronoun to be elicited with simple nouns, verbs and adjectives, as shown in (7.3).

(7.3)	a.	chéle na	b.	kasí na	c.	jíkó na
		[tʃe˥le˧nã˧]		[ka˧si˥nã˩]		[xi˥ko˥nã˧]
		/tʃéle=na`/		/kasí`=na`/		/xíkó=na`/
		rooster=3P		IR:eat.sweet=3P		high=3P
		‘their rooster’		‘they will eat (fruit)’		‘they are tall’

However, still some target words are semantically or pragmatically incompatible with the pronominal enclitic, and syntactically the pronominal enclitic cannot immediately follow manner adverbs or demonstratives. As a result, the words in (7.4) could not be elicited with the pronominal enclitic.

(7.4)	a.	nda̲kú	b.	saa	c.	sa̲a̲n
		[^{n}da˩ku˥]		[sa˧a˧]		[sã˨ã˨˩]
		/^{n}dàkú/		/saa/		/sàà$_n$´/
		‘straight (e.g. roads)’		‘fast’		‘here by you’

The semantics of the enclitics are similar for adjectives and verbs, where the pronominal enclitic is the argument of a predicate and the intensifier directly modifies the verb or adjective. This differs from the semantics of the enclitics on nouns, where the pronominal enclitic is the possessor of the noun, and the intensifier modifies the quantified noun phrase. Because the semantics of the adjectives and the verbs are similar, and these differ from the nouns, the targets are elicited in separate blocks, either consisting of nouns only or consisting of adjectives, verbs and adverbs.

The target words or phrases are elicited in quotative carrier sentences in order to better control the effects of utterance-level prosody. A sequence of three carrier sentences was used in order to reduce the repetitiveness of the task while still fulfilling the multiple repetitions of each target phrase that are required for statistical estimation of instance-level variation. The carrier sentences in sequence are shown in (7.5–7.7).

(7.5) kuni jo̠’o __ iin tyá’ndyá
[kũ˧nĩ˧xo̰˩o̰˧ __ ʔĩ˧ĩ˧ tʲa˥ʔⁿdʲa˥]
/kuni-xò^ʔo __ ii_n tʲáʔⁿdʲá/
IR:perceive-ear __ one cut
‘listen to __ one time’

(7.6) kuni jo̠’o __ inga tyá’ndyá
[kũ˧nĩ˧xo̰˩o̰˧ __ ʔi˧ᵑga˧ tʲa˥ʔⁿdʲa˥]
/kuni-xò^ʔo __ iᵑga tʲáʔⁿdʲá/
IR:perceive-ear __ another cut
‘listen to __ another time’

(7.7) ni̠ sini jo̠’o __ u̠ni̠ tyá’ndyá
[nĩ˩sĩ˧nĩ˧xo̰˩o̰˧ __ ʔũ˧nĩ˩ tʲa˩ʔⁿdʲa˧]
nì = sini-xò^ʔo __ ùnì tʲáʔⁿdʲá/
PFV = RE:perceive-ear __ three cut
‘__ was heard three times’

The carrier sentences place the word in post-verbal position, which is the canonical position for the object of command forms (7.5, 7.6) and the canonical position for the subject of declaratives (7.7) (Caponigro et al. 2013). While the phrasal prosody of Nieves Mixtec is not addressed in the present work, the working assumption is that the target position is delimited by prosodic word boundaries, with possible phrase-level boundaries as well, particularly in careful speech. It is also hypothesized that this design might induce effects associated with contrastive focus in the target position, such as perhaps pitch range expansion and segmental lengthening. The first two sentences (7.5, 7.6) are similar because greater disfluency is expected in the initial production, and utterances with disfluency in the target words are removed from the analysis.[1] None of the three carrier sentences

[1]A target word was considered disfluent if there was an audible pause or hesitation within the

induce tone sandhi on the target word, as in all cases the target word is preceded by an M tone vowel, without any floating tone. Similarly, the targets in the first two sentences are followed by words with M.M tone, which is expected to readily absorb any sandhi or coarticulation effects that can cross the word (and perhaps phrase) boundary. In the final sentence, the target is followed by L.L tone, which is expected to be resistant to sandhi and coarticulation effects.

Elicitation depended on visual presentation of written prompts, with some spoken prompts when difficulties arose. The target words were presented within the carrier sentences, on a computer screen with one sentence per slide. The target words were recorded with multiple speakers, but the data presented in this chapter is limited to the recordings with speaker OO. Speakers were asked to pronounce the target words in the three carrier sentences in sequence, as in (7.5–7.7). The sentences were written in the Ve'e Tu'un Savi orthography without tones marked, and the Spanish translation was provided underneath. For speakers who were less comfortable reading the prompt or when the speaker read the prompt as a different word, the investigator would read the Spanish translation, and when necessary, the Mixtec words, with the caveat "suena algo como ..." ("sounds something like ..."). The target words were presented in blocks, such that within each block, the targets were segregated by lexical category as much as possible, and the targets were either all in basic form or all with the same enclitic. The order of presentation of the targets was randomized for each speaker, but consistent across enclitic contexts.

For each utterance, the segment boundaries for the target word were annotated by visual inspection of the spectrogram in Praat (Boersma & Weenink 2013), according to standard practice. The consonant spans were segmented as the period of closure or constriction, plus the VOT in the case of voiceless segments. The voiced portions of the offglides of palatalized coronals and labialized dorsals were segmented as part of the vowel span. This criterion was chosen in order to maximize the consistency of the annotations, under the assumption that the pitch contour of the voiced vocalic portions of the target are sufficient to characterize the realization of tone. In addition, the /ni/ syllable in

target word. Utterances with false starts or pauses between words were not excluded.

the verb of the carrier sentence (/kuni-xòˀo/ ‘listen’ or /sini-xòˀo/ ‘heard’) and the word immediately following the target word (/ii$_{\text{n}}$/ ‘one’, /iᵑga/ ‘another’, or /ùnì/ ‘three’) were also annotated for reference measurements.

F0 measurements were extracted automatically via a version of the ProsodyPro script (Xu 2013). The script was modified to use Praat’s autocorrelation algorithm for F0 estimation rather than the default pulse-counting algorithm of ProsodyPro. F0 was measured at five points within the vocalic segment associated with each mora, where short vowels are assumed to correspond to one mora, and long vowels are assumed to correspond to two morae, with the boundary between the morae at the mid-point of the vowel span. The F0 scale is expressed in semitones (ST), centered on the mean F0 of all the tokens in the three studies. Measurements of other spectral properties were obtained via a modified version of the Praat script of Remijsen (2004). Spectral properties were sampled at two points per mora. For each kind of effect, the analysis begins with evaluation of the statistical significance of the relevant factor by likelihood ratio (X^2) tests comparing the full regression model with a model that leaves out that factor. The number of degrees of freedom for the likelihood ratio tests equals the number of parameters left out of the reduced model. Where this initial test suggests a reliable effect, we consider the parameter-wise t-tests and naive confidence intervals, which are based on the parameter standard errors and assumed normality. The full regression models with parameter t-tests and confidence intervals are presented in tabular format in Appendix D. The reported t-test significance judgements are not corrected for multiple comparisons, but the p-values are otherwise conservative (Hox 2002) as they are calculated using the minimum degrees of freedom $J - p - 1$ (Bryk & Raudenbush 1992), where J is the number of random effects groups in the term with the fewest groups (the number of target words here), and p is the number of fixed-effect parameters.

7.3 Tonal coarticulation in plain stems

The primary purpose of this initial study is to investigate tonal coarticulation and contrast maintenance. Because the variable realization of glottalization can make F0 measurements less reliable in glottalized stems, this study is limited to plain stems, with the tone contours of CVCV stems described first in §7.3.1, and then §7.3.2 compares the tone contours of CVV stems with those of CVCV stems.

Tonal coarticulation includes two distinct kinds of effects: anticipatory coarticulation, where the pitch realized on one mora is influenced by the tone specification of the following mora, and perseverative (or carryover) coarticulation, where the pitch realized on one mora is influenced by the tone specification of the preceding mora. The results of this study show large effects of perseverative coarticulation, as the F0 contour is strongly pulled toward the pitch target associated with the tone of the previous mora. In contrast, anticipatory coarticulation effects are negligible. In addition, an asymmetry is observed among the tones, in that M tone is the most susceptible to coarticulation effects and the weakest trigger of coarticulation.

7.3.1 CVCV stems

The target stems examined in this analysis are 63 CVCV stems, chosen to have at least 3 stems representing each of the 15 attested couplet tone patterns. The full list of CVCV stems included in this study is provided in Appendix D Table D.1. In order to control for interactions between consonant voicing and pitch, about half the words have a voiced initial consonant and about half the words have a voiced medial consonant. The distribution of consonant types for the initial and medial consonants is shown in Table 7.1. Similarly, the numbers of front ([i], [e]), back ([u], [o]) and low ([a]) vowels in each vowel position across the set of targets are comparable. The distribution of vowels for the first and second vowel positions in the targets is shown in Table 7.2.

Table 7.1: Distribution of consonant types in the CVCV targets

	COR–VC	COR + VC	DOR–VC	LAB + VC
C_1	16	27	18	2
C_2	19	17	15	12

Table 7.2: Distribution of vowels in the CVCV targets

	I	E	A	O	U
V_1	27	2	20	6	8
V_2	27	1	17	10	8

7.3.1.1 Analysis procedure

This analysis examines tonal coarticulation within the CVCV stem using mixed effects regression analyses to test whether the F0 realized on one vowel is influenced by the tonal specification of the other vowel. The analysis uses separate models for each mora, rather than depending on a single model that predicts the F0 values of all morae. This approach keeps the model parameters more interpretable, at the expense of somewhat lower statistical power.

The dependent variable in these models is the F0 value in semitones (ST), as measured at five points within the vocalic segment associated with the specified mora. It is assumed here that each short vowel represents one mora, and that the pitch contour of the vocalic portions of the target are sufficient to characterize the realization of tone. The independent variables included in the full models are shown in Appendix D Tables D.2–D.5. All factors are treatment coded, except for TIME, which is a centered numeric predictor.

The random effects in the regression models for the first mora (Table D.2) and second mora (Table D.3) include random effects for TARGET (stem) and INSTANCE (utterance event). Each TARGET group includes intercepts and slopes for the within-TARGET factors, and each INSTANCE group includes intercepts and slopes for the within-INSTANCE factors. TIME encodes the position within the five sampling points of each mora, and it is centered on the mid-point of the five sampling points. REP encodes the repetition order. The base level is the second carrier sentence (7.6), in which the target word was followed by /i^{ŋ}ga/ ‘another’. The other two levels are the first carrier sentence (7.5), in which the target was followed by /ii$_n$/ ‘one’, and the third carrier sentence (7.7), in which the target word was followed by /ùnì/ 'three'. CL encodes the clitic condition. The base level is the word's base form with no clitic, and the other conditions are with the pronominal clitic / = na`/ and intensifier clitic / = va/.

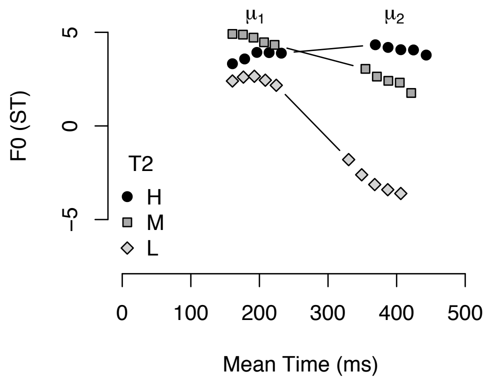
The fixed effects in the regression model for the first mora (Table D.4) and second mora (Table D.5) include the within-TARGET factors just described, as well as between-TARGET factors encoding the tone pattern and the segment categories. T_1, T_2 and T_3 encode the tone specification of the first mora, the second mora, and the floating tone position, respectively. The base level is M tone, so that the tone parameters encode differences between M tone and H tone and between M tone and L tone. VT encodes the vowel type, where the level A includes the low vowels ([a], [ã]), level I includes all front vowels ([i], [ĩ], [e], [ẽ]), and the level U includes all back vowels ([u], [ũ], [o], [õ]). A is chosen as the base level, because we expect differences from the low vowels to the high vowels but not differences between the high vowels. CT encodes the consonant type. Voiced coronal (COR + VC) was chosen as the base level because voiced coronals are best represented in the data, constituting almost 40% of consonants in the sample, whereas the other categories (LAB + VC: voiced labial; COR–VC: voiceless coronal; DOR–VC: voiceless dorsal) represent about 20% each. The interaction terms include interactions of TIME with each of the between-TARGET factors, as well as interactions between T_1 and T_2, between T_3 and CL, and the three-way interaction between TIME, T_3 and CL. Interactions between T_3 (floating tone) and basic stem tone (T_1, T_2) are not included because of the systematic gaps in floating tone distribution discussed in §6.2—floating +H does not follow H or M tone, and floating +L does not follow L tone.

7.3.1.2 Results

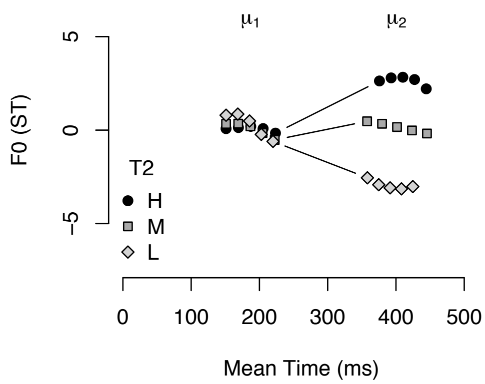
First I test for anticipatory tonal coarticulation—whether the pitch of the first mora of the couplet is affected by the tone specification of the second mora. In the regression model for the first mora (Table D.4), terms that include T_2 reflect anticipatory coarticulation effects. Results indicate that the anticipatory coarticulation effects are not statistically significant ($X^2 = 8.24$; df = 8; p = 0.41), according to model comparison between the full model and a model that leaves out these terms. Figure 7.1 shows mean pitch contours over the two morae of the couplets, arranged to highlight the stability of the pitch on the initial mora. In Figure 7.1a, the mean pitch contours of the tone patterns with initial H tone (H.H, H.M and H.L) are compared, collapsing across tone patterns that do or do not have a floating tone. As shown, the pitch on the first mora is only slightly different for these tone patterns. Similarly, the mean F0 contours on initial M tone (Figure 7.1b) and initial L tone (Figure 7.1c) are scarcely influenced by the following tone.

Next I test for perseverative tonal coarticulation effects—whether the pitch of the second mora of the couplet is affected by the tone specification of the first mora. In the regression model for the second mora (Table D.5), terms that include T_1 reflect perseverative coarticulation effects. As shown by model comparison between the full model and a model that leaves out these terms, the perseverative coarticulation effects are highly statistically significant ($X^2 = 69$; df = 8; p = 0.000). The results indicate that it is primarily initial H tone which is responsible for the perseverative coarticulation effects. An initial H tone both raises the pitch and changes the slope of the following pitch contour. Focusing on the overall pitch, after a H tone the mean F0 is higher than the mean F0 after a M tone or L tone. When T_1 is a H tone, the expected F0 value of a M tone second mora is raised by 2.4 ST (CI = [1.6, 3.2], t = 6.1, df = 20, p = 0.000), which is 1.2 ST more than a H tone second mora is raised (CI = [-2.2, -0.2], t = -2.4, df = 20, p = 0.000) and 1.3 ST more than a L tone second mora is raised (CI = [-2.5, -0.1], t = -2.2, df = 20, p = 0.000). In addition, focusing on the pitch change, the slope of the F0 contour after a H tone descends 0.15 ST per sampling point more than the slope after a M tone (CI = [-0.26, -0.03], t = -2.5, df = 20, p = 0.010). In other words, a H tone not only raises the overall F0 of the following mora but also raises the onset F0 value relative to the offset F0 value. Finally, the one statistically significant parameter associated with initial L tone is the lowering effect on H tone T_2—1.1 ST more than M tone is lowered (CI = [-2.1, 0.0], t = -2.0, df = 20, p = 0.029), a total of 1.7 ST lower.

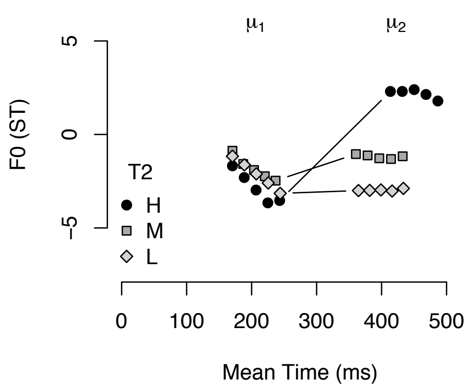
These effects are clearly visible in Figure 7.2, where the mean F0 contours over the two morae of the couplets are arranged to highlight the perseverative coarticulation



a.

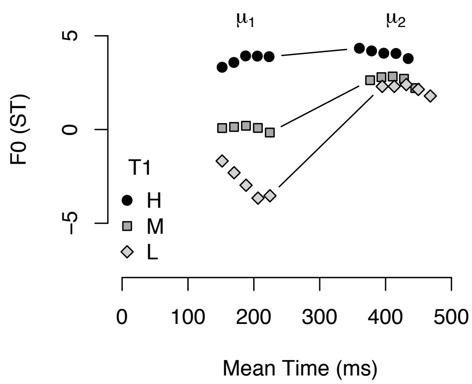


b.

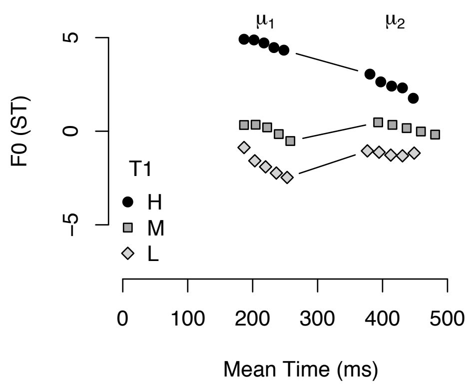


c.

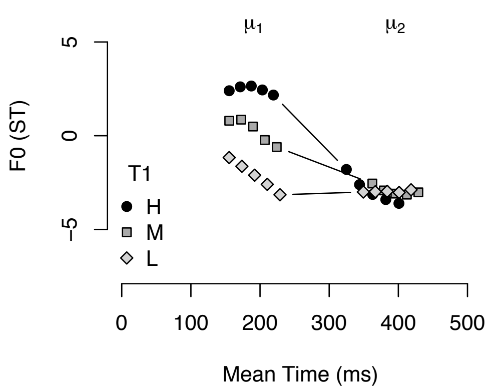
Figure 7.1: Anticipatory coarticulation effects of second syllable tone on F0 of first syllable, for (a) H tone first syllable, (b) M tone first syllable, and (c) L tone first syllable



a.



b.



c.

Figure 7.2: Perseverative coarticulation effects of first syllable tone on F0 of second syllable, for (a) H tone second syllable, (b) M tone second syllable, and (c) L tone second syllable

Table 7.3: Distribution of vowels and consonant types in CVV targets

	A	E	I	O	U
COR–VC	3	0	7	0	2
COR + VC	6	1	7	2	2
DOR–VC	6	1	2	3	0
LAB + VC	3	1	1	0	0

effects. Figure 7.2a compares the mean pitch contours of the tone patterns with H tone on the second mora (H.H, M.H, L.H), collapsing across the patterns that do or do not have a floating tone. Similarly, Figure 7.2b compares the mean pitch contours of the tone matterns with M tone on the second mora (H.M, M.M, L.M), disregarding differences in floating tones. The mean F0 after a H tone is considerably higher than the mean F0 after a M tone, and the mean F0 after a L tone is lower. In contrast, the mean F0 when the second mora bears a L tone (Figure 7.2c) is scarcely influenced by the preceding tone.

7.3.2 CVV stems

This analysis examines tone coarticulation in CVV stems. These are contrasted with the CVCV stems, where the morae are phonetically distinguished as discrete vowels, and thus alignment of tonal contours or tonal targets within the vowel is phonologically and phonetically anchored. In contrast, the morae in CVV stems are adjacent and have a single vowel quality, and so more coarticulation might be expected. The results of this study do show more coarticulation in CVV stems than in CVCV stems, but they nevertheless indicate that the pitch targets of the CVV couplets are generally comparable to the pitch targets of the CVCV couplets.

The target words in this study are 39 CVV words, chosen to have 3 words representing each of the 13 tone patterns attested in CVV stems. The full list of CVV stems included in the study is provided in Appendix D Table D.6. In order to control for interactions between segment type and pitch, one in three words has a voiced onset, and the words have approximately equal numbers of high and low vowels. The distribution of segment types is shown in Table 7.3.

7.3.2.1 Analysis Procedure

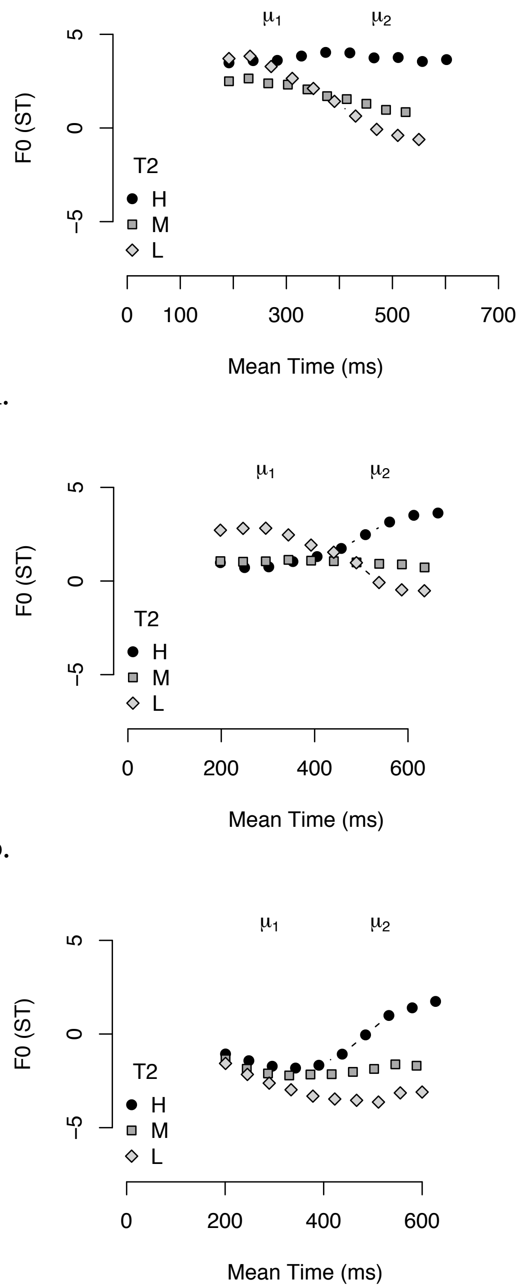
The analysis compares the F0 contours in CVV couplets to that of CVCV couplets within mixed effects regression models. As in §7.3.1, the coarticulation effects are tested with separate regression models for anticipatory coarticulation in the first mora and perseverative coarticulation in the second mora. For the sake of comparison, it is assumed that the vocalic span of the CVV couplets is equally divided between the first and second morae.

The factors included in the full regression models are shown in Tables D.7–D.10. The random effects in the model of the first mora, shown in Table D.7, and in the model of the second mora, shown in Table D.8, have the same design as the F0 coarticulation models for CVCV couplets, presented in the previous subsection (§7.3.1). However, the fixed effects in the models differ from the coarticulation models presented in §7.3.1. Both of the models in this study leave out the vowel type factor and consonant type is reduced to a binary distinction between voiced (+VC) and voiceless (–VC) consonants, with voiced as the base level. Couplet type is represented in the model by medial consonant type (C_2T), where no consonant (NO) represents the CVV couplets. Interactions between medial consonant type and tone as well as between medial consonant type and sampling point (TIME) are also added. Interactions between clitic and tone are not included in the model of the first mora, while interactions between clitic and floating tone (T_3) are included in the model of the second mora, because they are important for the second mora F0 contour.

7.3.2.2 Results

First I test for anticipatory tonal coarticulation—whether the pitch of the first mora of the couplet in affected by the tone specification of the second mora. In the regression model for the first mora (Table D.9), terms that include T_2 reflect anticipatory coarticulation effects, and the interaction term $C_2\text{T} \times T_2$ reflects differences in coarticulation effects associated with medial consonant (i.e. couplet) type. According to model comparison between the full model and the model that leaves out medial consonant type, the combined effects of medial consonant type are statistically significant ($X^2 = 57$; df = 12; p = 0.000). However, the results indicate that the statistically significant differences are primarily due to consonant-tone interactions rather than tonal coarticulation. The largest effect associated with medial consonant type is on the F0 slope. F0 on the vowel before a voiceless consonant descends 0.24 ST per sampling point more than on the vowel before a voiced consonant (CI = [-0.32, -0.16], t = -5.8, df = 75, p = 0.000). In addition, initial H tones in CVV couplets have an expected F0 that is 1.5 ST lower than an initial H tone in CVCV couplets (CI = [-2.7, -0.4], t = -2.6, df = 75, p = 0.006). The lack of anticipatory coarticulation effects in CVV couplets is shown in Figure 7.3, where the F0 contours are arranged to highlight the limited effects of T_2 on the F0 of the first half of the vowel.

Next I test for perseverative coarticulation—whether the pitch of the second mora is affected by the tone specification of the first mora. In the regression model for the second mora (Table D.10), terms that include T_1 reflect perseverative coarticulation effects, and the interaction term $C_2T \times T_1$ reflects differences in coarticulation effects associated with medial consonant (i.e. couplet) type. According to model comparison between the full model and the model that leaves out medial consonant type, the combined effects of medial consonant type are statistically significant ($X^2 = 57$, df = 12, p = 0.000), and results indicate that both consonant-tone interaction and tonal coarticulation are responsible. As in the regression analysis of the first mora, the F0 contour descends more (0.16 ST per sampling point) after voiceless consonants than after voiced consonants (CI = [-0.27, -0.05], t = -2.8, df = 69, p = 0.003), and in addition, the F0 contour ascends more (0.13 ST per sampling point) in the second half of CVV couplets than after voiced consonants in CVCV couplets (CI = [0.02, 0.23], t = 2.4, df = 69, p = 0.009). The tonal coarticulation aspect is that initial L tone in CVV couplets causes the F0 in the second half of the vowel to be 1.8 ST lower than otherwise expected (CI = [-2.94, -0.66], t = -3.1, df = 69, p = 0.001), and final L tone in CVV couplets is not as low as in CVCV couplets, that is, 1.7 ST higher than otherwise expected (CI = [0.62, 2.79], t = 3.1, df = 69, p = 0.001). So L tone causes more coarticulation in CVV couplets than in CVCV couplets and is more susceptible to coarticulation in CVV couplets than in CVCV couplets. These perseverative coarticulation



a.

b.

c.

Figure 7.3: Anticipatory coarticulation effects of second mora tone on F0 of first mora of CVV targets, for (a) H tone first mora, (b) M tone first mora, and (c) L tone first mora

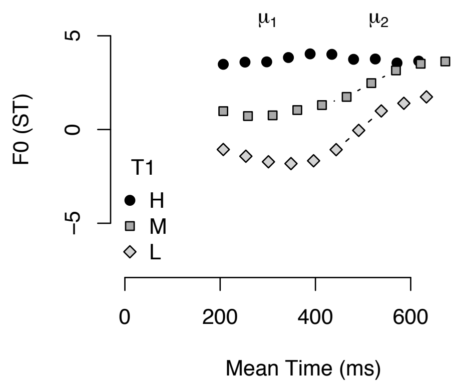
effects in CVV couplets are shown in Figure 7.4, where the F0 contours are arranged to highlight the effects of T_1 on the F0 of the second half of the vowel.

7.3.3 Discussion

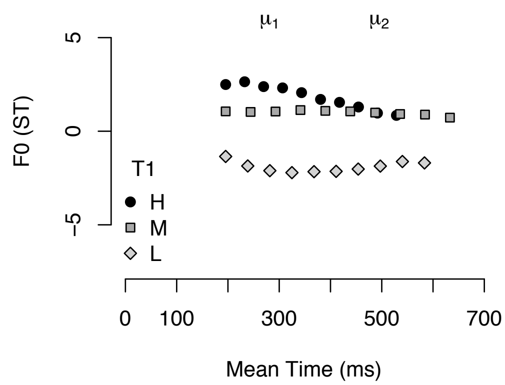
The results of this study indicate that there are large perseverative coarticulation effects within the couplet but negligible anticipatory coarticulation effects. Within the perseverative coarticulation effects, the largest effect is the raising effect on the F0 of a M tone second mora by a H tone first mora. A H tone first mora also raises the onset F0 on the following mora (of any tone), and an L tone first mora lowers the F0 of a H tone second mora. Furthermore, the tone contours in CVV stems closely resemble the tone contours in CVCV stems, with the exception that L tone in CVV stems causes a bit more lowering and is a bit more susceptible to raising than it is in CVCV stems.

The larger coarticulation effects in CVV stems is expected, as the F0 sample points for the first and second morae are adjacent. In CVCV stems, the medial consonant provides a clear boundary between the tone domains and allows the vocal folds more time to more closely approach the following pitch target. But in CVV stems, there is no such boundary and no such hiatus between tone domains. Considering this difference, we might actually expect more differences between CVV and CVCV stems in tonal coarticulation. However, the design of this study may have been insufficiently controlled to identify these differences.

The observed coarticulation effects show a number of parallels with the tone sandhi phenomena observed in Mixtec and in other languages. First of all, the large perseverative coarticulation effects and the negligible anticipatory coarticulation effects parallel the rightward bias in Mixtec tone sandhi, discussed in §6.4. In Mixtec tone sandhi processes, the triggering morpheme precedes the target morpheme, and in the same way within the couplets here, the coarticulation effects are caused by the tone of the initial mora and realized on the vowel of the final mora. A rightward trend is also found in surveys of tone spreading in Asian tone systems (J. Zhang 2007) and African tone systems (Hyman 2007). Second, the phonological asymmetry in the tone system is echoed



a.



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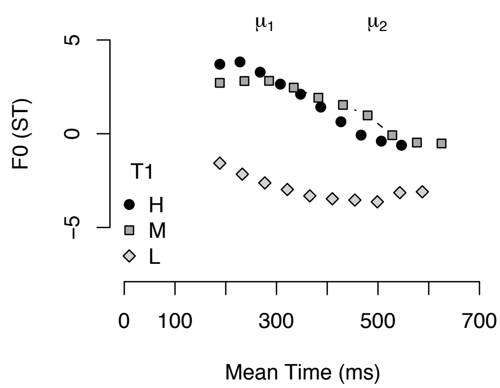

c.

Figure 7.4: Perseverative coarticulation effects of first mora tone on F0 of second mora of CVV targets, for (a) H tone second mora, (b) M tone second mora, and (c) L tone second mora

in the phonetic effects. In the each of Mixtec tone systems discussed in §6.4, M tone is the least marked tone, and the least marked tone in three-tone systems is typically the M tone (Pulleyblank 1986:124). Just as morae with underlying M (∅) tone are the most susceptible to tone changes in the morphology and lexical phonology of Nieves Mixtec, morae with default [M] tone show the largest coarticulation effects in this study. Just as H tone is the most active phonological trigger and the most common morphological tone, the largest coarticulation effects are caused by [H] tone.

One weakness of this study is that the initial mora of all the target stems is in the stressed syllable, so it is also possible that the directional asymmetry is an effect of stress rather than a general directionality in tonal coarticulation. As mentioned in §2.3, stressed syllables in Thai (Potisuk et al. 1996) and Mandarin (Kochanski et al. 2003) are less susceptible to tonal coarticulation than unstressed or less stressed syllables. Disentangling the effects of directionality and stress will require further studies examining coarticulation at morpheme boundaries.

7.4 The timing of tone contours

This study examines the duration of tone contours, comparing plain CVV and CVCV stems. The two couplet types carry the same bimoraic phonological weight, but in the CVCV couplets, the morae are in separate syllables, with an intervening consonant, whereas in CVV couplets, the morae are adjacent, associated to a single long vowel. The F0 contour which cues the tone categories is not realized in voiceless consonants, it is perturbed in neighboring vowels, and weakly realized in voiced consonants. These perception factors would tend to set a minimum total vowel duration to cue the tone contrasts. On the other hand, for tone patterns that require a change in F0, the minimum duration of both CVCV and CVV couplets would be limited by the time to articulate the F0 change from the beginning of the first vowel to the end of the couplet. These factors suggest the two hypotheses in (7.8).

(7.8) Hypotheses:

a. Vocalic equivalence: The duration of the long vowel in CVV couplets is comparable to the summed durations of the short vowels in CVCV couplets.

b. Couplet equivalence: The duration of the long vowel in CVV couplets is comparable to the summed durations of the medial consonant and the short vowels in CVCV couplets.

This study uses the same set of 63 CVCV couplets and 39 CVV couplets as in the previous study. The results indicate that the durations of the CVV couplets are generally comparable to the durations of the CVCV couplets, favoring the couplet equivalence hypothesis. However, couplets with an enclitic attached are much shorter, and syllable structure interacts with this shortening effect.

7.4.1 Analysis procedure

The analysis of duration compares the timing of CVCV couplets and CVV couplets. The hypotheses in (7.8) are investigated via two regression models. In the vocalic duration model, based on (7.8a), the dependent variable is the total duration of the vocalic spans associated with the two morae of the target couplets—two vocalic spans in the case of CVCV targets, and one vocalic span in the case of CVV targets. In the couplet duration model, based on (7.8b), the dependent variable is the same vocalic duration in the case of CVV targets, but in the case of CVCV targets, the duration of the medial consonant is also included. The duration of the initial consonant of the couplet is not included. The durations are represented in units of log_{10}(ms), as Shapiro normality tests of the model residuals confirmed that the residuals were more nearly normal in logarithmic time than in linear time. The duration models have the same random effects structure, shown in Tables D.11–D.12. The random effects include within-TARGET intercepts and slopes for the within-TARGET factors, CL (clitic) and REP (repetition).

The fixed effects in the model of vocalic duration are shown in Table D.13, and they are all treatment coded. Couplet type is represented in the model by medial consonant type (C_2T), where the base level represents CVCV couplets with voiced medial consonants (+VC), and the other levels represent CVCV couplets with voiceless medial consonants (–VC) and CVV couplets (NO). Other factors include the tone specification (T_1, T_2, T_3) and the within-TARGET control factors (CL, REP). In addition, interaction terms are included between the base tones ($T_1 \times T_2$) and between the floating tone and the clitic ($T_3 \times$ CL), as well as interaction terms between medial consonant type (C_2T) and each of the tone factors and the clitic. No three-way interactions were included in the model.

The fixed effects in the model of couplet duration are shown in Table D.14, and they are all treatment coded. The couplet equivalence hypothesis in (7.8) is crucially based on the intuition that rising and falling F0 contours may require longer time to articulate than level F0 contours do. Because of this, the three-way interaction between couplet type and base tones is essential. The design matrix for this interaction has a gap, as there are no L.H(+L) couplets with a voiced medial consonant included in the targets. So in this regression model, stem type (S) is reduced to a binary contrast between CVCV and CVV couplets, with CVCV as the base level. Besides this change in the stem type factor and the addition of the three-way interaction ($S \times T_1 \times T_2$), the fixed effects terms are the same as in the vocalic duration model.

7.4.2 Results

The summed durations are shown in Figure 7.5. The durations of the vocalic portions of the couplets are shown in Figure 7.5a, and the durations of the medial consonants plus the vocalic portions of the couplets are shown in Figure 7.5b.

First I test the validity of the vocalic equivalence hypothesis. Results disconfirm the vocalic equivalence hypothesis, as the vocalic duration of CVV couplets is considerably longer than the vocalic duration of CVCV couplets. Model comparison between the full model and a reduced model that leaves out the medial consonant (C_2T) terms finds that vocalic duration differences due to couplet type are highly statistically significant ($X^2 = 203$, df = 18, p = 0.000). The duration differences are primarily limited to simple effects of couplet type and the interaction between couplet type and clitic. The expected

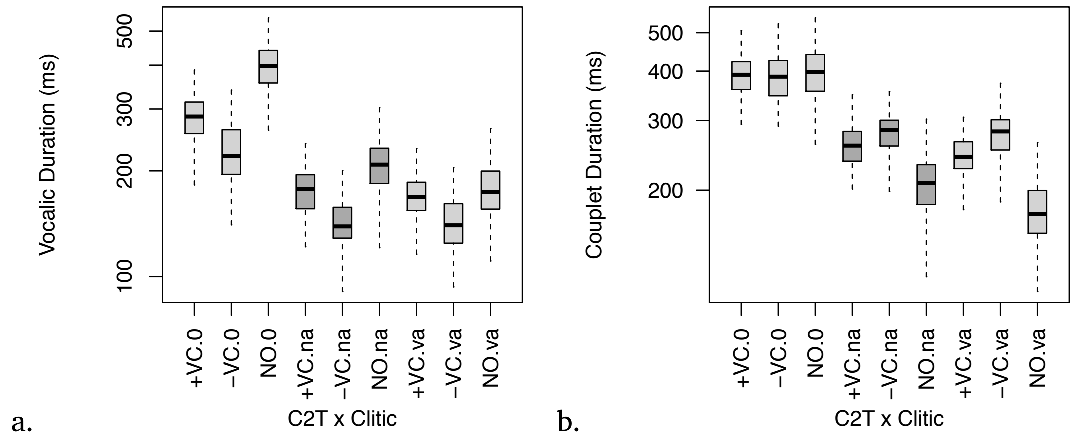

Figure 7.5: Durations of couplets with (+VC or –VC) or without (NO) medial consonants (a) counting only the vocalic portions or (b) counting the vocalic portions plus the medial consonant.

vocalic duration of CVCV couplets with a voiceless medial consonant is 88% ($10^{-0.056}$) as long as CVCV couplets with a voiced medial consonant (CI = [-0.104, -0.008], t = -2.3, df = 72, p = 0.012), and the expected vocalic duration of CVV couplets is 149% ($10^{0.173}$) as long as CVCV couplets with a voiced medial consonant (CI = [0.130, 0.215], t = 8.0, df = 72, p = 0.000). The clitics considerably shorten the expected vocalic duration across the board. Compared to the base form with no clitic, the expected vocalic duration of CVCV couplets with the pronominal clitic /=na`/ is 61% ($10^{-0.214}$) of the vocalic duration in the base form (CI = [-0.243, -0.185], t = -15, df = 72, p = 0.000). Similarly, the expected vocalic duration of CVCV couplets with the intensifier clitic /=va/ is 58% ($10^{-0.237}$) of the vocalic duration in the base form (CI = [-0.266, -0.208], t = -16, df = 72, p = 0.000). The interaction between clitic and couplet type produces an additional shortening effect in CVV couplets. CVV couplets with the pronominal clitic /=na`/ have an expected duration that is 15% shorter ($10^{-0.068} = 85\%$) beyond the simple effect of the pronominal clitic (CI = [-0.100, -0.037], t = -4.2, df = 72, p = 0.000), that is, 52% of the vocalic duration of CVV couplets in base form. CVV couplets with the intensifier clitic /=va/ have an expected duration that is 24% shorter ($10^{-0.117} = 76\%$) beyond the simple effect of the intensifier clitic (CI = [-0.149, -0.084], t = -7.0, df = 72, p = 0.000), or 44% of the vocalic duration of CVV couplets in base form. There is no statistically significant interaction found between couplet type and base tone, but there is a statistically significant interaction between couplet type and floating tone. CVCV couplets with a voiceless medial consonant and a +H floating tone have an expected vocalic duration that is 83% ($10^{-0.083}$) as long as otherwise predicted (CI = [-0.152, -0.014], t = -2.3, df = 72, p = 0.010).

Next I test the validity of the couplet equivalence hypothesis. Results indicate that the couplet durations are comparable when there is no enclitic attached, but when there is an enclitic, CVV couplets shorten more than CVCV couplets do. Model comparison between the full model and the reduced model that excludes S terms finds that there are statistically significant differences associated with couplet type ($X^2 = 147$, df = 13, p = 0.000), and the statistically significant effects are primarily limited to the interaction between couplet type and clitic. Couplet type has negligible effect when there is no clitic, but as in the vocalic duration model, couplet type interacts with clitic condition. The main effect of the clitics considerably shortens the duration, producing expected durations with the pronominal clitic /=na`/ that are 68% ($10^{-0.166}$) of base form durations (CI = [-0.185, -0.147], t = -17, df = 77, p = 0.000) and expected durations with the intensifier clitic /=va/ that are 66% ($10^{-0.182}$) of base form durations (CI = [-0.203, -0.162], t = -17, df = 77, p = 0.000). With CVV couplets, the clitics produce even shorter durations, 23% shorter ($10^{-0.116} = 77\%$) in the case of the pronominal clitic (CI = [-0.140, -0.093], t = -9.8, df = 77, p = 0.000)—that is, 52% of the duration of CVV couplets in base form—and 33% shorter ($10^{-0.171} = 67\%$) in the case of the intensifier clitic (CI = [-0.196, -0.146], t = -13, df = 77, p = 0.000)—44% of the duration of CVV couplets in base form.

The couplet equivalence hypothesis is further problematized by the lack of tone dependence. Neither T_1 nor T_2 are found to be statistically significant predictors of duration. Model comparison between the full model and the reduced model that excludes T_1 finds that duration differences associated with T_1 are only marginally statistically significant ($X^2 = 20$, df = 12, p = 0.070). Model comparison for the reduced model that excludes T_2 finds that duration differences associated with T_2 are not statistically significant ($X^2 = 14$, df = 12, p = 0.272).

7.4.3 Discussion

The results of this study indicate that the durations of disyllabic CVCV couplets and monosyllabic CVV couplets are comparable when they do not host a clitic, but the durations are not comparable more generally. When they do host clitics, the CVCV and CVV couplet types differ in duration, and the differences are structured in a way that suggests the differences are not due to tonal coarticulation constraints. The interactions between tone and couplet type are generally negligible.

A large difference between couplet types was found in the total vocalic duration (Table D.13), but the main effect of couplet type was not statistically significant in the couplet duration model (Table D.14), indicating that the duration of the long vowel in CVV couplets is comparable to the combined duration of the short vowels plus the medial consonant in CVCV couplets. The remaining duration differences between the couplet types are dominated by the clitic interaction effects, not the tone interaction effects. In the F0 model of the first mora (Table D.9), just one of the eight parameters in the tone/couplet interaction terms is found to be statistically significant. In the F0 model of the second mora (Table D.10), just two of the eight parameters in the tone/couplet interaction terms are found to be statistically significant.

The large effects of the clitic on the durations of both CVCV and CVV couplets suggests that the duration differences may be due to segmental lengthening at the word boundary or perhaps a phrase boundary. In base form, the couplet ends at the edge of a prosodic word, which might also coincide with the edge of a prosodic phrase. But in the forms with clitics, the couplet is non-final, with the clitic at the edge of the prosodic word. It may be that the clitic absorbs the domain final lengthening, leading to a 'reduction' in vowel duration in the couplet.

7.5 The interaction of tone and glottalization

This study considers the interaction between tone categories and phonation types. How does glottalization influence the realization of tone, and how does tone category

Table 7.4: Distribution of tone patterns in stems included in phonation analyses

	Tones		
Type	H.H	M.M	L.L
CVV	6	5	9
CVˀV	8	4	8

influence the realization of glottalization? Diachronically in Mixtec languages, glottalization is known to influence the distribution of tone patterns (Hollenbach 2003), and it is thought to be the tonogenetic source of H tone (Dürr 1987). Given the historical association between glottalization and tone, as well as the cross-linguistic association between tone and phonation discussed in §2.3, we may expect important subphonemic differences in the language today. The results of this study indicate an association between glottalization and higher F0 and an association between L tone and lower periodicity.

The acoustic correlates of glottalization and tone are investigated here by comparison of monosyllabic glottalized stems (CVˀV) with monosyllabic plain stems (CVV), all having level base tone patterns (H.H, M.M or L.L, ignoring floating tones). The target words in this study include 20 glottalized CVˀV stems, chosen from the three level tone patterns, and 20 plain CVV stems from the previous study, with the same tone pattern categories. The distribution of base tone in these stems is shown in Table 7.4. As previously, the 20 glottalized stems have a balance of voiced and voiceless consonants and of high and low vowels.

7.5.1 Discriminant Analysis

Considering that the realizations of both glottalization and tone are multidimensional, we first identify which of the acoustic properties under consideration are most important to each distinction. This is done via discriminant analysis, where each of the acoustic properties are z-score normalized and these properties are projected onto a single dimension that best separates the stem categories. The acoustic properties were sampled at four points within the vowel, but in these analyses, the acoustic properties are averaged across the vowel.

Table 7.5: Standardized discriminant coefficients (DC), structure coefficients (SC) and statistical significance (p) in the discriminant analysis of (a) glottalization and (b) tone (first discriminant only)

a. Glottalization

	DC	SC	t	p
F0	1.036	0.422	4.371	0.000
CPP	-0.877	-0.830	-13.973	0.000
HNR	-0.628	-0.706	-9.347	0.000
H1–H2	-0.341	-0.273	-2.659	0.005
H1–A2	0.033	-0.455	-4.799	0.000
Int	-0.113	-0.383	-3.891	0.000

b. Tone

	DC_1	SC_1	t	p
F0	1.694	0.915	21.217	0.000
CPP	0.496	0.401	4.106	0.000
HNR	0.005	0.443	4.636	0.000
H1–H2	0.255	0.650	8.018	0.000
H1–A2	0.139	0.245	2.369	0.010
Int	0.231	0.313	3.092	0.001

The results of the discriminant analyses are shown in Table 7.5. The standardized discriminant coefficients indicate the unique contribution of the acoustic measures to the discriminant dimension, while the structure coefficients indicate the simple correlations between the acoustic measures and the discriminant. Positive coefficients indicate that higher values of the acoustic measures are associated with glottalization or higher tone, while negative coefficients indicate that lower values of the acoustic measures are associated with these categories. The statistical significance values shown are based on the structure coefficients as Pearson's correlations, assuming the degrees of freedom are determined by the number of stems in the analysis.

The results indicate that the glottalization categories are distinguished by a combination of factors, but especially F0 and periodicity. The glottal stems are associated with higher F0 and lower periodicity (both CPP and HNR), as well as shallower low-band spectral tilt (H1–H2). The mid-band spectral tilt (H1–A2) and intensity have statistically significant structure coefficients, but their independent contributions to the glottalization contrast (as indicated by the discriminant coefficients) is small. In contrast, as expected, the tone categories are strongly distinguished by F0 alone, though CPP periodicity is also highly associated with the tone contrast. HNR periodicity, low-band spectral tilt (H1–H2), mid-band spectral tilt (H1–A2) and intensity also have statistically significant structure coefficients, but their independent contributions to the glottalization contrast (as shown by the discriminant coefficients) is reduced, especially in the case of HNR periodicity.

Both glottalization and higher tone are associated with higher F0, but glottalization is associated with lower periodicity, lower spectral tilt and lower intensity, while higher tone is associated with higher periodicity, higher spectral tilt and higher intensity. Because F0, CPP, HNR and low-band spectral tilt are all found to be important for the realization of glottalization, while F0 and CPP are important for the realization of tone, we focus on these four acoustic correlates. We now consider each of them individually, in mixed effects regression analyses that allow us to account for control variables and stem groups.

7.5.2 Fundamental Frequency

This analysis considers how tone category and glottalization influence fundamental frequency. The distribution of F0 by tone category and glottalization is shown in Figure 7.6. As the figure shows, higher tones tend to have higher F0, and glottalized stems tend to have higher F0 than corresponding non-glottalized stems.

The random effects included in the regression model of F0 are shown in Table D.16. The factors are the same as the random effects in §7.3, except that TIME is reduced to a three-level categorical variable. The base level is the initial sampling point in the vowel, and the other two levels are medial (M), which averages across the two middle sampling points in the vowel, and final (F), the final sampling point in the vowel. The terms include INSTANCE intercepts, and intercepts and slopes for each of the within-TARGET factors as well as the interaction between clitic and sampling point (CL $\times$ TIME). The fixed effects included in the regression model of F0 are shown in Table D.17. Besides the within-TARGET factors, the model includes factors for tone (T), stem glottalization (S), and the interaction between them.

First I test whether stem glottalization affects F0, and the results indicate that glot-

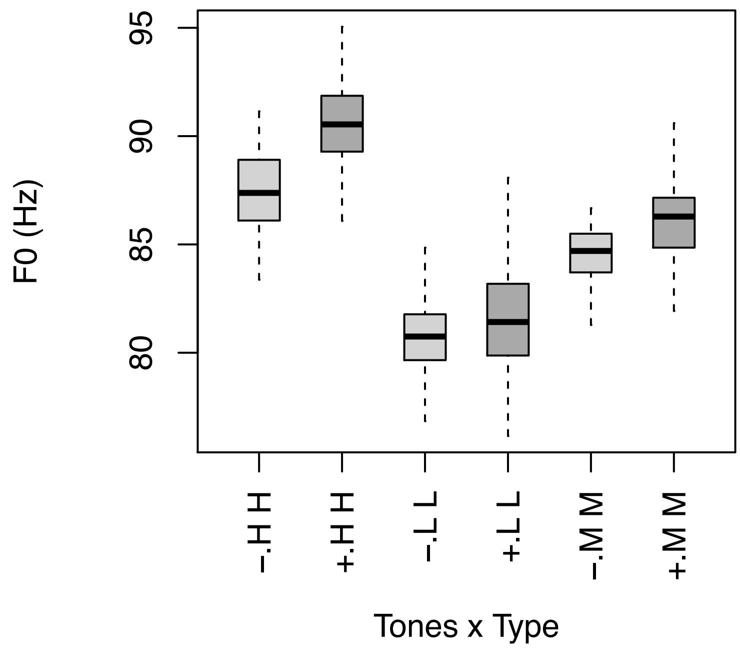

Figure 7.6: Distribution of F0 values in CVˀV (+) and CVV (–) couplets, with H.H, M.M or L.L basic tone patterns

talization raises the expected F0 value, especially for H tone. All the terms that include glottalization stem type (S) reflect differences between the plain and glottalized stems. Model comparison between the full model and the model that excludes these terms indicates that the combined effects of stem type are highly statistically significant ($X^2 = 26$, df = 5, p = 0.000). The effects of stem type are dominated by the main effect, which captures the generalization that CVˀV stems have 1.6 ST higher F0 overall than CVV stems (CI: [0.16, 3.03], t = 2.2, df = 21, p = 0.020). In addition, H tone CVˀV stems have an overall F0 that is an additional 1.5 ST higher than otherwise expected (CI: [-0.23, 3.23], t = 1.7, df = 21, p = 0.052).

Though the association between tone and F0 has already been well-established, I also test whether tone specification affects F0, and as expected, the results show that F0 is strongly affected by tone specification. Model comparison between the full model and the model that excludes the tone terms indicates that the combined effects of tone are highly statistically significant ($X^2 = 70$, df = 4, p = 0.000). The effects of tone are overwhelming

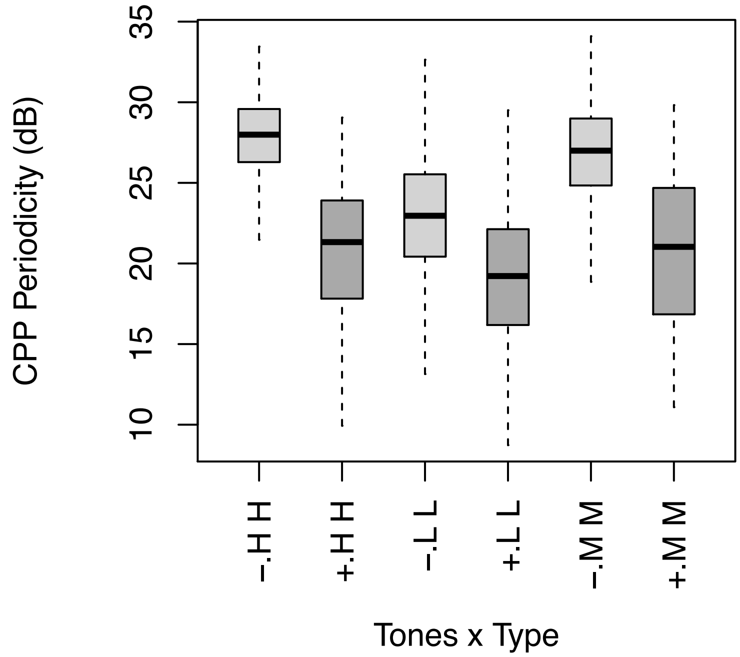

Figure 7.7: Distribution of CPP periodicity values in CVˀV (+) and CVV (–) couplets, with H.H, M.M or L.L basic tone patterns

dominated by the main effect, which captures the generalization that H tones are 3.2 ST higher than M tones (CI: [2.1, 4.4], t=5.5, df=21, p=0.000), and L tones are 3.5 ST lower than M tones (CI: [-4.6, -2.5], t=-6.5, df=21, p=0.000).

7.5.3 Cepstral Peak Prominence

The next analysis considers how tone category and glottalization influence CPP periodicity. The distribution of CPP by tone category and glottalization is shown in Figure 7.7. As shown in the figure, glottalized stems tend to have lower CPP values than plain stems, and L tone stems tend to have somewhat lower CPP values than other stems. The model terms included in the regression model of CPP—both the random effect and the fixed effects—are the same as in the model of F0. The random effects included in the regression model of CPP are shown in Table D.18. The fixed effects included in the regression model of CPP are shown in Table D.19.

First I test whether stem glottalization affects CPP periodicity, and the results indicate that CPP is lower overall in CVˀV couplets. Model comparison between the full model and the model that excludes the stem glottalization terms indicates that the combined effects of stem type are highly statistically significant (X^2 = 74, df = 5, p = 0.000). The vowel-initial value of CPP in CVˀV stems is 1.6 dB lower than in CVV stems (CI = [-3.23, 0.07], t = -1.9, df = 21, p = 0.037). In the middle of the vowel, the CPP of plain CVV stems rises while the CPP of glottalized stems drops, so that the difference between stem types in the middle of the vowel is 5.3 dB greater (CI = [-6.6, -4.3], t = -9.3, df = 21, p = 0.000), and the difference is still 3.0 dB greater than the vowel-initial difference at the vowel-final sampling point (CI = [-4.88, -1.71], t = -4.1, df = 21, p = 0.000).

Next I test whether tone category affects CPP periodicity, and results indicate that H tone is more periodic than M tone, and L tone is less periodic than M tone. Model comparison between the full model and the model that excludes tone terms indicates that the combined effects of tone category are highly statistically significant (X^2 = 52, df = 4, p = 0.000). The main effects of tone indicate that compared to M tone plain stems, the expected CPP value is 0.9 dB higher in H tone plain stems (CI = [-0.11, 1.97], t = 1.75, df = 21, p = 0.048) and 4.4 dB lower in L tone plain stems (CI = [-5.3, -3.4], t = 9.1, df = 21, p = 0.000). However, these differences are reduced in glottalized stems, as the interaction effects between stem type and tone indicate that the expected CPP value in H tone glottalized stems is 1.1 dB less than otherwise expected (CI = [-2.7, 0.5], t = -1.3, df = 21, p = 0.101) and the expected CPP value in L tone glottalized stems is 2.5 dB greater than otherwise expected (CI = [1.0, 4.0], t = 3.3, df = 21, p = 0.002).

7.5.4 Harmonics to Noise Ratio

The next analysis considers how tone category and glottalization influence HNR periodicity. The distribution of HNR values by tone category and glottalization is shown in Figure 7.8. As shown in the figure, L tone stems tend to have lower HNR values than other stems, and glottalized stems tend to have lower HNR values than plain stems. The model terms included in the regression model of HNR—both the random effect and the fixed effects—are the same as in the models of CPP and F0. The random effects included

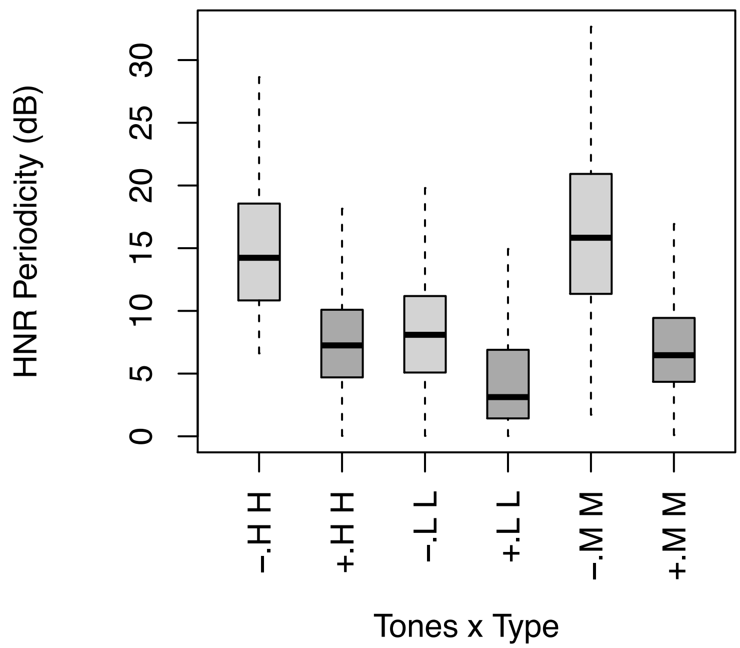

Figure 7.8: Distribution of HNR periodicity values in CVʔV (+) and CVV (–) couplets, with H.H, M.M or L.L basic tone patterns

in the regression model of HNR are shown in Table D.20. The fixed effects included in the regression model of HNR are shown in Table D.21.

First I test whether stem glottalization affects HNR periodicity, and results indicate that glottalization strongly reduces HNR periodicity. The terms that include stem type reflect differences between the plain and glottalized stems, and model comparison between the full model and the model that excludes these terms indicates that the combined effects of stem type are highly statistically significant ($X^2 = 42$, df = 5, p = 0.000). At the vowel onset of M-tone stems, glottalized stems have 5.9 dB lower HNR than plain stems (CI: [-8.8, -2.9], t = 3.9, df = 21, p = 0.000), and the difference is even greater later in the vowel—5.4 dB greater at the mid-point (CI: [-7.0, -3.8], t = -6.5, df = 21, p = 0.000) and 3.7 dB greater in the final portion (CI: [-3.7, -5.4], t = -4.3, df = 21, p = 0.000).

Next I test whether tone category affects HNR periodicity, and results indicate that the effect of tone is limited to the glottalization contrast within L tone stems. The terms that include tone reflect differences between tone categories, and model comparison between the full model and the model that excludes these terms indicates that the combined effects of tone are highly statistically significant ($X^2=18$, df = 4, p = 0.000). However, the parameter-wise t-tests indicate that the effect of tone is mostly limited to the contrast between L tone CVV and CVˀV stems. Compared to M-tone stems, the expected HNR values in plain L-tone stems are 8.0 dB lower (CI = [-10.0, -5.8], t = -7.35, df = 21, p = 0.000), but this difference is nearly cancelled in glottalized stems. The differences between M tones and H tones are smaller and do not reach statistical significance.

7.5.5 Low-band spectral tilt

The final analysis considers how tone category and glottalization influence low-band spectral tilt (H1–H2). The distribution of H1–H2 values by tone category and glottalization is shown in Figure 7.9. As shown in the figure, higher tones tend to have higher values of H1–H2 than lower tones do, and glottalized stems tend to have lower values than plain stems do.

The random effects included in the regression model of H1–H2, which have the same terms as the random effects included in the previous models, are shown in Table D.22. The fixed effects included in the regression model of H1–H2 are shown in Table D.23. The fixed effects included in the model of H1–H2 are the same as in the previous models, except that vowel quality (V) is additionally included as a control factor. The H1–H2 measurements are corrected for the filtering effects of vowels, but because the effects of F1 are difficult to estimate accurately in high vowels, we may expect some residual effect of vowel quality. The fitted parameters show that the high vowels do indeed have higher estimated H1–H2 values, 4.7 dB in the case of /i/ (CI = [3.4, 6.1], t = 7.1, df = 17, p = 0.000) and 4.5 dB in the case of /u/ (CI = [2.4, 6.5], t = 4.3, df = 17, p = 0.000). The mid vowels do not show statistically significant differences than /a/, the base level.

First I test whether glottalization influences H1–H2, and results indicate that glottalization has limited effect. Model comparison between the full model and the model that excludes stem type terms indicates that the combined effects of stem type are marginally statistically significant ($X^2=10.4$, df = 5, p = 0.064). The only parameter that reaches

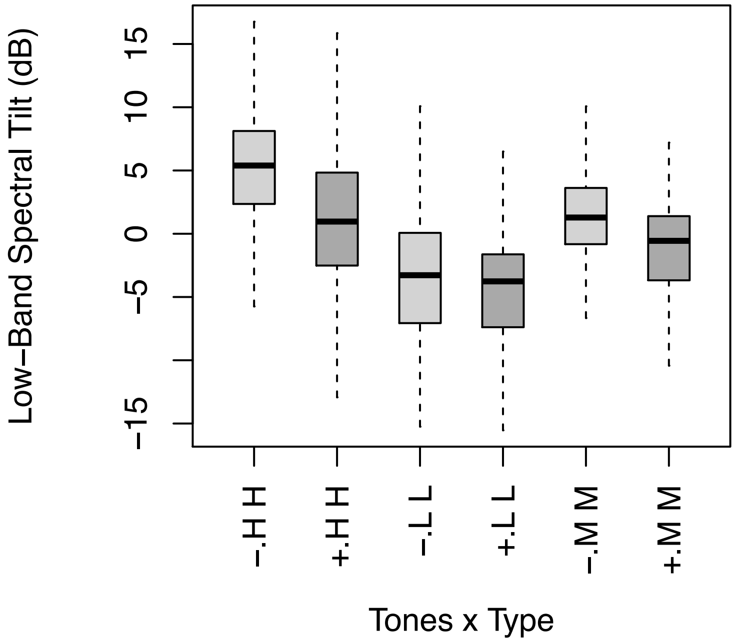

Figure 7.9: Distribution of H1–H2 values in CVˀV (+) and CVV (–) couplets, with H.H, M.M or L.L basic tone patterns

statistical significance is associated with the interaction between stem type and time, indicating that H1–H2 values in the final portion of CVˀV stems are 1.6 dB higher than otherwise expected (CI: [-0.06, 3.30], t = 1.9, df = 17, p = 0.038).

Next I test whether tone category influences H1–H2, and results indicate that H tones are have higher H1–H2 values than M tones, and M tones have higher H1–H2 values than L tones do. Model comparison between the full model and the model that excludes tone terms indicates that the combined effects of tone are highly statistically significant ($X^2 = 48$, df = 4, p = 0.000). Compared to M-tone CVV stems, spectral tilt in H-tone CVV stems descends 4.5 dB more (CI: [2.5, 6.5], t = 4.4, df = 17, p = 0.000) and in L-tone CVV stems descends 3.0 dB less (CI: [-4.9, -1.2], t = -3.2, df = 17, p = 0.002). These differences are reduced in glottalized stems, though not cancelled.

Table 7.6: Association of tone or glottalization with each of the acoustic correlates in focus in this study

	Contrast	
Acoustic Property	Tone	Glottalization
F0	+ +	+
CPP	✓	+
HNR	+	✓
H1–H2	+	✓

7.5.6 Discussion

The results of this study showed that the acoustic correlates of tone contrasts in Nieves Mixtec strongly overlap with the acoustic correlates of the glottalization contrast. F0 is the primary acoustic correlate of tone, while glottalized stems are also associated with higher F0. CPP periodicity is a primary acoustic correlate of the glottalization contrast, but it also helps distinguish L tone from the other tones. HNR periodicity is highly correlated with the tone contrast, but it also helps distinguish the glottalization contrast among L tone stems. Finally, H1–H2 is highly correlated with the tone contrast, while it weakly interacts to realize glottalization. These results are summarized in Table 7.6.

These results re-emphasize the close association between tone and phonation observed in the cross-linguistic survey in §2.3. Not only do tone and phonation often interact phonologically and co-occur in the same languages, but they are largely realized by the same phonetic dimensions. They differ only in that for tone, F0 is the primary correlate and the others are secondary, while for phonation, F0 is a secondary correlate and periodicity or spectral tilt is the primary correlate.

The association of lower tone with lower periodicity and spectral tilt indicates that H tone tends to have modal voicing while L tone tends to have creaky voice, for speaker OO, the speaker in this study. However, this contrasts with the results in §5.3, which indicated that speaker MO had breathy voice L tone and speaker MC had no statistically significant voicing differences between tone categories. Moreover, the acoustic results indicating creaky L tone for speaker OO contrast with an auditory impression of breathy L tone in his speech as well. These discrepancies highlight the need for both studies of speaker variation and production studies such as glottography. The results of these studies confirm that there are important between speaker differences in the realization of Nieves Mixtec tone, but they are too limited to warrant speculation as to the sociolinguistic correlates of this variation.

7.6 Summary

In sum, in this chapter I described three acoustic studies which investigated the realization of tone. In section §7.2, I set out the general design of these studies. In section §7.3, I presented analysis of the tonal coarticulation in plain couplets. A strong rightward asymmetry was found, as perseverative coarticulation effects were quite strong, while anticipatory coarticulation effects were negligible. The observed F0 on one mora is pulled toward the pitch target associated with the tone of the previous mora, but F0 is scarcely affected by the tone of the following mora. In section §7.4, I presented analysis contrasting tone contour timing in plain disyllabic couplets versus plain monosyllabic couplets. The differences in syllable structure alone had negligible effect on the duration of the couplet as a whole. However, the couplets with an attached enclitic were dramatically shorter, and a strong interaction with syllable structure was observed in this shortening effect. The results suggest that the observed differences in vowel duration are associated with the boundary of a word or phrase domain. Finally, in section §7.5, I presented analysis of contrasting plain monosyllabic couplets with glottalized monosyllabic couplets. The glottalized couplets were found to have higher fundamental frequency and lower periodicity throughout the vowel, though the periodicity differences were greatest in the middle of the vowel. Besides the definitional differences in F0 between tone categories, differences in periodicity and low-band spectral tilt were also found, suggesting that H tone tends to have modal voicing while L tone tends to be creaky, with M tone in between. Combined with the variable realization of stem glottalization also noted, these findings call for more thorough studies of the phonetic properties and timing of tone and phonation in Nieves Mixtec.

Chapter 8

Conclusions

8.1 Summary

This dissertation presents a phonological and acoustic description of the word prosody of Ixpantepec Nieves Mixtec, involving both a complex tone system and a default stress system. The description and analysis of word prosody in Nieves Mixtec is complicated by the role of phonation type in the language and by the close association between morphological structure and prosodic structure. I have worked to contextualize these systems within the phonological system of Nieves Mixtec as a whole, within the literature on other Mixtec varieties, as well as within the literature on cross-linguistic prosodic typology.

I began in chapter 2 by reviewing the literature on prosodic typology, in respect to both the phonological and acoustic properties of stress and tone. The reviewed literature indicates that stress is necessarily defined abstractly. For each language, a set of phonological and phonetic properties jointly indicate syllable prominence based on a metrical structure, where only one syllable bears the highest degree of prominence within each word. But the particular phonological and phonetic properties that indicate stress vary from language to language. In contrast, tone is defined more concretely, as it necessarily involves pitch as a phonemic feature, used as a contrastive value within the word. However, the realization of tone is not limited to pitch, as other acoustic properties may act as secondary cues.

Chapter 3 described the general phonology of Nieves Mixtec, apart from issues of stress and tone. After presenting the segmental inventory, I introduced several phonotactic restrictions and phonological properties of morphemes. They are first dealt with independent of prosody, but the long-range phonological properties become key evidence of prosodic structure in chapter 4.

In chapter 4, I described the phonological properties of stress in Nieves Mixtec. I reviewed previous descriptions of stress in other Mixtec varieties, showing that default stress on the initial syllable of the couplet is widely reported, though some descriptions suggest final stress or mobile stress. I then presented the phonological evidence that Nieves Mixtec word prosody does involve a stress system, with fixed stress on the initial syllable of the couplet. The data indicate that stress in Nieves Mixtec is based on trochaic feet aligned to the root.

Chapter 5 turned to the acoustic properties of stress. I presented one acoustic study comparing stressed syllables to pre-tonic and post-tonic syllables, for ten potential acoustic correlates of stress. The results indicate that the acoustic correlates of stress in Nieves Mixtec include segmental duration, vowel height, intensity, and CPP periodicity. The other acoustic correlates considered were found to be associated with stress for one or the other speaker, but not both speakers.

In chapter 6, I described the phonological properties of the tone system. I showed that the distribution of tone and the tone processes support an analysis in which morae may bear H, M or L tone, where M tone is underlyingly unspecified, and each morpheme may sponsor a final +H or +L floating tone. Bimoraic couplets thus host up to two linked tones and one floating tone, while monomoraic clitics host just one linked tone and one floating tone, and tonal morphemes are limited to a single floating tone. The tone processes are mostly reducible to two processes—H or L tone replacing M tone, and L tone displacing H tone, both analyzable as the action of autosegmental tone associating to morae.

Chapter 7 turned to the acoustic properties of tone. I presented three studies describing the acoustic realization of tone and comparing the realization of tone in couplets of different prosodic types. The first study describes tonal coarticulation in plain couplets. The results show a strong directional asymmetry, in which F0 is strongly influenced by the tone target associated with the previous mora but not affected by the tone target associated with following mora. The second study examined duration differences between disyllabic and monosyllabic couplets, finding that duration differences are dominated by effects of the word or phrase boundary, not by syllable structure alone. Finally, plain monosyllabic couplets were compared to glottalized monosyllabic couplets. The results indicate that glottalized vowels differ from plain vowels throughout the vowel, and that both glottalization and tone are associated with both periodicity—a stereotypical correlate of phonation—and f0—a necessary correlate of tone.

8.2 Contributions

The contributions of this thesis are aligned with the aims set forth in the introduction: (i) to provide a first description of Nieves Mixtec phonology, (ii) to contextualize the word prosody of Nieves Mixtec within other Mixtec varieties, and (iii) to contextualize the word prosody of Nieves Mixtec within cross-linguistic prosodic typology.

In regard to the first aim, this thesis provides a basic description of the segmental phonology in chapter 3, and important suprasegmental aspects of the phonology are elaborated in chapters 4 and 6. Particular attention is paid to phonological properties that are strongly associated with the whole morpheme: glottalization, nasalization, and vowel quality. Not only do these properties present puzzles for phonemic analysis, but their distribution and realization are restricted by morpheme size and word prosody. The distribution and realization of these properties are important phonological issues, as much for typological and theoretical work as for understanding language change or designing curricula.

In regard to the dialectological aim, chapters 4 and 6 each place Nieves Mixtec word prosody within the literature on the word prosody of other Mixtec varieties. The evidence supporting trochaic stress aligned with the root in Nieves Mixtec parallels the descriptions from some other Mixtec varieties, such as Santo Domingo Nuxaá Mixtec (McKendry 2013) and San Esteban Atatlahuca Mixtec (R. M. Alexander 1980), while contrasting with descriptions of final stress in Yoloxochitl Mixtec (DiCanio et al. submitted) or mobile stress in Silacayoapan Mixtec (North & Shields 1977) and Ayutla Mixtec (Pankratz & Pike 1967), among others. Likewise, the tone system of Nieves Mixtec resembles other Group A tone systems such as Alcozauca Mixtec (Stark et al. 2003), San Juan Colorado Mixtec (Stark & Johnson 1991), and Santo Domingo Nuxaá Mixtec (McKendry 2013), with particularly close parallels to San Miguel el Grande Mixtec (K. L. Pike 1948) and San Esteban Atatlahuca Mixtec (R. M. Alexander 1980). The inventory of couplet tone patterns in Nieves Mixtec is moderate within the spread of Group A tone pattern inventories, and the tone sandhi of Nieves Mixtec is also greater than some (e.g. Alcozauca Mixtec) and less than others (e.g. San Juan Colorado).

In regard to cross-linguistic prosodic typology, Table 8.1 updates the table from §2.3 to show how the results of this dissertation place Nieves Mixtec word prosody within the cross-linguistically attested acoustic properties of stress, tone, and phonation systems. I have placed the results of chapter 5 in the "Word Stress" column, though properly speaking it is not yet clear whether some of the observed effects should instead be considered properties of phrasal stress. In either case, the stressed syllables of Nieves Mixtec are associated with increased vowel duration and increased vowel intensity, like many other languages, plus increased consonant duration—as in Raramuri (Caballero & Carroll 2015) or Greek (Arvaniti 1994)—, more peripheral vowel quality—as in English (Cho & Keating 2009) or Papiamentu (Remijsen & van Heuven 2005)—, and greater periodicity—as in Tongan (Garellek & White 2015). Chapter 7 results show that in addition to higher F0, higher tone is associated with higher periodicity as in Mazatec (Garellek & Keating 2011), and tones also differ in low-band spectral tilt as in Mandarin (Lee 2009) and Vietnamese (Brunelle 2009b). In addition, the glottalization contrast in Nieves Mixtec is correlated with periodicity, like the phonation contrasts in Zapotec (Chávez-Peón 2010) and Hmong

(Garellek et al. 2013), as well as correlated with F0, like the phonation contrasts in Korean (Kenstowicz & Park 2006) and Triqui (DiCanio 2012a). These results further establish these acoustic properties as cross-linguistically possible correlates of these phonological contrasts, and they show one way that stress, tone and glottalization contrasts may coexist in the acoustic space.

8.3 Directions of future research

Given the complexity of the word prosodic system in Nieves Mixtec, this work just begins to describe it. Here I discuss directions to be pursued in further investigation of the prosody of Nieves Mixtec.

One outstanding problem is the distinction between primary stress and secondary stress as well as the distinction between word stress and phrasal stress. Do the phonological properties licensed by stress—vowel length, glottalization and nasalization—pattern together in the secondary stress environments? Or do some of these properties weaken under secondary stress, relative to full stress? Do some of these properties (variably or gradiently) persist even when unstressed? Similarly, the phonological properties of phrasal stress should be distinguished from the properties of word stress. The acoustic study of stress in Chapter 5 may be conflating these different stress domains. It is observed impressionistically that the realization of glottalization is more often localized as a glottal stop in deliberate speech or in contexts that probably bear phrasal stress. These differences should be described in more detail.

More comprehensive description of Mixtec languages is also important to our understanding of the interaction between prosodic and morphological domains. Prosodic domains and morphological structures are highly restricted and tightly coupled in Mixtec languages, presenting several analytic problems and suggesting functional advantages of alignment between morphology and prosody (Kager 1997). In addition to stress, other prosodic aspects such as vowel length and tone process domains may have demarcative roles in word construction and phrasal syntax. The role of tone processes in marking

Table 8.1: Acoustic properties correlated with the phonological categories of interest. See §2.3 for references and discussion.

Acoustic Property	Phonological System			
	Phrase Stress	Word Stress	Tone	Phonation
Vowel Duration	English, Dutch, Nahuatl, Mixtec	English, Dutch, Greek, Menominee, Spanish, Tongan, Arabic, Nahuatl, Raramuri, Pirahã, Chickasaw, Papiamentu, Maˈya, Zapotec, Triqui, **Nieves Mixtec**	Mandarin, Mixtec	Hmong, Mixtec
Vowel Intensity	English, Dutch, Swedish, Spanish	Spanish, Berber, Quechua, Tongan, Chickasaw, Papiamentu, Zapotec, Pirahã, **Nieves Mixtec**	Mandarin, Maˈya	Mazatec
Consonant Duration	English, Dutch	Dutch, English, Raramuri, Pirahã, Greek, Triqui, **Nieves Mixtec**	Mandarin	Korean
Vowel Quality	English	English, Arabic, Tongan, Papiamentu, Maˈya, **Nieves Mixtec**	Shuijingping Hmong, Fuzhou	Western Cham
Mid-band spec tilt	English, Swedish	Dutch, Spanish, Nahuatl	Triqui	Yi, Gujarati, Mazatec, Triqui
Low-band spec tilt		Tongan, Nahuatl	Mandarin, Vietnamese, Hmong, **Nieves Mixtec**	Korean, Yi, Gujarati, Mazatec, Zapotec, Hmong, Triqui
Periodicity		Tongan, **Nieves Mixtec**	Mazatec, **Nieves Mixtec**	Mazatec, Yi, Zapotec, Hmong, **Nieves Mixtec**
Fundamental Frequency	English, Swedish, Quechua, Spanish, Berber	Nahuatl, Quechua, Menominee, Tongan, Creek, Chickasaw	Papiamentu, Maˈya, Creek, Chickasaw, Mandarin, Zapotec, Gujarati, Kyungsang Korean, Triqui, Mazatec, **Nieves Mixtec**	Korean, Arabic, Triqui, Western Cham, **Nieves Mixtec**

syntactic domains has been explored considerably in Asian and African tone languages (L. Bickmore 1990; M. Y. Chen 1987; 1990; Hyman 1999; Selkirk 2011), but much less so in American tone languages.

The interaction between phonation and tone is itself a topic of recent phonetic typology work. Based on phonological work in individual languages, associations between laryngeal features and tone have been widely noted (Hombert et al. 1979). Reviews of acoustic studies in different languages (e.g. Kuang 2013) and cross-linguistic comparisons of the acoustic and articulatory correlates of phonation (Edmondson & Esling 2006; Keating et al. 2011) suggest that the phonetic variety of phonation types and phonation-tone interactions well exceeds what was expected from the phonological descriptions or phonetic studies of single languages. Otomanguean languages are well-known for laryngeal complexity (Silverman 1997), and studies of the acoustic correlates of phonation have included other Otomanguean languages, such as Triqui (DiCanio 2014), Mazatec (Garellek & Keating 2011), and Zapotec (Esposito 2010b; Avelino 2010; Chávez-Peón 2011). However, there is sufficient diversity within the language family—even within the Mixtecan branch (Macaulay & Salmons 1995; Gerfen & Baker 2005)—, such that further documentation of these properties is critical.

Appendix A

Mixtec Varieties

Table A.1: Mixtec varieties of the Baja region, with the abbreviations used here, along with the corresponding Josserand and ISO codes

Community	Abbreviation	Josserand	ISO code	Group
San Jorge Nuchita	Nch	Nuch	mks	Baja:C
Guadalupe Portezuelo	Gua	Guad	mxa	Baja:C
Alacatlatzala	Ala	Alac	mim	Baja:G
Cahuatache	Cah	Cah	mim	Baja:G
Alcozauca	Alc	Alco	xta	Baja:G
Yoloxochitl	Yol	Yolx	xty	Baja:G
Yucunany Mixtepec	Mix	–	mix	Baja:M
San Juan Mixtepec	Mix	Mix	mix	Baja:M
Chigmecatitlán	Chg	Chig	mii	Baja:N
Xayacatlan de Bravo	Aca	Xay	mit	Baja:N
Santiago Chazumba	Chz	Chaz	xtb	Baja:N
Coicoyán	Coi	Coi	jmx	Baja:S
Ayutla de los Libres	Ayu	Ayut	miy	Baja:S
Ixpantepec Nieves	Ixp	IxpN	mks	Baja:S
Metlatonoc	Met	Metl	mxv	Baja:S
Tecomaxtlahuaca	Jux	Teco	vmc	Baja:S
Santiago Juxtlahuaca	Jux	Juxt	vmc	Baja:S
Santiago Cacaloxtepec	Cac	Cac	miu	Baja:T
San Andres Yutatio	Ytt	Yucñ	mxb	Baja:T
San Jeronimo Progreso	Sil	SilP	mks	Baja:W
San Martin del Estado	Sil	SilM	mks	Baja:W

Table A.2: Mixtec varieties of the Alta and Costa regions, with the abbreviations used here, along with the corresponding Josserand and ISO codes

Community	Abbreviation	Josserand	ISO code	Group
Yutanduchi de Guerrero	Ytd	Yutn	mab	Alta:E
Santa Maria Peñoles	Pñl	Peño	mil	Alta:E
Santiago Tlazoyaltepec	Tlz	Tlaz	mqh	Alta:E
San Pedro Tidaá	Tid	Tida	mtx	Alta:E
San Antonio Huitepec	Hui	Huit	mxs	Alta:E
Santo Domingo Nuxaá	Nux	Nuxa	mxy	Alta:E
San Juan Tamazola	Tam	Tamz	vmx	Alta:E
San Juan Diuxi	Diu	Diux	xtd	Alta:E
San Miguel Piedras	Pdr	Pied	xtp	Alta:E
Santa Mateo Sindihui	Snd	Sind	xts	Alta:E
San Juan Coatzospam	Coa	Coat	miz	Alta:N
Cuyamecalco	Cuy	Cuya	xtu	Alta:N
Santiago Apoala	Apo	Apoa	mip	Alta:NE
Santiago Mitlatongo	Mit	Mitl	vmm	Alta:NE
San Bartolo Soyaltepec	Soy	Soy	vmq	Alta:NE
Santa Cruz Itundujia	Itu	Itun	mce	Alta:W
Santa Lucía Monteverde	Mon	Verd	mdv	Alta:W
Santiago Nuyoo	Nuy	Nuyo	meh	Alta:W
San Esteban Atatlahuca	Ata	Atat	mib	Alta:W
Santo Tomas Ocotepec	Oco	Oco	mie	Alta:W
Chalcatongo de Hidalgo	Chl	Chal	mig	Alta:W
San Pedro Molinos	Chl	Moli	mig	Alta:W
San Miguel Grande	Chl	Mig	mig	Alta:W
Santiago Yosondúa	Ysd	Yoso	mpm	Alta:W
San Bartolomé Yucuañe	Ycñ	Yuca	mvg	Alta:W
San Juan Teita	Tei	Teit	xtj	Alta:W
San Pablo Tijaltepec	Tij	–	xtl	Alta:W
Magdalena Peñasco	Mag	Peña	xtm	Alta:W
San Juan Ñumí	Ñum	Ñumi	xtn	Alta:W
Santa Cruz Tacahua	Tac	Yolt	xtt	Alta:W
Santa Maria Zacatepec	Zac	Zac	ctz	Costa
Santiago Amoltepec	Amo	–	mbz	Costa
San Agustín Chayuco	Chy	Chay	mih	Costa
Pinotepa National	Pin	PinN	mio	Costa
San Juan Colorado	Col	Colo	mjc	Costa
San Pedro Tututepec	Tut	Tut	mtu	Costa
Santiago Jamiltepec	Jam	Jam	mxt	Costa
Santiago Ixtayutla	Ixt	Ixty	vmj	Costa

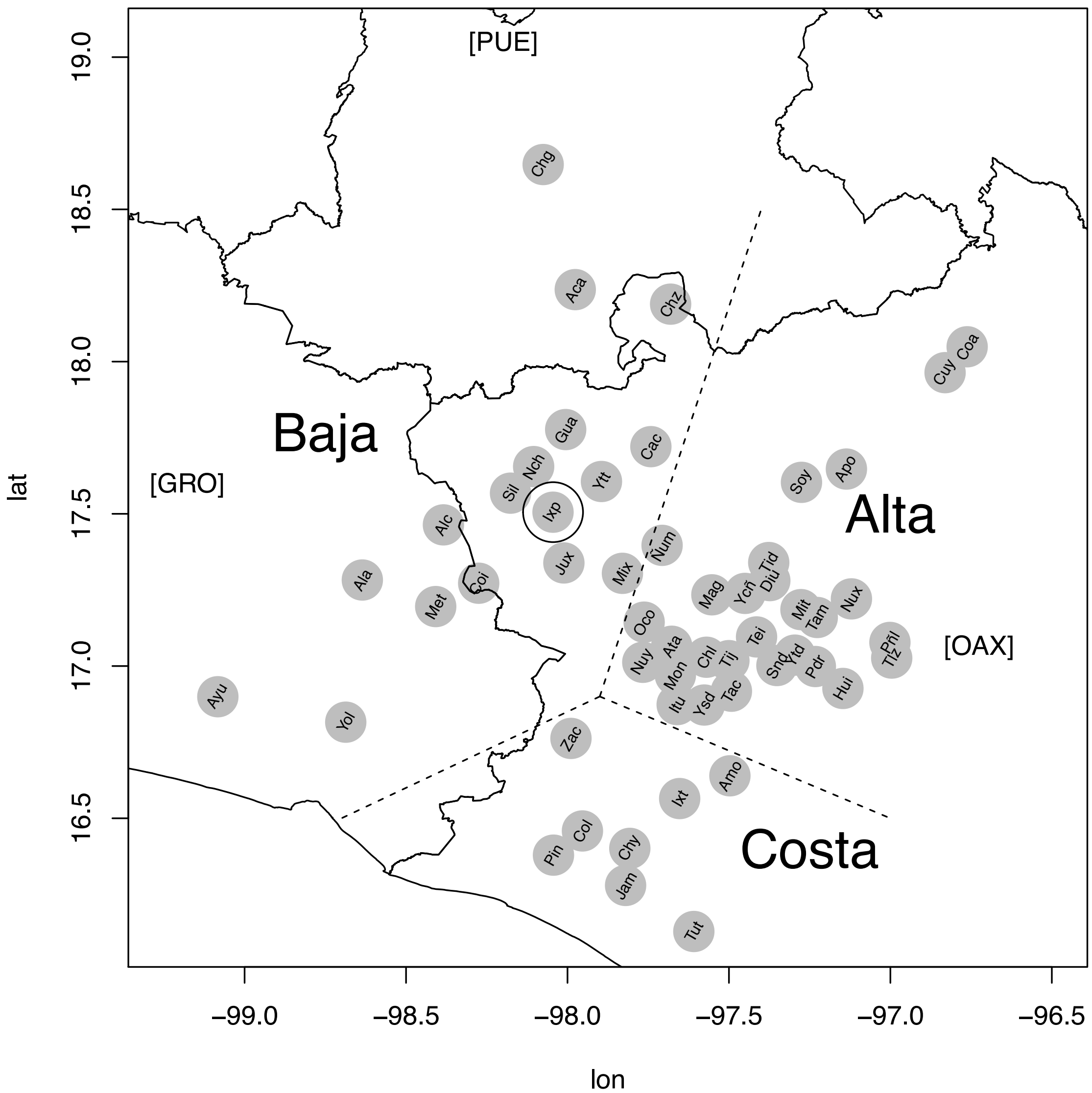

Figure A.1: The location of Ixpantepec Nieves (IXP) and of other Mixtec varieties. Except for Ixpantepec Nieves and San Jorge Nuchita (NCH), each gray circle represents the central location of one ISO language.

Appendix B

Glossing Conventions

Morphophonemic transcriptions and glosses mostly follow conventional practice. Prosodic words are separated by white space, clitics are set apart by an equals sign (=), and other morpheme boundaries are marked by a dash (–). In addition, suprasegmental morphemes (e.g. tonal morphemes) are set apart by a backslash (\). Within the gloss tier, fused properties are separated by a period (.), while properties associated with recognizable but weakly productive affixes are separated by a colon (:). Glossing follows conventional use, except that I abbreviate realis as 'RE' and irrealis as 'IR', and I use the idiosyncratic abbreviations 'WD' (noun class of wood, etc.), 'RND' (noun class of round things) and 'LIQ' (noun class of liquids). The full table of abbreviations is shown in Table B.1.

Table B.1: Table of gloss abbreviations

Abbreviation	Semantics
1	first person
2	second person
3	third person
CAUS	causative
COP	copula
DIM	noun class of the small and sacred
DIST	distal
DIV	noun class of divine
DUB	dubitative
EMPH	emphatic
EX	exclusive
EXIST	existential
F	feminine
FAM	familiar
FORM	formal
HAB	habitual
IMP	imperative
IN	inclusive
INT	intensive
IPFV	imperfective
IR	irrealis
LAT	lative
LIQ	noun class of liquids
M	masculine
MED	medial
NEG	negative
N	neuter
OPT	optative
P or PL	plural
PFV	perfective
POT	potential
PRO	pronoun
PROX	proximal
Q	polar question particle
RE	realis
RED	reduplicant
REP	repetitive
RND	noun class of round things
S or SG	singular
STAT	stative
WD	noun class of wood, etc.
ZO	noun class of animals

Appendix C

Stress supplement

C.1 Stress study recorded utterances

Table C.1: Stress study recorded utterances, speaker MO

Words	Syll	Segs	Tone	Bound	Gloss
ni nda̱ká’a̱n-ra̱	pre	DAK	L	syll	hablar
ni nda̱ká’a̱n-ra̱ sa’a-v-i	pre	DAK	L	syll	hablar
si̱ nda̱kā’a̱n	pre	DAK	L	syll	hablar
si̱ nda̱ká’a̱n-sī	pre	DAK	L	syll	habló
ndāká’a̱n-ra̱	pre	DAK	M	utt	hablar
ndākā’an-í-na̱	pre	DAK	M	utt	pensar
ndánē’ē-rā	pre	DAN	H	utt	levantar
tyilo’o ká .. ndánē’ē-rā yu̱u̱	pre	DAN	H	phrase	levantar
ndānē’ē-rā yu̱u̱	pre	DAN	M	utt	levantar
tyilo’o ká ndānē’ē-rā yu̱u̱	pre	DAN	M	phrase	levantar
ndānē’ē-rā yu̱u̱	pre	DAN	M	utt	levantar
ndyúkwe̱’e̱-ra̱	pre	DIK	H	utt	enojarse
ni ndyukwé’é-rā	pre	DIK	L	syll	arrepentir
ni ndyu̱kwē’é-rā	pre	DIK	L	syll	arrepentir
ndyi̱kwē’ē-rā	pre	DIK	L	utt	enojarse
ndyi̱kwē’ē-ra̱	pre	DIK	L	utt	enojarse
ni ndyi̱kwē’e̱-ra̱	pre	DIK	L	syll	enojarse
vītyī káā ndyi̱sa̱tyi̱rǎ	pre	DIS	L	phrase	picoso
ndyúsa̱tyi̱-ra̱	pre	DIS	H	utt	picoso

Table C.1: Stress study recorded utterances, speaker MO (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ndyúsātyi̱-rǎ	pre	DIS	H	utt	picoso
ndyúsa̱tyi̱-ra̱	pre	DIS	H	utt	picoso
nī ndyu̱sa̱tyi̱-ra̱	pre	DIS	L	syll	picoso
nīndyu̱sa̱tyi̱-ra̱	pre	DIS	L	syll	picoso
ndyūsa̱tyi̱ra̱	pre	DIS	M	utt	picoso
ndyūsa̱tyi̱-ra̱	pre	DIS	M	utt	picoso
tyīló'o̱ ka̱ nákānīrā	pre	NAK	H	phrase	contar
nákānī-rā	pre	NAK	H	utt	contar
tyiló'o̱ ká .. ni na̱-kānī-ra	pre	NAK	L	syll	contar
nī na̱kānī-rā	pre	NAK	L	syll	contar
tyilo'o ka ni na̱ kē'ēn-rā	pre	NAK	L	syll	dar
na̱ká'a̱n-na̱	pre	NAK	L	utt	hablaron
ná nānā-rā	pre	NAN	H	utt	subir
ná nānā-rā	pre	NAN	H	utt	subir
ná nānā tyilo'o	pre	NAN	H	utt	subir
ka'an-o si'in-ra ná nānā-rā	pre	NAN	H	phrase	subir
ka'a̱n si'i̱n-rā ná nānā-rā	pre	NAN	H	phrase	subir
sī yātyī nási̱no̱-ra̱	pre	NAS	H	word	bajar
si̱ yātyī nási̱no̱-ra̱	pre	NAS	H	word	bajar
sī na̱ síno̱-ra̱	pre	NAS	L	syll	bajar
tyilo'o ká sī na̱ síno̱-rā	pre	NAS	L	syll	bajar
sī na̱ sīno̱-ra̱	pre	NAS	L	syll	bajar
ko̱ ní kānī-ñāā tyilo'o yoo	pre	NIK	H	syll	pegar
ko̱ ndáa̱ ko̱ ni̱ kānī ñāā tyilo'o yoo	pre	NIK	H	syll	pegar
tyiló'o̱ ká ni̱ kā'vī-rā	pre	NIK	L	phrase	leer
ni̱ kā'vī-rā	pre	NIK	L	utt	leer
ni̱ kāni tá'ān-rā	pre	NIK	L	utt	pegar
ni̱ kānī tá'ān-rā	pre	NIK	L	utt	pegar
ni̱ kānī-rā	pre	NIK	L	utt	pegar
tyi-lo'o ká ni̱-kānī-ra	pre	NIK	L	phrase	pegar
ni̱-kānī-ra tyilo'o yoo	pre	NIK	L	utt	pegar
ja'yi-un tyilo'o saan ni̱ kānī-rā ja'yi-i	pre	NIK	L	phrase	pegar
ko̱ ní kānī-ñā tyilo'o yoo	pre	NIK	L	syll	pegar
ko̱ ní kānī ñā'ā tyilo'o yoo	pre	NIK	L	syll	pegar
ko̱ ní-nānā-rā xi̱ni̱ yúku̱	pre	NIN	H	syll	subir

Table C.1: Stress study recorded utterances, speaker MO (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ni̱ nānā nū̱u̱ yíto̱	pre	NIN	L	utt	retoñar
ni̱ nānā ndā'a̱ to̱	pre	NIN	L	utt	retoñar
ni̱ nānā-rā ndyi̱ka̱ ká	pre	NIN	L	utt	subir
ni̱ nānā-rā	pre	NIN	L	utt	subir
ni̱-nānā-rā xi̱ni̱ yúku̱	pre	NIN	L	utt	subir
tyiló'o̱ yó'ō ni̱-nānā-rā xi̱ni̱ yúku̱	pre	NIN	L	phrase	subir
tyi̱va̱li̱ káā ni̱ si̱kā-rā	pre	NIS	L	phrase	caminar
tyi̱va̱li̱ ká kákānī tá'ān-rā	pre	KAK	H	phrase	pegar
ni̱ ka̱ kānī tá'ān-rā	pre	KAK	L	syll	pegar
nīka̱kānī-rā aaaa̱	pre	KAK	L	syll	pegar
ni̱ ka̱ kānī tá'ān-rā	pre	KAK	L	syll	pegar
tyilo'o ká kánē'ē-rā	pre	KAN	H	phrase	levantar
kánē'ē-rā īīn yu̱u̱	pre	KAN	H	utt	levantar
kánē'ē-rā	pre	KAN	H	utt	levantar
kánē'ē-rā yīto̱	pre	KAN	H	utt	levantar
kánānā-rā kása̱'a̱n-ra	pre	KAN	H	utt	subir
nī ka̱nānā-rā	pre	KAN	L	syll	subir
nī ka̱nānā-rā	pre	KAN	L	syll	subir
kānē'ē-rā yu̱u̱ ka	pre	KAN	M	utt	levantar
kási̱kā-rā	pre	KAS	H	utt	caminar
kásīkā nūū-rāa	pre	KAS	H	utt	caminar
kaa kásīkā-rā	pre	KAS	H	phrase	caminar
tyīva̱li̱ kā kásīkā nūū-rā	pre	KAS	H	phrase	caminar
ko̱o̱ sí kānī-ñā-rā	pre	SIK	H	syll	pegar
ko̱ sí kānī-ñā-rā	pre	SIK	H	syll	pegar
ni si̱ kānī-rā tyikáā	pre	SIK	L	syll	pegar
ko̱ sínānā-rā	pre	SIN	H	syll	subir
táyāchi̱ ni si̱nānā-rā	pre	SIN	L	syll	subir
tyiló'o̱ ká ni si̱nānā-rā	pre	SIN	L	syll	subir
nii̱ si̱ sīkā-rā	pre	SIS	L	syll	caminar
tyilo'o ka ni̱ si̱ sīkā-rā	pre	SIS	L	syll	caminar
ndáka̱-rā	tonic	DAK	H	utt	pedir
ni̱ nda̱ka̱-ra̱ yo̱jó	tonic	DAK	L	syll	pedir
tyilo'o kaa ndásí-ra̱	tonic	DAS	H	phrase	desatar
tyilo'o ka si .. si̱ ndásí-vā-rā	tonic	DAS	H	syll	desatar

Table C.1: Stress study recorded utterances, speaker MO (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ndásī-rā	tonic	DAS	H	utt	mojarse
ndásī-rā	tonic	DAS	H	utt	mojarse
si̱ ndásī-vā-rā	tonic	DAS	H	syll	mojarse
tyilo’o ka si̱ ndásī-rā	tonic	DAS	H	syll	mojarse
ni̱ ndāsí-rā me̱ērā	tonic	DAS	M	syll	desatar
ni̱ ndāsí-rā me̱ērā	tonic	DAS	M	syll	desatar
ni̱ ndāsí-rā me̱ērā	tonic	DAS	M	syll	desatar
ni̱ ndāsī-rā	tonic	DAS	M	syll	mojarse
ni̱ ndāsī-rā	tonic	DAS	M	syll	mojarse
ni̱ ndyi̱ko̱-ra̱ (tata-ra)	tonic	DIK	L	syll	seguir
ndávā ndyísí-rí	tonic	DIS	H	word	ala
ndávā ndyísí-rí	tonic	DIS	H	word	ala
tyívī ndyi̱si̱-ri̱	tonic	DIS	L	word	ala
tyívī ndyi̱si̱-ri̱	tonic	DIS	L	word	ala
si̱ nánā tyīló’o̱	tonic	NAN	H	syll	subir
tyiló’o̱ káa ni̱-nānā-rā	tonic	NAN	M	syll	subir
chīnūú-ña̱ cháa-kā chíni̱no̱	tonic	NIN	L	word	abajo
chíni̱no̱ jé’ē	tonic	NIN	L	syll	abajo
cháá-ka̱ chíni̱nō chīkāa̱-u̱n-ña̱	tonic	NIN	L	word	arriba
chíni̱nō jē’ē	tonic	NIN	L	syll	arriba
si̱ kákū léé	tonic	KAK	H	syll	nacer
si̱ kákū-nā	tonic	KAK	H	syll	nacer
si̱ ka̱ka̱-na̱ kwī’ī	tonic	KAK	L	syll	pedir
si̱ ka̱ka̱ kwī’ī	tonic	KAK	L	syll	pedir
si̱ kánī-rā	tonic	KAN	H	syll	pegar
ni̱ kānī-rā	tonic	KAN	M	syll	pegar
si̱ kásī-rā jā’ma̱-ra̱	tonic	KAS	H	syll	escoger
si̱ kásī-rā jā’ma̱-ra̱	tonic	KAS	H	syll	escoger
si̱ ni̱ ka̱sī-rā	tonic	KAS	L	syll	escoger
si̱ ni̱ ka̱sī-rā jā’ma̱-ra̱	tonic	KAS	L	syll	escoger
si̱ kāsí-na̱ kwi̱’ī	tonic	KAS	M	syll	comer
tye’e-ra ki̱kī-rā	tonic	KIK	L	word	tejer
tye’e-ra ki̱kī-rā	tonic	KIK	L	word	tejer
si̱ ni̱ ki̱kī-rā	tonic	KIK	L	syll	tejer
si̱ ni̱ ki̱kī-rā	tonic	KIK	L	syll	tejer

Table C.1: Stress study recorded utterances, speaker MO (continued)

Words	Syll	Segs	Tone	Bound	Gloss
si tye’e-ra kīní-rā	tonic	KIN	M	word	cazar
kīní-ra̱ īlō kúni̱-ra̱	tonic	KIN	M	utt	cazar
kīní-ra̱ īīn īlō kúni̱-ra̱	tonic	KIN	M	utt	cazar
ni̱ kīní-ra̱	tonic	KIN	M	syll	cazar
ni̱ ku̱kīnī-rā	tonic	KIN	M	syll	malo
ni̱ ku̱kīnī-rā	tonic	KIN	M	syll	malo
si̱ kǐní-rā	tonic	KIN	R	syll	cazar
kísī-rā	tonic	KIS	H	utt	venir
si̱ kísī-rā	tonic	KIS	H	syll	venir
si̱kísī-rā jánā’ā-rā	tonic	KIS	H	syll	venir
ni̱ kīsī-rā ndáka̱-ra̱ yo̱jó	tonic	KIS	M	syll	venir
ni̱ kīsī-rā ndáka̱-ra̱ yo̱jó	tonic	KIS	M	syll	venir
ni̱ kīsī tyi̱ló’o̱	tonic	KIS	M	syll	venir
sī ni̱ kīsī-rā	tonic	KIS	M	syll	venir
si̱ sákū-rā	tonic	SAK	H	syll	llorar
si̱ sákū-ra̱	tonic	SAK	H	syll	llorar
si̱ sáku̱-ra̱	tonic	SAK	H	syll	reir
si̱ sáku̱-ra̱	tonic	SAK	H	syll	reir
si̱ ni̱-sa̱ku̱-ra̱	tonic	SAK	L	syll	reir
si̱ ni̱-sa̱ku̱-ra̱	tonic	SAK	L	syll	reir
si̱ ni̱-sākū-rā	tonic	SAK	M	syll	llorar
si̱ ni̱-sākū-rā	tonic	SAK	M	syll	llorar
sáni̱-ra̱	tonic	SAN	H	utt	pisar
si̱ sáni̱-ra̱	tonic	SAN	H	syll	pisar
si̱ sáni̱-ra̱	tonic	SAN	H	syll	pisar
ni̱-sa̱ni̱-ra̱	tonic	SAN	L	syll	pisar
si̱ ni̱-sa̱ni̱-ra̱	tonic	SAN	L	syll	pisar
si̱ ni̱-sa̱ni̱-ra̱	tonic	SAN	L	syll	pisar
ni̱ sa̱ní-ra̱	tonic	SAN	L	syll	soñar
ni̱ sa̱ní-ra̱	tonic	SAN	L	syll	soñar
ni̱ sa̱ní-ra̱	tonic	SAN	L	syll	soñar
si̱ ni̱-sa̱ní-ra̱	tonic	SAN	L	syll	soñar
sa̱ní-ra̱	tonic	SAN	L	utt	soñar
sa̱ní-ra̱	tonic	SAN	L	utt	soñar
si̱ sǎní-ra̱	tonic	SAN	R	syll	soñar

Table C.1: Stress study recorded utterances, speaker MO (continued)

Words	Syll	Segs	Tone	Bound	Gloss
si̱ ni̱ sāsí-rā kwī’ī	tonic	SAS	M	syll	comer
si̱ ni̱ sāsí-rā kwī’ī	tonic	SAS	M	syll	comer
si̱ sǎsí-rā kwī’i̱	tonic	SAS	R	syll	comer
si̱ sǎsí-rā kwī’ī	tonic	SAS	R	syll	comer
si̱ síkā tyīló’o̱	tonic	SIK	H	syll	caminar
si̱ síkā-rā	tonic	SIK	H	syll	caminar
tyilo’o ká si̱ síka̱-ra̱	tonic	SIK	H	syll	pedir
si̱ ni̱ si̱ka̱-ra̱	tonic	SIK	L	syll	pedir
si̱ ni̱ sīkā-vā-rā	tonic	SIK	M	syll	caminar
sī ni̱ si̱no̱-ra̱	tonic	SIN	L	syll	bajar
sísī-rā xi̱ta̱	tonic	SIS	H	utt	comer
tyilo’o si̱ sísī-rā xi̱ta̱	tonic	SIS	H	syll	comer
kwa̱’a̱n sísī-rā	tonic	SIS	H	word	entumir
sísī-rā	tonic	SIS	H	utt	grocero
ni̱ si̱sī-rā	tonic	SIS	L	syll	entumir
ni̱ si̱sī-rā	tonic	SIS	L	syll	entumir
si̱ ni̱ sīsī-rā xi̱ta̱	tonic	SIS	M	syll	comer
tyívī lāndyī-na̱	post	DIN	M	syll	ombligo
tyívī lāndyī-na̱	post	DIN	M	syll	ombligo
ko̱ tyívī-ka̱ lāndyī-na̱	post	DIN	M	syll	ombligo
tyívī lāndyī-sī	post	DIS	M	syll	ombligo
tyívī lāndyī-sī	post	DIS	M	syll	ombligo
ko̱ su̱ná-ka̱-ra̱	post	NAK	H	syll	abrir
ko̱ kánā-kā-sī	post	NAK	M	syll	salir
ni̱ su̱ná-na̱ yu̱ yéé	post	NAN	H	syll	abrir
ni̱ sūná-na̱	post	NAN	H	syll	abrir
ni̱ sūná-na̱	post	NAN	H	syll	abrir
kánā-nā kwa’an-na	post	NAN	M	syll	salir
ni̱ sūná-sī	post	NAS	H	syll	abrir
kánā-sī	post	NAS	M	syll	salir
kánā-sī kwa̱’a̱n-si̱	post	NAS	M	syll	salir
kánā-sī kwa̱’a̱n-sī	post	NAS	M	syll	salir
ko̱ na̱ní-ka̱-si̱ jwáa̱n	post	NIK	H	syll	llamarse
ko̱ kóma̱ni̱-ká-sī	post	NIK	L	syll	faltar
na̱vē’ē ká nāní-na̱a̱	post	NIN	H	syll	llamarse

Table C.1: Stress study recorded utterances, speaker MO (continued)

Words	Syll	Segs	Tone	Bound	Gloss
kóma̱ni̱-ná	post	NIN	L	syll	faltar
kómâni̱-ná	post	NIN	L	syll	faltar
tákáā nāní-si̱	post	NIS	H	syll	llamarse
kómâni̱-sí	post	NIS	L	syll	faltar
ko̱o̱ sáa̱n si̱ká-ka̱-sī	post	KAK	H	syll	lejos
ko̱ síka̱-ka̱-sī	post	KAK	L	syll	pedir
ko̱ síkā-kā-rā	post	KAK	M	syll	caminar
ni̱ ku̱síká-nā kwa̱’a̱n-na̱	post	KAN	H	syll	alejar
ni̱ ku̱síká-na̱ kwa̱’a̱n-na̱	post	KAN	H	syll	alejar
na̱yīví nī si̱ka̱-na̱	post	KAN	L	syll	pedir
kwa̱’a̱n si̱ká-sī	post	KAS	H	syll	lejos
sá’a̱n si̱ká-sī	post	KAS	H	syll	lejos
ni̱ si̱ka̱-si̱	post	KAS	L	syll	pedir
nī si̱ka̱-si̱	post	KAS	L	syll	pedir
ko̱o̱ síjíkí-ka̱-na̱	post	KIK	H	syll	jugar
ko̱ kíkī-kā-sī	post	KIK	M	syll	tejer
ko̱ kíkī-ka̱-sī	post	KIK	M	syll	tejer
sí-jíkí-na̱	post	KIN	H	syll	jugar
síjíkí-na̱	post	KIN	H	syll	jugar
kíkī-nā	post	KIN	M	syll	tejer
si̱kíkī-nā	post	KIN	M	syll	tejer
si̱ kíkī-nā	post	KIN	M	syll	tejer
sí-jíkí-sī	post	KIS	H	syll	jugar
kíkī-sī	post	KIS	M	syll	tejer
si̱ kíkī-sī	post	KIS	M	syll	tejer
ko̱ ka̱júsá-ka̱-ra̱	post	SAK	H	syll	flojo
ko̱ kājúsá-ka̱-ra̱	post	SAK	H	syll	flojo
júsá-na̱	post	SAN	H	syll	flojo
kājúsá-na̱	post	SAN	H	syll	flojo
júsá-na̱	post	SAN	H	syll	flojo
ndyu̱sa̱-ná	post	SAN	L	syll	guaraches
ndyúsā-nā	post	SAN	M	syll	vomitar
ndyúsā-nā	post	SAN	M	syll	vomitar
ndyúsā-nā	post	SAN	M	syll	vomitar
kājúsá-sī	post	SAS	H	syll	flojo

Table C.1: Stress study recorded utterances, speaker MO (continued)

Words	Syll	Segs	Tone	Bound	Gloss
kājúsá-sí	post	SAS	H	syll	flojo
ko̱ sa̱sí-ka̱-sī	post	SIK	H	syll	comer
ko̱ sa̱sí-ka̱-sī kwi̱'ī	post	SIK	H	syll	comer
ko̱ kásī-ka̱-sī	post	SIK	M	syll	escoger
ko̱ kásī-ka̱-sī	post	SIK	M	syll	escoger
ko̱ ndásī-kā-rā	post	SIK	M	syll	mojarse
sásí-na̱ kwi̱'ī	post	SIN	H	syll	comer
ku̱'u̱n-na̱ kāsí-na̱ kwi̱'ī	post	SIN	H	syll	comer
kásī-nā kwi̱'ī	post	SIN	M	syll	escoger
kū'ūn-na̱ ka̱sī-nā	post	SIN	M	syll	escoger
kū'u̱n-sī kāsí-si̱	post	SIS	H	syll	comer
kū'u̱n-si ka̱sī-sī	post	SIS	M	syll	escoger
ku̱'u̱n-sī ka̱sī-sī kwi̱'ī	post	SIS	M	syll	escoger

Table C.2: Stress study recorded utterances, speaker MC

Words	Syll	Segs	Tone	Bound	Gloss
ndákā'a̱n-ra̱	pre	DAK	H	utt	hablar
tyi̱ló'o̱ ká nī nda̱kā'a̱n-ra̱	pre	DAK	L	syll	hablar
nda̱kākā-rā	pre	DAK	L	utt	caminar
nda̱kā'a̱n-ra̱	pre	DAK	L	utt	hablar
ni̱ ku̱sáá nda̱kā'a̱n-ra̱	pre	DAK	L	word	hablar
ni̱ ku̱sáá nda̱kā'a̱n-ra̱	pre	DAK	L	word	hablar
ko̱ ní ndākākā-rā	pre	DAK	M	syll	caminar
tyi̱ló'o̱ ká ndánē'ē-rā yu̱u̱	pre	DAN	H	phrase	levantar
tyi̱ló'o̱ káā ndánē'ē-rā īīn yu̱u̱	pre	DAN	H	phrase	levantar
ko̱ ni̱ ndánānā-rā	pre	DAN	H	syll	subir
jándánānā tyūkū-rā	pre	DAN	H	syll	subir
ndánē'ē-rā yu̱u̱	pre	DAN	H	utt	levantar
nda̱nānā-rā	pre	DAN	L	utt	parecer
tyi̱ló'o̱ kā ndānē'ē-rā yu̱u̱	pre	DAN	M	phrase	levantar
ndānē'ē-rā yu̱u̱	pre	DAN	M	utt	levantar
ndānē'ē-rā yu̱u̱	pre	DAN	M	utt	levantar
ndānē'ē-rā yu̱u̱	pre	DAN	M	utt	levantar
ndānē'ē-rā yu̱u̱	pre	DAN	M	utt	levantar

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ko̱ ní nákākā-rā	pre	NAK	H	syll	caminar
nákānī-rā	pre	NAK	H	utt	contar
kūsáá nákā'a̱n-ra̱	pre	NAK	H	word	hablar
ni̱ ku̱sáá nákā'a̱n-ra̱	pre	NAK	H	word	hablar
ni̱ ku̱sāā nákā'a̱n-ra̱	pre	NAK	H	word	hablar
tyi̱ló'o̱ na̱kānī-rā	pre	NAK	L	phrase	contar
tyi̱ló'o̱ na̱kānī-rā tu̱'ūn	pre	NAK	L	phrase	contar
na̱kākā-rā	pre	NAK	L	utt	caminar
ka̱'a̱n sī'i̱n-ra̱ ná nānā-rā	pre	NAN	H	phrase	subir
ka̱'a̱n si̱'i̱n-ra̱ ná nānā-rā	pre	NAN	H	phrase	subir
ka̱'a̱n si̱'i̱n-ra̱ ná nānā-rā	pre	NAN	H	phrase	subir
ko̱ ni̱ nánānā-rā	pre	NAN	H	syll	subir
ko̱ ni̱ nánānā-rā	pre	NAN	H	syll	subir
ka̱'a̱n sī'i̱n-rá .. sī na̱nānā-rā	pre	NAN	L	syll	subir
ka̱'a̱n sī'i̱n-rá sī na̱nānā-rā	pre	NAN	L	syll	subir
na̱nānā-rā	pre	NAN	L	utt	subir
na̱nānā tyúkū-rā	pre	NAN	L	utt	subir
na̱nānā tyúkū-rā	pre	NAN	L	utt	subir
si̱ násīno̱-ra̱	pre	NAS	H	syll	bajar
jānási̱sī	pre	NAS	H	syll	colar
jānási̱sī	pre	NAS	H	syll	entumir
násīno̱-ra̱	pre	NAS	H	utt	bajar
tyi̱ló'o̱ yó'ō si̱ na̱sīno̱-ra̱	pre	NAS	L	syll	bajar
tyi̱ló'o̱ yó'ō si̱ na̱sīno̱-ra̱	pre	NAS	L	syll	bajar
tyi̱ló'o̱ yó'ō .. si̱ na̱sīno̱-ra̱	pre	NAS	L	syll	bajar
na̱sīno̱-ra̱	pre	NAS	L	utt	bajar
na̱sīno̱-ra̱	pre	NAS	L	utt	bajar
tyītya̱kú ní kānī-rā	pre	NIK	H	phrase	pegar
ko̱ ni̱ kánī-rā	pre	NIK	L	syll	pegar
ko̱ ni̱ kánī-rā	pre	NIK	L	syll	pegar
ko̱ ni̱ kánī-rā	pre	NIK	L	syll	pegar
ko̱ ni̱ kánī-rā	pre	NIK	L	syll	pegar
ni̱ kānī-rā	pre	NIK	L	utt	pegar
ko̱ ní nánā-ka̱-ra̱	pre	NIN	H	syll	subir
ko̱ ní nánā-ka̱-ra̱	pre	NIN	H	syll	subir

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ko̲ ní nánā-ka̲-ra̲	pre	NIN	H	syll	subir
tyītya̲kú ni̲-nānā-rā	pre	NIN	L	phrase	subir
tyītya̲kú ni̲-nānā-rā	pre	NIN	L	phrase	subir
tyītya̲kú ni̲-nānā-rā	pre	NIN	L	phrase	subir
tyītya̲kú ko̲ ni̲-nánā-rā	pre	NIN	L	syll	subir
ko̲ ni̲-nánā-rā	pre	NIN	L	syll	subir
ko̲ ní síkā-rā	pre	NIS	H	syll	caminar
ko̲ ní síkā-rā	pre	NIS	H	syll	caminar
ko̲ ní sīkā-rā	pre	NIS	H	syll	caminar
tyi̲tya̲kú ni̲ sīkā-rā	pre	NIS	L	phrase	caminar
nī si̲kā-rā	pre	NIS	M	utt	caminar
tyīva̲lí .. kákānī-rā	pre	KAK	H	phrase	pegar
tyīva̲lī kákānī-rā	pre	KAK	H	phrase	pegar
kákānī-rā	pre	KAK	H	utt	pegar
tyīva̲lí ... ni̲ ka̲kānī tá’ān-rā	pre	KAK	L	syll	pegar
tyi̲va̲lí nī ka̲kānī tá’ān-rā	pre	KAK	L	syll	pegar
ni̲ ka̲kānī tá’ān-rā	pre	KAK	L	syll	pegar
tyīva̲lī kánānā-rā	pre	KAN	H	phrase	subir
kánānā-rā	pre	KAN	H	utt	subir
kánānā-rā	pre	KAN	H	utt	subir
ni̲ ka̲nānā-rā	pre	KAN	L	syll	subir
tyi̲va̲lí nī ka̲nānā-rā	pre	KAN	L	syll	subir
ni̲ ka̲nānā-rā	pre	KAN	L	syll	subir
ni̲ ka̲nānā-rā	pre	KAN	L	syll	subir
tyīva̲lí kásīka̲-rā	pre	KAS	H	phrase	caminar
kásīka̲-rā	pre	KAS	H	utt	caminar
kásīka̲-rā	pre	KAS	H	utt	caminar
kásīka̲-rā	pre	KAS	H	utt	caminar
kásīkā-rā	pre	KAS	H	utt	caminar
kásīkā-rā	pre	KAS	H	utt	caminar
kásíka̲-ra̲	pre	KAS	H	utt	pedir
tyīva̲lí .. ni̲ ka̲sīkā-rā	pre	KAS	L	syll	caminar
tyīva̲lí ní ka̲sīkā-rā	pre	KAS	L	syll	caminar
ni̲ ka̲sīkā-rā	pre	KAS	L	syll	caminar
ko̲ sí kákā-rā	pre	SIK	H	syll	caminar

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ko̱ sí kákā-rā	pre	SIK	H	syll	caminar
ko̱o̱ síkānī-rā	pre	SIK	H	word	pegar
tyi̱ló’o̱ ká si̱ ká’a̱n-ra̱	pre	SIK	L	phrase	hablar
si̱-kānī-rā	pre	SIK	L	utt	pegar
tyi̱ló’o̱ ká sī-kānī-rā	pre	SIK	M	phrase	pegar
sī-kānī-rā	pre	SIK	M	utt	pegar
tyi̱ló’o̱ ká ko̱ sí-nānā-rā	pre	SIN	H	syll	subir
ko̱ sí-nānā-rā	pre	SIN	H	syll	subir
tyi̱ló’o̱ ká ko̱ sí-nānā-rā	pre	SIN	H	syll	subir
ko̱ sí-nánā-rā	pre	SIN	H	syll	subir
ko̱ sí-nānā-rā	pre	SIN	H	syll	subir
tyi̱ló’o̱ ká si̱nānā-rā	pre	SIN	L	phrase	subir
si̱nānā-rā	pre	SIN	L	utt	subir
ko̱ sí síkā-rā	pre	SIS	H	syll	caminar
ko̱ sí síkā-rā	pre	SIS	H	syll	caminar
tyi̱ló’o̱ ká si̱sīkā-rā	pre	SIS	L	phrase	caminar
si̱ ndáka̱-ra̱ kōtó-rā	tonic	DAK	H	syll	pedir
ndáka̱-ra̱ kōtó-rā	tonic	DAK	H	utt	pedir
ndáka̱-ra̱ kōtó-rā	tonic	DAK	H	utt	pedir
sī ni̱ nda̱ka̱-ra̱ kōtó-rā	tonic	DAK	L	syll	pedir
sī ni̱ nda̱ka̱-ra̱ kōto-ún	tonic	DAK	L	syll	pedir
tyi̱ló’o̱ si̱ ndásī-rā	tonic	DAS	H	syll	mojar
si̱ ndásī-rā	tonic	DAS	H	syll	mojar
si̱ nda̱sí-rā	tonic	DAS	L	syll	desatar
si̱ nda̱sí-rā	tonic	DAS	L	syll	desatar
tyi̱ló’o̱ si̱ ni̱ ndāsí-rā	tonic	DAS	M	syll	desatar
sī ni̱ ndāsí-rā	tonic	DAS	M	syll	desatar
tyi̱ló’o̱ si̱ ni̱ ndāsī-rā	tonic	DAS	M	syll	mojar
si̱ ni̱ ndāsī-rā	tonic	DAS	M	syll	mojar
tyi̱ló’o̱ ndyíko̱-ra̱ ta̱tá-rā	tonic	DIK	H	phrase	seguir
si̱ ndyíko̱-ra̱ ta̱tá-rā	tonic	DIK	H	syll	seguir
si̱ ndyíko̱-ra̱ ta̱tá-rā	tonic	DIK	H	syll	seguir
ndyíko̱-ra̱ ta̱tá-rā	tonic	DIK	H	utt	seguir
ndyíko̱-ra̱ ta̱tá-rā	tonic	DIK	H	utt	seguir
ndyíko̱-ra̱ ta̱tá-rā	tonic	DIK	H	utt	seguir

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
si̱ ni̱ na̱ndyi̱ko̱-ra̱ ta̱tá-rā	tonic	DIK	L	syll	seguir
si̱ ni̱ na̱ndyīko̱-ra̱ ta̱tá-rā	tonic	DIK	L	syll	seguir
sī na̱ndyīko̱-ra̱ ta̱tá-rá	tonic	DIK	M	syll	seguir
si̱ na̱ndyīko̱-ra̱	tonic	DIK	M	syll	seguir
ndávā ndyísí-rí	tonic	DIS	H	word	ala
lāā ndávā ndyísí-rí	tonic	DIS	H	word	ala
tyívī ndyi̱si̱-rǐ	tonic	DIS	L	word	ala
si̱ tyívī ndyi̱si̱-rǐ	tonic	DIS	L	word	ala
si̱ nánā-nā	tonic	NAN	H	syll	subir
si̱ nánā-rā	tonic	NAN	H	syll	subir
si̱ kua̱nānā-nā	tonic	NAN	M	syll	subir
si̱ kua̱nānā-nā nu̱ú ndyi̱kā	tonic	NAN	M	syll	subir
si̱ sínānā-rā	tonic	NAN	M	syll	subir
sī ni̱ nānā-rā	tonic	NAN	M	syll	subir
si̱ kua̱nānā-rā	tonic	NAN	M	syll	subir
si̱ kua̱nānā-rā	tonic	NAN	M	syll	subir
chīndyáā ndyī-ni̱nō	tonic	NIN	L	syll	arriba
chīndyáā ndyī-ni̱nō	tonic	NIN	L	syll	arriba
tyi̱ló’o̱ si̱ kákū-rā	tonic	KAK	H	syll	nacer
si̱ kákū-rā	tonic	KAK	H	syll	nacer
tyi̱ló’o̱ ku̱’u̱n-ra̱ ka̱ka̱-ra̱ kwi̱’ī	tonic	KAK	L	phrase	pedir
si̱ ka̱ka̱-ra̱ kwi̱’ī	tonic	KAK	L	syll	pedir
tyi̱ló’o̱ na̱kākā-rā	tonic	KAK	M	syll	caminar
si̱ na̱kākā-rā	tonic	KAK	M	syll	caminar
kāka̱-ra̱ kwi̱’i̱	tonic	KAK	M	utt	pedir
tyi̱ló’o̱ si̱ kánī-rā	tonic	KAN	H	syll	pegar
si̱ kánī-rā	tonic	KAN	H	syll	pegar
si̱ kání-rā	tonic	KAN	H	syll	pegar
kánī-rā	tonic	KAN	H	utt	pegar
kání-rā	tonic	KAN	H	utt	pegar
tyi̱ló’o̱ .. si̱ ni̱ kānī-rā	tonic	KAN	M	syll	pegar
si̱ ni̱ kānī-rā	tonic	KAN	M	syll	pegar
tyi̱ló’o̱ si̱ ni̱ ka̱sī-rā kui̱’ī	tonic	KAS	L	syll	escoger
si̱ ni̱ ka̱sī-rā kui̱’ī	tonic	KAS	L	syll	escoger
ka̱sī-rā kwi̱’ī	tonic	KAS	L	utt	escoger

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ka̱sī-rā kwi̱'ī	tonic	KAS	L	utt	escoger
ka̱sī-rā já'ma̱	tonic	KAS	L	utt	escoger
ka̱sī-rā kwi̱'ī	tonic	KAS	L	utt	escoger
na̱kāsí-rā	tonic	KAS	M	syll	comer
na̱kāsí-rá	tonic	KAS	M	syll	comer
si̱ kāsí-rā kwi̱'ī	tonic	KAS	M	syll	comer
si̱ kāsí-rā kwi̱'ī	tonic	KAS	M	syll	comer
kāsí-rā kwi̱'ī	tonic	KAS	M	utt	comer
kāsí-rā	tonic	KAS	M	utt	comer
tyi̱ló'o̱ si̱ kíkī-rā	tonic	KIK	H	syll	coser
tyi̱ló'o̱ si̱ kíkī-ra̱	tonic	KIK	H	syll	coser
si̱ ni̱ ki̱kī-rā	tonic	KIK	L	syll	coser
sī ni̱ ki̱kī-rā	tonic	KIK	L	syll	coser
kíní-ra̱ īlō	tonic	KIN	H	utt	cazar
si̱ ki̱ní-ra̱	tonic	KIN	L	syll	cazar
si̱ kǐní-ra̱	tonic	KIN	L	syll	cazar
si̱ ni̱ kīní-ra̱	tonic	KIN	M	syll	cazar
si̱ ni̱ kīní-ra̱ īlō	tonic	KIN	M	syll	cazar
kīní-ra̱	tonic	KIN	M	syll	cazar
ja̱ā kīní-ra̱	tonic	KIN	M	word	cazar
ja̱ā kīní-ra̱	tonic	KIN	M	word	cazar
si̱ síkísī-rā	tonic	KIS	H	syll	venir
si̱ sī kísī-rā	tonic	KIS	H	syll	venir
si̱ síkísī-rā	tonic	KIS	H	syll	venir
ni̱ kīsí-rā	tonic	KIS	M	syll	venir
si̱ ni̱ kīsī-rā	tonic	KIS	M	syll	venir
si̱ ni̱ kīsī-rā	tonic	KIS	M	syll	venir
tyi̱lóo si̱ sákū-rā	tonic	SAK	H	syll	llorar
tyi̱ló'o̱ si̱ sákū-rā	tonic	SAK	H	syll	llorar
tyi̱ló'o̱ ... si̱ sáku̱-ra̱	tonic	SAK	H	syll	reir
si̱ sáku̱-ra̱	tonic	SAK	H	syll	reir
tyi̱ló'o̱ si̱ ni̱ sāku̱-ra̱	tonic	SAK	L	syll	reir
si̱ ni̱ sa̱ku̱-ra̱	tonic	SAK	L	syll	reir
tyi̱ló'o̱ sī ni̱ sākū-rā	tonic	SAK	M	syll	llorar
sī ni̱ sākū-rā	tonic	SAK	M	syll	llorar

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
sání-ra̱	tonic	SAN	H	utt	desbaratar
sání-ra̱	tonic	SAN	H	utt	desbaratar
sání-ra̱	tonic	SAN	H	utt	soñar
tyi̱ló’o̱ si̱ sǎní-rā-tyi̱	tonic	SAN	L	syll	desbaratar
tyi̱ló’o̱ si̱ sǎní-rā	tonic	SAN	L	syll	desbaratar
si̱ sǎní-rā	tonic	SAN	L	syll	desbaratar
si̱ sa̱ní-ra̱	tonic	SAN	L	syll	desbaratar
si̱ sǎní-rā	tonic	SAN	L	syll	desbaratar
tyi̱ló’o̱ si̱ sǎní-ra̱	tonic	SAN	L	syll	soñar
ni̱ sa̱ní-ra̱	tonic	SAN	L	syll	soñar
si̱sa̱ní-rā	tonic	SAN	L	syll	soñar
si̱sa̱ní-rā	tonic	SAN	L	syll	soñar
si̱sa̱ní-ra̱	tonic	SAN	L	syll	soñar
si̱sa̱nǐ-ra̱	tonic	SAN	L	syll	soñar
si̱sa̱nǐ-ra̱	tonic	SAN	L	syll	soñar
si̱sāní-rá	tonic	SAN	M	syll	desbaratar
si̱sāní-rā	tonic	SAN	M	syll	desbaratar
si̱sāní-rā	tonic	SAN	M	syll	desbaratar
si̱ ni̱ sāní-rā	tonic	SAN	M	syll	desbaratar
si̱ ni̱ sāní-rā	tonic	SAN	M	syll	desbaratar
tyi̱ló’o̱ si̱ sa̱sí-rā kui̱’ī	tonic	SAS	L	syll	comer
tyi̱ló’o̱ si̱ sa̱sí-rā kui̱’ī	tonic	SAS	L	syll	comer
si̱ ni̱ sāsí-rá kwi̱’ī	tonic	SAS	M	syll	comer
si̱ ni̱ sāsí-rá kwi̱’ī	tonic	SAS	M	syll	comer
tyi̱ló’o̱ si̱ síkā-rā	tonic	SIK	H	syll	caminar
tyi̱ló’o̱ si̱ síkā-rā	tonic	SIK	H	syll	caminar
tyi̱ló’o̱ si̱ síkā-rā	tonic	SIK	H	syll	caminar
si̱ síka̱-ra̱ kōtó-rā	tonic	SIK	H	syll	pedir
si̱ síka̱-ra̱	tonic	SIK	H	syll	pedir
si̱ síka̱-ra̱ kōtó-rā	tonic	SIK	H	syll	pedir
síka̱-ra̱ kōtó	tonic	SIK	H	utt	pedir
ni̱ si̱ka̱-ra̱ kwi̱’ī	tonic	SIK	L	syll	pedir
tyi̱ló’o̱ sī ni̱ sīka̱-ra̱	tonic	SIK	M	syll	pedir
tyi̱ló’o̱ si̱ ni̱ sīka̱-ra̱	tonic	SIK	M	syll	pedir
ni̱ sīka̱-ra̱ kwi̱’ī	tonic	SIK	M	syll	pedir

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
ni̱ ku̱sa̱á tyúkū-rā sínō-rā	tonic	SIN	H	phrase	correr
ni̱ ku̱sa̱ā tyúkū-rā sínō-rā	tonic	SIN	H	phrase	correr
tyīló'o̱ si̱ sínō-rā	tonic	SIN	H	syll	correr
si̱ sínō-rā	tonic	SIN	H	syll	correr
nāsīno̱-ra̱	tonic	SIN	L	syll	bajar
na̱sīno̱-ra̱	tonic	SIN	M	syll	bajar
si̱ na̱sīno̱-ra̱	tonic	SIN	M	syll	bajar
ni̱ sīno̱-ra̱	tonic	SIN	M	syll	bajar
na̱sīno̱-ra̱	tonic	SIN	M	syll	bajar
tyi̱ló'o̱ sī na̱sīno̱-ra̱	tonic	SIN	M	syll	bajar
tyi̱ló'o̱ si̱ na̱sīno̱-ra̱	tonic	SIN	M	syll	bajar
tyīló'o̱ si̱ sísī-rā xi̱ta̱	tonic	SIS	H	syll	comer
tyi̱ló'o̱ si̱ sísī-rā xi̱ta̱	tonic	SIS	H	syll	comer
nāsi̱sī-rā	tonic	SIS	L	syll	entumir
si̱ ni̱ si̱sī-rā	tonic	SIS	L	syll	entumir
si̱ ni̱ si̱si̱-rā	tonic	SIS	L	syll	entumir
na̱si̱sī-rā	tonic	SIS	L	syll	entumir
ni̱ sīsī-rā	tonic	SIS	M	syll	comer
ko̱ su̱ná-ká-na̱	post	NAK	H	syll	abrir
ko̱ su̱ná-ká-na̱	post	NAK	H	syll	abrir
ko̱ su̱ná-ka̱-na̱	post	NAK	H	syll	abrir
ndyíko̱-ra̱ mēé tyi̱nā ká .. ra̱	post	NAK	M	syll	perro
ko̱ kánā-ka̱-na̱	post	NAK	M	syll	salir
súná-na̱	post	NAN	H	syll	abrir
súná-na̱ ye̱'é	post	NAN	H	syll	abrir
súná-na̱ ye̱'é	post	NAN	H	syll	abrir
tyi̱tya̱ā ká kūná-na̱ ye̱'é	post	NAN	H	syll	abrir
si̱ kánā-nā	post	NAN	M	syll	salir
si̱ kánā-nā	post	NAN	M	syll	salir
si̱ kánā-nā	post	NAN	M	syll	salir
kūná-sī	post	NAS	H	syll	abrir
kūná-sī yé'é	post	NAS	H	syll	abrir
kūná-sī yé'é	post	NAS	H	syll	abrir
kānā-sī	post	NAS	M	syll	salir
kānā-sī	post	NAS	M	syll	salir

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
kānā-sī	post	NAS	M	syll	salir
kānā-sí kū’u̠n-sī	post	NAS	M	syll	salir
kānā-sī kū’u̠n-sī	post	NAS	M	syll	salir
kānā-sī kū’u̠n-sī	post	NAS	M	syll	salir
ko̠ na̠ní-kā-na̠	post	NIK	H	syll	llamarse
ko̠ na̠ní-kā-na̠	post	NIK	H	syll	llamarse
ko̠ na̠ní-kā-na̠	post	NIK	H	syll	llamarse
ko̠ na̠ní-kā-na̠	post	NIK	H	syll	llamarse
ko̠ na̠ní-ká-na̠	post	NIK	H	syll	llamarse
ko̠ kíxi ma̠ni̠-ká-na̠	post	NIK	L	syll	faltar
ko̠ kíxi ma̠ni̠-ká-na̠	post	NIK	L	syll	faltar
tākáá ko̠ kíxī ma̠ni̠-ká-sī	post	NIK	L	syll	faltar
ko̠ kíxī ma̠ni̠-ká-sī	post	NIK	L	syll	faltar
na̠káā ñānínā	post	NIN	H	syll	llamarse
na̠káā ñānínā	post	NIN	H	syll	llamarse
kíxi māni̠nǎ	post	NIN	L	syll	faltar
nāní-sī	post	NIS	H	syll	llamarse
nāní-sī	post	NIS	H	syll	llamarse
tā-yó’ō nāní-sī	post	NIS	H	syll	llamarse
tā-yó’ō nāní-sī	post	NIS	H	syll	llamarse
kíxī ma̠ni̠-sí	post	NIS	L	syll	faltar
kíxī ma̠ni̠-sí	post	NIS	L	syll	faltar
ko̠ kíxī ma̠ni̠-sí	post	NIS	L	syll	faltar
Words	Syll	Segs	Tone	Bound	Gloss
na̠yīví ... kāsījíkí-na̠	post	KIN	H	syll	jugar
na̠yīvi kāsījíkí-na̠	post	KIN	H	syll	jugar
na̠yīví kāsījíkí-na̠	post	KIN	H	syll	jugar
nāyīví kāsījíkí-na̠	post	KIN	H	syll	jugar
kíkī-nā	post	KIN	M	syll	coser
táñá’a̠ ... kíkī-sī	post	KIS	M	syll	coser
táñá’a̠ kíkī-sī	post	KIS	M	syll	coser
náñá’a̠ kíkī-sī	post	KIS	M	syll	coser
kíkī-sī	post	KIS	M	syll	coser
táñá’a̠ si̠ kíkī-sī	post	KIS	M	syll	coser
júsá-ka̠-ra̠	post	SAK	H	syll	flojo

Table C.2: Stress study recorded utterances, speaker MC (continued)

Words	Syll	Segs	Tone	Bound	Gloss
júsá-kā-ra̱	post	SAK	H	syll	flojo
ko̱ ju̱sá-kā-ra̱	post	SAK	H	syll	flojo
na̱yīví júsá-na̱	post	SAN	H	syll	flojo
na̱yīví júsá-na̱	post	SAN	H	syll	flojo
na̱yīví júsá-na̱	post	SAN	H	syll	flojo
júsá-na̱	post	SAN	H	syll	flojo
júsá-na̱	post	SAN	H	syll	flojo
nándyúkú-nā ju̱sā-na̱	post	SAN	M	syll	copal
tásīva̱ā júsá-sī	post	SAS	H	syll	flojo
nándyúkú-sī ju̱sa̱-sī	post	SAS	L	syll	copal
nandyuku-si ju̱sa̱-sī	post	SAS	L	syll	copal
nándyúkú-sī ju̱sā-sī	post	SAS	M	syll	copal
ko̱ sa̱sí-kā-na̱ kwi̱’i̱	post	SIK	H	syll	comer
ko̱ sa̱sí-kā-na̱ kwi̱’i̱	post	SIK	H	syll	comer
ko̱ sa̱sí-kā-nā kwi̱’i̱	post	SIK	H	syll	comer
ko̱ sa̱sí-kā-na̱ kwi̱’i̱	post	SIK	H	syll	comer
ko̱ kásī-ka̱-na̱	post	SIK	M	syll	escoger
ko̱ kásī-ka̱-na̱ kwi̱’i̱	post	SIK	M	syll	escoger
ko̱ kásī-ka̱-na̱ kwi̱’i̱	post	SIK	M	syll	escoger
kāsí-nā kwi̱’i̱	post	SIN	H	syll	comer
na̱yīví kāsí-nā kwi̱’i̱	post	SIN	H	syll	comer
na̱yīví ... kāsí-nā kwi̱’i̱	post	SIN	H	syll	comer
ku̱’u̱n-nā ka̱sīnā kwi̱’ī	post	SIN	M	syll	escoger
tātya̱a̱ kāsí-sí kwi̱’i̱	post	SIS	H	syll	comer
tātya̱a̱ kāsí-sí kwi̱’i̱	post	SIS	H	syll	comer
tátya̱a̱ kāsí-sí kwi̱’i̱	post	SIS	H	syll	comer
tātya̱a̱ kāsí-sī	post	SIS	H	syll	comer
ka̱sī-sī kwi̱’i̱	post	SIS	M	syll	escoger
tátya̱a̱ ka̱sī-sī kwi̱’ī	post	SIS	M	syll	escoger

C.2 Regression models

Table C.3: Vowel duration model for speaker MO: VDur ~RDur + Tone + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 25.096$, p(2) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(12)
	(Intercept)	90.677	85.328	96.026	2.729	33.23	0.000
RDur	(centered)	0.121	0.099	0.143	0.011	10.83	0.000
T:	L (1) v. M (-1)	4.094	0.044	8.144	2.066	1.98	0.035
T:	H (1) v. M (-1)	-5.994	-9.187	-2.801	1.629	-3.68	0.002
C1:	[ⁿd] (1) v. [s] (-1)	7.599	1.768	13.430	2.975	2.55	0.013
C1:	[k] (1) v. [s] (-1)	-9.357	-14.016	-4.698	2.377	-3.94	0.001
C1:	[n] (1) v. [s] (-1)	14.319	9.167	19.471	2.629	5.45	0.000
C2:	[k] (1) v. [s] (-1)	-11.593	-15.635	-7.551	2.062	-5.62	0.000
C2:	[n] (1) v. [s] (-1)	6.316	2.326	10.305	2.036	3.10	0.005
V:	[a] (1) v. [i] (-1)	11.009	8.139	13.878	1.464	7.52	0.000
Syll:	pre (1) v. ton (0)	-23.116	-30.957	-15.274	4.001	-5.78	0.000
Syll:	post (1) v. ton (0)	-21.559	-27.794	-15.324	3.181	-6.78	0.000

Table C.4: Vowel duration model for speaker MC: VDur ~RDur + Tone + C1 + C2 + V + (Syll +Tone | Segs) + Syll, $X^2 = 19.857$; p(2) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(10)
	(Intercept)	107.964	101.206	114.721	3.448	31.31	0.000
RDur	(centered)	0.150	0.134	0.166	0.008	18.42	0.000
T:	L (1) v. M (-1)	1.528	-1.018	4.075	1.299	1.18	0.133
T:	H (1) v. M (-1)	-1.230	-3.379	0.919	1.097	-1.12	0.144
C1:	[ⁿd] (1) v. [s] (-1)	-0.759	-7.119	5.600	3.245	-0.23	0.410
C1:	[k] (1) v. [s] (-1)	-5.262	-9.501	-1.023	2.163	-2.43	0.018
C1:	[n] (1) v. [s] (-1)	16.595	12.790	20.399	1.941	8.55	0.000
C2:	[k] (1) v. [s] (-1)	-4.556	-7.520	-1.593	1.512	-3.01	0.007
C2:	[n] (1) v. [s] (-1)	1.056	-1.762	3.874	1.438	0.73	0.240
V:	[a] (1) v. [i] (-1)	2.889	0.405	5.373	1.268	2.28	0.023
Syll:	pre (1) v. ton (0)	-27.499	-39.125	-15.873	5.932	-4.64	0.000
Syll:	post (1) v. ton (0)	-33.310	-41.109	-25.512	3.979	-8.37	0.000

Table C.5: Intensity model for speaker MO: Int ~RDur + Tone + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 9.9358$, p(2) = 0.007

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(12)
	(Intercept)	68.812	68.149	69.475	0.338	203.52	0.000
RDur	(centered)	-0.000	-0.004	0.004	0.002	-0.07	0.471
T:	L (1) v. M (-1)	-2.587	-3.329	-1.845	0.379	-6.83	0.000
T:	H (1) v. M (-1)	1.578	0.994	2.163	0.298	5.29	0.000
C1:	[^{n}d] (1) v. [s] (-1)	0.647	-0.159	1.453	0.411	1.57	0.071
C1:	[k] (1) v. [s] (-1)	-0.469	-1.114	0.176	0.329	-1.43	0.090
C1:	[n] (1) v. [s] (-1)	0.971	0.185	1.757	0.401	2.42	0.016
C2:	[k] (1) v. [s] (-1)	-0.453	-1.026	0.120	0.292	-1.55	0.074
C2:	[n] (1) v. [s] (-1)	0.858	0.313	1.402	0.278	3.09	0.005
V1:	[a] (1) v. [i] (-1)	-0.268	-0.665	0.130	0.203	-1.32	0.106
Syll:	pre (1) v. ton (0)	0.220	-0.865	1.306	0.554	0.40	0.349
Syll:	post (1) v. ton (0)	-1.924	-2.858	-0.990	0.476	-4.04	0.001

Table C.6: Intensity model for speaker MC: Int ~RDur + Tone + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 22.921$, p(2) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(10)
	(Intercept)	71.961	71.403	72.518	0.284	252.95	0.000
RDur	(centered)	0.001	-0.002	0.005	0.002	0.78	0.226
T:	L (1) v. M (-1)	-1.824	-2.336	-1.312	0.261	-6.98	0.000
T:	H (1) v. M (-1)	1.996	1.408	2.585	0.300	6.65	0.000
C1:	[^{n}d] (1) v. [s] (-1)	0.312	-0.440	1.064	0.384	0.81	0.217
C1:	[k] (1) v. [s] (-1)	-0.174	-0.824	0.476	0.332	-0.52	0.306
C1:	[n] (1) v. [s] (-1)	-0.009	-0.726	0.707	0.366	-0.03	0.490
C2:	[k] (1) v. [s] (-1)	-1.250	-1.793	-0.708	0.277	-4.52	0.001
C2:	[n] (1) v. [s] (-1)	1.300	0.790	1.809	0.260	5.00	0.000
V1:	[a] (1) v. [i] (-1)	0.759	0.365	1.152	0.201	3.78	0.002
Syll:	pre (1) v. ton (0)	-4.134	-5.051	-3.216	0.468	-8.83	0.000
Syll:	post (1) v. ton (0)	-1.625	-3.104	-0.147	0.754	-2.15	0.028

Table C.7: Onset duration model for speaker MO: C1Dur ~RDur + Tone + C1 + C2 + V + (Syll +Tone | Segs) + Syll; $X^2 = 9.0958$, p(2) = 0.011

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(12)
	(Intercept)	116.092	111.461	120.724	2.363	49.13	0.000
RDur	(centered)	0.218	0.189	0.248	0.015	14.65	0.000
T:	L (1) v. M (-1)	-1.365	-6.206	3.476	2.470	-0.55	0.295
T:	H (1) v. M (-1)	2.884	-0.663	6.431	1.810	1.59	0.069
C1:	[^{n}d] (1) v. [s] (-1)	-3.148	-8.750	2.453	2.858	-1.10	0.146
C1:	[k] (1) v. [s] (-1)	15.609	10.748	20.471	2.480	6.29	0.000
C1:	[n] (1) v. [s] (-1)	-29.304	-35.264	-23.343	3.041	-9.64	0.000
C2:	[k] (1) v. [s] (-1)	-3.940	-8.162	0.282	2.154	-1.83	0.046
C2:	[n] (1) v. [s] (-1)	9.913	5.738	14.089	2.130	4.65	0.000
V:	[a] (1) v. [i] (-1)	-5.815	-8.786	-2.844	1.516	-3.84	0.001
Syll:	pre (1) v. ton (0)	-8.846	-16.250	-1.441	3.778	-2.34	0.019
Syll:	post (1) v. ton (0)	4.698	-3.198	12.593	4.029	1.17	0.133

Table C.8: Onset duration model for speaker MC: C1Dur ∼RDur + Tone + C1 + C2 + V + (Syll + Tone | Segs) + Syll; $X^2 = 3.9431$, p(2) = 0.139

Var	Param	Estimate	CI [low, high]		Std Err	t	p(10)
	(Intercept)	123.734	117.983	129.484	2.934	42.17	0.000
RDur	(centered)	0.182	0.161	0.204	0.011	16.80	0.000
T:	L (1) v. M (-1)	-2.424	-6.594	1.745	2.127	-1.14	0.140
T:	H (1) v. M (-1)	0.284	-2.872	3.439	1.610	0.18	0.432
C1:	[^{n}d] (1) v. [s] (-1)	6.229	-0.221	12.679	3.291	1.89	0.044
C1:	[k] (1) v. [s] (-1)	9.572	4.761	14.384	2.455	3.90	0.001
C1:	[n] (1) v. [s] (-1)	-30.373	-35.093	-25.654	2.408	-12.61	0.000
C2:	[k] (1) v. [s] (-1)	3.542	-0.299	7.383	1.960	1.81	0.050
C2:	[n] (1) v. [s] (-1)	0.422	-3.245	4.088	1.871	0.23	0.413
V:	[a] (1) v. [i] (-1)	-1.044	-3.917	1.829	1.466	-0.71	0.246
Syll:	pre (1) v. ton (0)	-9.740	-17.969	-1.511	4.199	-2.32	0.021
Syll:	post (1) v. ton (0)	-4.397	-12.690	3.896	4.231	-1.04	0.162

Table C.9: Following consonant duration model for speaker MO: C2Dur ∼Tone + RDur + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 27.733$, p(2) = 0.000

Var	Param	Estimate	CI [low, high]		Std Err	t	p(12)
	(Intercept)	127.999	118.450	137.547	4.872	26.27	0.000
RDur	(centered)	0.162	0.129	0.194	0.017	9.68	0.000
T:	L (1) v. M (-1)	-0.763	-5.135	3.609	2.231	-0.34	0.369
T:	H (1) v. M (-1)	1.075	-3.260	5.410	2.212	0.49	0.318
C1:	[^{n}d] (1) v. [s] (-1)	-6.257	-12.488	-0.026	3.179	-1.97	0.036
C1:	[k] (1) v. [s] (-1)	5.651	0.290	11.012	2.735	2.07	0.031
C1:	[n] (1) v. [s] (-1)	2.075	-3.949	8.100	3.074	0.68	0.256
C2:	[k] (1) v. [s] (-1)	8.787	4.252	13.321	2.314	3.80	0.001
C2:	[n] (1) v. [s] (-1)	-25.867	-30.344	-21.390	2.284	-11.32	0.000
V1:	[a] (1) v. [i] (-1)	-3.714	-6.951	-0.478	1.651	-2.25	0.022
Syll:	pre (1) v. ton (0)	-11.754	-24.433	0.926	6.469	-1.82	0.047
Syll:	post (1) v. ton (0)	-44.832	-58.995	-30.668	7.226	-6.20	0.000

Table C.10: Following consonant duration model for speaker MC: C2Dur ~Tone + RDur + C1 + C2 + V + (Syll + Tone| Segs) + Syll; $X^2 = 12.995$, p(2) = 0.002

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(10)
	(Intercept)	114.482	110.308	118.655	2.129	53.76	0.000
RDur	(centered)	0.131	0.114	0.148	0.009	15.16	0.000
T:	L (1) v. M (-1)	0.025	-3.675	3.725	1.888	0.01	0.495
T:	H (1) v. M (-1)	0.004	-3.490	3.498	1.783	0.00	0.499
C1:	[ⁿd] (1) v. [s] (-1)	3.949	-0.860	8.759	2.454	1.61	0.069
C1:	[k] (1) v. [s] (-1)	1.927	-1.668	5.523	1.834	1.05	0.159
C1:	[n] (1) v. [s] (-1)	-0.510	-4.394	3.374	1.982	-0.26	0.401
C2:	[k] (1) v. [s] (-1)	3.987	0.943	7.032	1.553	2.57	0.014
C2:	[n] (1) v. [s] (-1)	-23.804	-26.705	-20.902	1.480	-16.08	0.000
V1:	[a] (1) v. [i] (-1)	-2.690	-5.077	-0.303	1.218	-2.21	0.026
Syll:	pre (1) v. ton (0)	0.045	-7.132	7.222	3.662	0.01	0.495
Syll:	post (1) v. ton (0)	-24.013	-34.563	-13.464	5.382	-4.46	0.001

Table C.11: Vowel quality (F1) model for speaker MO: 12*log2(F1) ~ Tone + RDur + C1 + C2 + V × Syll + (Syll + Tone | Segs); $X^2 = 34.1$, p(4) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(10)
	(Intercept)	104.484	103.889	105.079	0.304	344.01	0.000
RDur	(centered)	0.005	0.002	0.009	0.002	2.88	0.008
T:	L (1) v. M (-1)	0.151	-0.475	0.777	0.319	0.47	0.323
T:	H (1) v. M (-1)	-0.343	-0.795	0.108	0.230	-1.49	0.083
C1:	[ⁿd] (1) v. [s] (-1)	0.101	-0.645	0.847	0.381	0.27	0.398
C1:	[k] (1) v. [s] (-1)	-0.634	-1.262	-0.007	0.320	-1.98	0.038
C1:	[n] (1) v. [s] (-1)	-0.165	-0.918	0.588	0.384	-0.43	0.338
C2:	[k] (1) v. [s] (-1)	-0.592	-1.138	-0.047	0.278	-2.13	0.030
C2:	[n] (1) v. [s] (-1)	0.325	-0.207	0.857	0.271	1.20	0.129
V:	[a] (1) v. [i] (-1)	7.435	6.891	7.979	0.277	26.81	0.000
Syll:	pre (1) v. ton (0)	0.880	-0.052	1.812	0.476	1.85	0.047
Syll:	post (1) v. ton (0)	-0.652	-1.757	0.454	0.564	-1.16	0.137
V×Syll:	pre [a] v. [i]	-3.090	-3.942	-2.238	0.435	-7.11	0.000
V×Syll:	post [a] v. [i]	-2.159	-3.234	-1.084	0.549	-3.94	0.001

Table C.12: Vowel quality (F1) model for speaker MC: 12*log2(F1) ~ Tone + RDur + C1 + C2 + V × Syll + (Syll + Tone | Segs); $X^2 = 26.2$, p(4) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(8)
	(Intercept)	110.515	109.908	111.122	0.310	356.84	0.000
RDur	(centered)	0.006	0.002	0.009	0.002	3.11	0.007
T:	L (1) v. M (-1)	-0.380	-0.922	0.161	0.276	-1.38	0.103
T:	H (1) v. M (-1)	0.504	-0.010	1.018	0.262	1.92	0.045
C1:	[ⁿd] (1) v. [s] (-1)	0.673	-0.365	1.712	0.530	1.27	0.120
C1:	[k] (1) v. [s] (-1)	-0.306	-1.112	0.501	0.411	-0.74	0.239
C1:	[n] (1) v. [s] (-1)	-0.684	-1.762	0.394	0.550	-1.24	0.124
C2:	[k] (1) v. [s] (-1)	-0.738	-1.452	-0.023	0.365	-2.02	0.039
C2:	[n] (1) v. [s] (-1)	0.672	-0.007	1.351	0.346	1.94	0.044
V:	[a] (1) v. [i] (-1)	6.414	5.867	6.961	0.279	22.98	0.000
Syll:	pre (1) v. ton (0)	-1.518	-2.854	-0.182	0.682	-2.23	0.028
Syll:	post (1) v. ton (0)	-2.173	-3.363	-0.984	0.607	-3.58	0.004
V×Syll:	pre [a] v. [i]	-2.527	-3.802	-1.251	0.651	-3.88	0.002
V×Syll:	post [a] v. [i]	-4.172	-5.233	-3.110	0.542	-7.70	0.000

Table C.13: Mid-band spectral tilt model for speaker MO: H1.A2 ~ RDur + Tone + C1 + C2 + V + (Syll+Tone | Segs) + Syll; $X^2 = 6.6586$, p(2) = 0.036

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(12)
	(Intercept)	4.308	3.949	4.667	0.183	23.52	0.000
RDur	(centered)	0.004	0.001	0.006	0.001	3.08	0.005
T:	L (1) v. M (-1)	0.585	0.264	0.906	0.164	3.57	0.002
T:	H (1) v. M (-1)	-0.381	-0.763	0.001	0.195	-1.95	0.037
C1:	[ⁿd] (1) v. [s] (-1)	-0.019	-0.466	0.427	0.228	-0.08	0.467
C1:	[k] (1) v. [s] (-1)	-0.225	-0.586	0.136	0.184	-1.22	0.123
C1:	[n] (1) v. [s] (-1)	-0.186	-0.601	0.230	0.212	-0.88	0.199
C2:	[k] (1) v. [s] (-1)	-0.433	-0.746	-0.120	0.160	-2.71	0.009
C2:	[n] (1) v. [s] (-1)	0.285	-0.019	0.588	0.155	1.84	0.046
V1:	[a] (1) v. [i] (-1)	0.835	0.620	1.051	0.110	7.60	0.000
Syll:	pre (1) v. ton (0)	0.915	0.249	1.581	0.340	2.69	0.010
Syll:	post (1) v. ton (0)	0.031	-0.543	0.605	0.293	0.10	0.459

Table C.14: Mid-band spectral tilt model for speaker MC: H1.A2 ∼ RDur + Tone + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 5.5144$, p(2) = 0.063

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(10)
	(Intercept)	5.313	4.807	5.819	0.258	20.57	0.000
RDur	(centered)	-0.003	-0.006	-0.000	0.001	-2.16	0.028
T:	L (1) v. M (-1)	-0.545	-0.944	-0.147	0.203	-2.68	0.011
T:	H (1) v. M (-1)	0.651	0.295	1.007	0.181	3.59	0.002
C1:	[ⁿd] (1) v. [s] (-1)	-0.138	-0.910	0.634	0.394	-0.35	0.366
C1:	[k] (1) v. [s] (-1)	-0.181	-0.810	0.447	0.321	-0.57	0.292
C1:	[n] (1) v. [s] (-1)	0.362	-0.445	1.169	0.412	0.88	0.200
C2:	[k] (1) v. [s] (-1)	-0.087	-0.634	0.459	0.279	-0.31	0.380
C2:	[n] (1) v. [s] (-1)	0.013	-0.513	0.540	0.269	0.05	0.481
V1:	[a] (1) v. [i] (-1)	0.382	0.003	0.761	0.193	1.97	0.038
Syll:	pre (1) v. ton (0)	-0.206	-1.105	0.693	0.459	-0.45	0.331
Syll:	post (1) v. ton (0)	0.912	-0.292	2.116	0.614	1.48	0.084

Table C.15: Low-band spectral tilt model for speaker MO: H1.H2 ∼ RDur + Tone + C1 + C2 + V + (Syll +Tone | Segs) + Syll; $X^2 = 2.1579$, p(2) = 0.340

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(12)
	(Intercept)	-2.644	-3.654	-1.634	0.515	-5.13	0.000
RDur	(centered)	0.004	-0.002	0.011	0.003	1.31	0.107
T:	L (1) v. M (-1)	2.715	1.825	3.606	0.454	5.98	0.000
T:	H (1) v. M (-1)	-1.704	-2.594	-0.814	0.454	-3.75	0.001
C1:	[ⁿd] (1) v. [s] (-1)	0.284	-0.902	1.469	0.605	0.47	0.324
C1:	[k] (1) v. [s] (-1)	-0.002	-1.079	1.074	0.549	-0.00	0.498
C1:	[n] (1) v. [s] (-1)	-1.217	-2.486	0.052	0.647	-1.88	0.042
C2:	[k] (1) v. [s] (-1)	-0.128	-1.046	0.790	0.469	-0.27	0.395
C2:	[n] (1) v. [s] (-1)	-0.859	-1.753	0.035	0.456	-1.88	0.042
V1:	[a] (1) v. [i] (-1)	0.051	-0.578	0.679	0.321	0.16	0.439
Syll:	pre (1) v. ton (0)	1.058	-0.601	2.718	0.847	1.25	0.118
Syll:	post (1) v. ton (0)	-0.289	-1.868	1.290	0.806	-0.36	0.363

Table C.16: Low-band spectral tilt model for speaker MC: H1.H2 ~ RDur + Tone + C1 + C2 + V + (Syll + Tone | Segs) + Syll; $X^2 = 10.532$, p(2) = 0.005

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(10)
	(Intercept)	4.341	3.204	5.479	0.580	7.48	0.000
RDur	(centered)	-0.004	-0.011	0.003	0.004	-1.15	0.138
T:	L (1) v. M (-1)	-0.924	-2.110	0.262	0.605	-1.53	0.079
T:	H (1) v. M (-1)	0.917	-0.258	2.093	0.600	1.53	0.079
C1:	[ⁿd] (1) v. [s] (-1)	-0.216	-1.847	1.415	0.832	-0.26	0.400
C1:	[k] (1) v. [s] (-1)	-0.513	-1.804	0.779	0.659	-0.78	0.227
C1:	[n] (1) v. [s] (-1)	-1.056	-2.392	0.280	0.682	-1.55	0.076
C2:	[k] (1) v. [s] (-1)	-0.142	-1.190	0.907	0.535	-0.26	0.398
C2:	[n] (1) v. [s] (-1)	0.290	-0.691	1.270	0.500	0.58	0.288
V1:	[a] (1) v. [i] (-1)	-1.897	-2.641	-1.154	0.379	-5.00	0.000
Syll:	pre (1) v. ton (0)	-3.623	-5.630	-1.616	1.024	-3.54	0.003
Syll:	post (1) v. ton (0)	-1.231	-3.239	0.777	1.024	-1.20	0.129

Table C.17: Harmonics-to-Noise Ratio model for speaker MO: HNR ~RDur + Tone + C1 + C2 + V + (Syll | Segs) + Syll; $X^2 = 16.65$, p(2) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(12)
	(Intercept)	5.719	4.907	6.531	0.414	13.80	0.000
RDur	(centered)	0.008	0.003	0.014	0.003	3.15	0.004
T:	L (1) v. M (-1)	-1.568	-2.464	-0.673	0.457	-3.43	0.002
T:	H (1) v. M (-1)	0.967	0.244	1.689	0.369	2.62	0.011
C1:	[ⁿd] (1) v. [s] (-1)	0.192	-0.944	1.328	0.580	0.33	0.373
C1:	[k] (1) v. [s] (-1)	-0.138	-1.024	0.749	0.452	-0.30	0.383
C1:	[n] (1) v. [s] (-1)	1.951	0.751	3.152	0.613	3.19	0.004
C2:	[k] (1) v. [s] (-1)	-2.158	-2.962	-1.354	0.410	-5.26	0.000
C2:	[n] (1) v. [s] (-1)	1.470	0.706	2.234	0.390	3.77	0.001
V1:	[a] (1) v. [i] (-1)	0.316	-0.232	0.863	0.279	1.13	0.140
Syll:	pre (1) v. ton (0)	-1.477	-3.101	0.147	0.829	-1.78	0.050
Syll:	post (1) v. ton (0)	-3.302	-4.600	-2.004	0.662	-4.99	0.000

Table C.18: Harmonics-to-Noise Ratio model for speaker MC: HNR ∼ RDur + Tone + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 2.3474$, p(2) = 0.309

Var	Param	Estimate	CI [low, high]		Std Err	t	p(10)
	(Intercept)	12.185	11.500	12.871	0.350	34.83	0.000
RDur	(centered)	0.003	-0.001	0.008	0.002	1.61	0.070
T:	L (1) v. M (-1)	-2.505	-3.252	-1.757	0.381	-6.57	0.000
T:	H (1) v. M (-1)	1.727	1.052	2.402	0.344	5.01	0.000
C1:	[^{n}d] (1) v. [s] (-1)	-0.147	-1.203	0.910	0.539	-0.27	0.395
C1:	[k] (1) v. [s] (-1)	0.543	-0.309	1.396	0.435	1.25	0.120
C1:	[n] (1) v. [s] (-1)	0.960	-0.038	1.959	0.509	1.89	0.044
C2:	[k] (1) v. [s] (-1)	-0.648	-1.363	0.068	0.365	-1.77	0.053
C2:	[n] (1) v. [s] (-1)	-0.122	-0.817	0.573	0.354	-0.34	0.369
V1:	[a] (1) v. [i] (-1)	-0.821	-1.320	-0.321	0.255	-3.22	0.005
Syll:	pre (1) v. ton (0)	-0.614	-2.007	0.780	0.711	-0.86	0.204
Syll:	post (1) v. ton (0)	0.779	-0.662	2.221	0.736	1.06	0.157

Table C.19: Cepstral Peak Prominence model for speaker MO: CPP ∼ RDur + Tone + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 7.5573$, p(2) = 0.023

Var	Param	Estimate	CI [low, high]		Std Err	t	p(12)
	(Intercept)	21.407	20.577	22.236	0.423	50.56	0.000
RDur	(centered)	0.004	-0.001	0.010	0.003	1.46	0.086
T:	L (1) v. M (-1)	-2.036	-2.775	-1.296	0.377	-5.40	0.000
T:	H (1) v. M (-1)	1.179	0.527	1.830	0.332	3.54	0.002
C1:	[^{n}d] (1) v. [s] (-1)	-0.022	-1.007	0.962	0.502	-0.04	0.483
C1:	[k] (1) v. [s] (-1)	-0.854	-1.680	-0.028	0.421	-2.03	0.033
C1:	[n] (1) v. [s] (-1)	2.108	1.155	3.061	0.486	4.34	0.000
C2:	[k] (1) v. [s] (-1)	-0.812	-1.526	-0.098	0.364	-2.23	0.023
C2:	[n] (1) v. [s] (-1)	1.880	1.193	2.568	0.351	5.36	0.000
V1:	[a] (1) v. [i] (-1)	0.887	0.397	1.378	0.250	3.55	0.002
Syll:	pre (1) v. ton (0)	0.054	-1.327	1.435	0.705	0.08	0.470
Syll:	post (1) v. ton (0)	-1.702	-2.931	-0.472	0.627	-2.71	0.009

Table C.20: Cepstral Peak Prominence model for speaker MC: CPP ∼ RDur + Tone + C1 + C2 + V + (Syll +Tone| Segs) + Syll; $X^2 = 25.875$, p(2) = 0.000

Var	Param	Estimate	CI [low, high]		Std Err	t	p(10)
	(Intercept)	24.847	24.292	25.403	0.283	87.66	0.000
RDur	(centered)	0.001	-0.002	0.005	0.002	0.80	0.222
T:	L (1) v. M (-1)	-1.490	-2.024	-0.957	0.272	-5.47	0.000
T:	H (1) v. M (-1)	0.894	0.291	1.496	0.307	2.91	0.008
C1:	[^{n}d] (1) v. [s] (-1)	0.147	-0.609	0.903	0.386	0.38	0.355
C1:	[k] (1) v. [s] (-1)	0.411	-0.212	1.034	0.318	1.29	0.112
C1:	[n] (1) v. [s] (-1)	0.420	-0.259	1.100	0.347	1.21	0.127
C2:	[k] (1) v. [s] (-1)	-1.165	-1.694	-0.636	0.270	-4.31	0.001
C2:	[n] (1) v. [s] (-1)	0.676	0.191	1.161	0.247	2.73	0.011
V1:	[a] (1) v. [i] (-1)	1.782	1.406	2.157	0.192	9.30	0.000
Syll:	pre (1) v. ton (0)	-3.807	-4.703	-2.911	0.457	-8.33	0.000
Syll:	post (1) v. ton (0)	-1.504	-2.539	-0.470	0.528	-2.85	0.009

Table C.21: Fundamental frequency model for speaker MO: 12*log2(F0) ~RDur + Tone + C1 + C2 + V + (Syll +Tone | Segs) + Syll; $X^2 = 1.4959$, p(2) = 0.473

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(12)
	(Intercept)	80.354	79.961	80.747	0.201	400.62	0.000
RDur	(centered)	0.000	-0.002	0.003	0.001	0.17	0.433
T:	L (1) v. M (-1)	-2.675	-3.088	-2.262	0.211	-12.70	0.000
T:	H (1) v. M (-1)	2.577	2.142	3.013	0.222	11.59	0.000
C1:	[ⁿd] (1) v. [s] (-1)	-0.456	-0.950	0.037	0.252	-1.81	0.047
C1:	[k] (1) v. [s] (-1)	0.539	0.137	0.941	0.205	2.63	0.011
C1:	[n] (1) v. [s] (-1)	0.067	-0.387	0.520	0.232	0.29	0.389
C2:	[k] (1) v. [s] (-1)	0.301	-0.042	0.644	0.175	1.72	0.056
C2:	[n] (1) v. [s] (-1)	-0.026	-0.364	0.312	0.173	-0.15	0.441
V1:	[a] (1) v. [i] (-1)	-0.360	-0.597	-0.123	0.121	-2.97	0.006
Syll:	pre (1) v. ton (0)	0.009	-0.716	0.735	0.370	0.03	0.490
Syll:	post (1) v. ton (0)	-0.430	-1.100	0.239	0.342	-1.26	0.116

Table C.22: Fundamental frequency model with Syll × Tone interaction, for speaker MO: 12 * log2(F0) ~ RDur + Tone + C1 + C2 + V + (Syll + Tone | Segs) + Syll + Tone:Syll; $X^2 = 9.0365$, p(6) = 0.172

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(8)
	(Intercept)	80.363	79.975	80.752	0.198	405.07	0.000
RDur	(centered)	-0.000	-0.003	0.003	0.001	-0.02	0.494
T:	L (1) v. M (-1)	-2.992	-3.547	-2.438	0.283	-10.58	0.000
T:	H (1) v. M (-1)	2.746	2.143	3.349	0.307	8.93	0.000
C1:	[ⁿd] (1) v. [s] (-1)	-0.358	-0.854	0.138	0.253	-1.41	0.097
C1:	[k] (1) v. [s] (-1)	0.530	0.125	0.936	0.207	2.56	0.017
C1:	[n] (1) v. [s] (-1)	-0.030	-0.482	0.422	0.231	-0.13	0.449
C2:	[k] (1) v. [s] (-1)	0.285	-0.053	0.623	0.173	1.65	0.069
C2:	[n] (1) v. [s] (-1)	0.055	-0.283	0.393	0.172	0.32	0.379
V1:	[a] (1) v. [i] (-1)	-0.325	-0.560	-0.090	0.120	-2.71	0.013
Syll:	pre (1) v. ton (0)	-0.401	-1.137	0.335	0.376	-1.07	0.159
Syll:	post (1) v. ton (0)	-0.503	-1.195	0.190	0.353	-1.42	0.096
T:Syll	T (L v. M):pre	1.021	0.216	1.825	0.410	2.49	0.019
T:Syll	T (H v. M):pre	0.126	-0.753	1.005	0.448	0.28	0.393
T:Syll	T (L v. M):post	0.124	-0.882	1.131	0.514	0.24	0.407
T:Syll	T (H v. M):post	-0.232	-1.029	0.564	0.407	-0.57	0.292

Table C.23: Fundamental frequency model for speaker MC: 12*log2(F0) ~RDur + Tone + C1 + C2 + V + (Tone + Syll | Segs) + Syll; $X^2 = 23.491$, p(2) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(10)
	(Intercept)	93.629	93.397	93.860	0.118	794.24	0.000
RDur	(centered)	-0.001	-0.002	0.001	0.001	-0.78	0.227
T:	L (1) v. M (-1)	-2.285	-2.497	-2.073	0.108	-21.12	0.000
T:	H (1) v. M (-1)	2.565	2.268	2.861	0.151	16.94	0.000
C1:	[^{n}d] (1) v. [s] (-1)	-0.314	-0.626	-0.003	0.159	-1.98	0.038
C1:	[k] (1) v. [s] (-1)	-0.019	-0.282	0.244	0.134	-0.14	0.445
C1:	[n] (1) v. [s] (-1)	0.401	0.112	0.691	0.148	2.72	0.011
C2:	[k] (1) v. [s] (-1)	0.104	-0.116	0.324	0.112	0.92	0.189
C2:	[n] (1) v. [s] (-1)	-0.159	-0.366	0.047	0.105	-1.51	0.081
V1:	[a] (1) v. [i] (-1)	-0.233	-0.393	-0.073	0.082	-2.85	0.009
Syll:	pre (1) v. ton (0)	-0.838	-1.227	-0.449	0.198	-4.22	0.001
Syll:	post (1) v. ton (0)	-1.297	-1.870	-0.723	0.293	-4.43	0.001

Table C.24: Fundamental frequency model with Syll × Tone interaction, for speaker MC: 12 * log2(F0) ~ RDur + Tone + C1 + C2 + V + (Syll + Tone | Segs) + Syll + Tone:Syll; $X^2 = 44.645$, p(6) = 0.000

Var	Param	Estimate	CI [low,	high]	Std Err	t	p(6)
	(Intercept)	93.645	93.420	93.870	0.115	815.75	0.000
RDur	(centered)	-0.001	-0.002	0.001	0.001	-1.08	0.160
T:	L (1) v. M (-1)	-2.474	-2.769	-2.180	0.150	-16.47	0.000
T:	H (1) v. M (-1)	2.960	2.603	3.317	0.182	16.26	0.000
C1:	[^{n}d] (1) v. [s] (-1)	-0.332	-0.645	-0.019	0.160	-2.08	0.041
C1:	[k] (1) v. [s] (-1)	-0.040	-0.298	0.219	0.132	-0.30	0.387
C1:	[n] (1) v. [s] (-1)	0.415	0.128	0.702	0.146	2.84	0.015
C2:	[k] (1) v. [s] (-1)	0.007	-0.211	0.224	0.111	0.06	0.477
C2:	[n] (1) v. [s] (-1)	-0.119	-0.321	0.082	0.103	-1.16	0.145
V1	[a] (1) v. [i] (-1)	-0.221	-0.377	-0.064	0.080	-2.77	0.016
Syll:	pre (1) v. ton (0)	-0.832	-1.270	-0.394	0.223	-3.73	0.005
Syll:	post (1) v. ton (0)	-1.464	-2.046	-0.882	0.297	-4.93	0.001
T:Syll	T (L v. M):pre	0.504	-0.006	1.015	0.260	1.94	0.050
T:Syll	T (H v. M):pre	-0.777	-1.314	-0.240	0.274	-2.84	0.015
T:Syll	T (L v. M):post	-0.628	-1.342	0.087	0.365	-1.72	0.068
T:Syll	T (H v. M):post	-0.329	-0.848	0.190	0.265	-1.24	0.130

Appendix D

Tone Supplement

D.1 Tonal coarticulation in plain stems

Table D.1: Tone study CVCV target words

Orthographic	Phonemic	Gloss	Category	Tones
jiko	xiko	high	Adj	HH
kusu	kusu	white	Adj	HH
ndyivi	$^{n}d^{j}$ivi	both	Num	HH
nana	nana	mother	N	HH
ndaji	^{n}daxi	closed	Adj	HH/L
kochi	kotʃi	pig	N	HH/L
nuna	nuna	open	Adj	HH/L
yuyu	ʒuʒu	dew	N	HH/L
ndyika	$^{n}d^{j}$ika	wide	Adj	HL
leka	leka	bag	N	HL
kolo	kolo	tom turkey	N	HL
iñima	iɲima	mind	N	HL
kani	kani	long	Adj	HL/H
kuxu	kuʃu	speckled	Adj	HM
sako	sako	opossum	N	HM
tyivi	t^{j}ivi	appear	V	HM
chele	tʃele	rooster	N	HM
ndyixi	$^{n}d^{j}$iʃi	light blue	Adj	MH
yata	ʒata	old	Adj	MH

Table D.1: Tone study CVCV target words (continued)

Orthographic	Phonemic	Gloss	Category	Tones
koto	koto	shirt	N	MH
kava	kava	spin (TR)	V	MH
yivi	ʒivi	people	N	MH
indyivi	i^{n}d^{j}ivi	sky	N	MH
vita	vita	soft	Adj	MH/L
kasi	kasi	eat (sweet)	V	MH/L
kata	kata	itch	V	MH/L
yiko	ʒiko	furrow	N	ML
taka	taka	nest	N	ML
nama	nama	earthen wall	N	ML
tyayi	t^{j}aʒi	stool	N	ML
xikua	ʃik^{w}a	eyebrow	N	ML/H
yuku	ʒuku	mountain	N	ML/H
ndyayi	^{n}d^{j}aʒi	mole	N	ML/H
yavi	ʒavi	agave	N	ML/H
ndyixi	^{n}d^{j}ixi	liquor	N	MM
satyi	sat^{j}i	pants	N	MM
kini	kini	ugly	Adj	MM
landyi	la^{n}d^{j}i	navel	N	MM
kisi	kisi	come	V	MM/L
yoko	ʒoko	corn tassel	N	MM/L
chiño	ʧiɲo	work	N	MM/L
tyinana	t^{j}inana	tomato	N	MM/L
chiki	ʧiki	cactus pear	N	LH
yojo	ʒoxo	mortar	N	LH
tyichi	t^{j}iʧi	avocado	N	LH
ndyuxu	^{n}d^{j}uʃu	pretentious	Adj	LH/L
xatya	ʃat^{j}a	shave	V	LH/L
ndaku	^{n}daku	straight	Adj	LH/L
jutyu	xut^{j}u	priest	N	LL
ndyisi	^{n}d^{j}isi	wing	N	LL
kuiya	k^{w}iʒa	year	N	LL
ñuñu	ɲuɲu	honey	N	LL
kivi	kivi	name	N	LL
kivi	kivi	day	N	LL

Table D.1: Tone study CVCV target words (continued)

Orthographic	Phonemic	Gloss	Category	Tones
xita	ʃita	tortilla	N	LL/H
viko	viko	cloud	N	LL/H
ndyivi	^{n}d^{j}ivi	egg	N	LL/H
xini	ʃini	head	N	LL/H
kiji	kixi	pot	N	LM
ndyika	^{n}d^{j}ika	wall	N	LM
tomi	tumi	feather	N	LM
sano	sanu	daughter-in-law	N	LM
tyina	t^{j}ina	dog	N	LM

Table D.2: Random effects in regression model of F0 in μ_1 of CVCV couplets

Groups	Term	Parameter	Variance	Std.Dev.
Instance		(Intercept)	0.4305754	0.656182
	Time	Time	0.0148960	0.122049
Target		(Intercept)	0.9351022	0.967007
	Time	Time	0.0297493	0.172480
	Cl	Cl = na	0.9542471	0.976856
		Cl = va	1.9551833	1.398279
	Rep	Rep = iin	0.0037357	0.061120
		Rep = uni	0.0209276	0.144664
	Time × Cl	Time:Cl = na	0.0063485	0.079677
		Time:Cl = va	0.0119211	0.109184
Residual			0.0872554	0.295390

Table D.3: Random effects in regression model of F0 in μ_2 of CVCV couplets

Groups	Term	Parameter	Variance	Std.Dev.
Instance		(Intercept)	0.962586	0.98111
	Time	Time	0.168987	0.41108
Target		(Intercept)	0.254718	0.50470
	Time	Time	0.075901	0.27550
	Cl	Cl = na	1.022173	1.01103
		Cl = va	1.707387	1.30667
	Rep	Rep = iin	0.068030	0.26083
		Rep = uni	0.170850	0.41334
	Time × Cl	Time:Cl = na	0.092440	0.30404
		Time:Cl = va	0.087180	0.29526
Residual			0.598002	0.77331

Table D.4: Fixed effects in regression model of F0 in μ_1 of CVCV couplets

Term	Parameter	Estimate	CI.lower	CI.upper	t.value	p.20
	(Intercept)	0.302	-0.533	1.138	0.709	0.243
TIME	TIME	-0.105	-0.228	0.018	-1.674	0.055
CL	CL = NA	-0.670	-1.056	-0.285	-3.411	0.001
	CL = VA	-0.593	-1.102	-0.084	-2.284	0.017
REP	REP = IIN	0.370	0.242	0.498	5.658	0.000
	REP = UNI	-0.152	-0.284	-0.021	-2.265	0.017
T_1	T_1 = H	4.354	3.297	5.412	8.071	0.000
	T_1 = L	-2.239	-3.304	-1.173	-4.119	0.000
T_2	T_2 = H	0.452	-0.361	1.265	1.091	0.144
	T_2 = L	-0.129	-1.129	0.870	-0.254	0.401
T_3	T_3 = H	-0.200	-1.011	0.611	-0.483	0.317
	T_3 = L	0.332	-0.467	1.131	0.814	0.213
VT	VT = I	0.266	-0.286	0.818	0.945	0.178
	VT = U	0.180	-0.468	0.828	0.544	0.296
CT	CT = LAB + VC	0.958	-0.314	2.231	1.477	0.078
	CT = COR–VC	-0.341	-0.969	0.287	-1.064	0.150
	CT = DOR–VC	-0.269	-0.813	0.275	-0.970	0.172
$T_2 \times T_1$	T_2 = H:T_1 = H	-1.422	-2.774	-0.070	-2.061	0.026
	T_2 = L:T_1 = H	-1.340	-2.906	0.226	-1.677	0.055
	T_2 = H:T_1 = L	-0.945	-2.259	0.368	-1.411	0.087
	T_2 = L:T_1 = L	0.027	-1.300	1.355	0.040	0.484
CL $\times$ T_3	CL = NA:T_3 = H	0.367	-0.300	1.033	1.078	0.147
	CL = VA:T_3 = H	1.084	0.210	1.959	2.431	0.012
	CL = NA:T_3 = L	-0.359	-1.034	0.316	-1.042	0.155
	CL = VA:T_3 = L	-0.502	-1.389	0.384	-1.110	0.140
T_1 $\times$ TIME	T_1 = H:TIME	0.205	0.106	0.304	4.042	0.000
	T_1 = L:TIME	-0.196	-0.286	-0.106	-4.281	0.000
T_2 $\times$ TIME	T_2 = H:TIME	-0.046	-0.155	0.063	-0.824	0.210
	T_2 = L:TIME	-0.066	-0.194	0.061	-1.020	0.160
TIME $\times$ VT	TIME:VT = I	-0.024	-0.113	0.066	-0.516	0.306
	TIME:VT = U	-0.147	-0.254	-0.041	-2.705	0.007
TIME $\times$ CT	TIME:CT = LAB + VC	0.002	-0.215	0.218	0.016	0.494
	TIME:CT = COR–VC	-0.196	-0.299	-0.093	-3.733	0.001
	TIME:CT = DOR–VC	-0.039	-0.127	0.049	-0.874	0.196
TIME $\times$ CL	TIME:CL = NA	0.032	-0.018	0.082	1.247	0.113
	TIME:CL = VA	0.016	-0.040	0.071	0.547	0.295
TIME $\times$ T_3	TIME:T_3 = H	-0.139	-0.284	0.006	-1.882	0.037
	TIME:T_3 = L	0.102	-0.039	0.243	1.422	0.085
TIME $\times$ CL $\times$ T_3	TIME:CL = NA:T_3 = H	0.106	0.018	0.194	2.361	0.014
	TIME:CL = VA:T_3 = H	0.035	-0.064	0.133	0.688	0.250
	TIME:CL = NA:T_3 = L	-0.030	-0.117	0.057	-0.666	0.256
	TIME:CL = VA:T_3 = L	-0.009	-0.107	0.089	-0.181	0.429

Table D.5: Fixed effects in regression model of F0 in μ_2 of CVCV couplets

Term	Parameter	Estimate	CI.lower	CI.upper	t.value	p.20
	(Intercept)	-1.059	-1.699	-0.418	-3.241	0.002
TIME	TIME	0.013	-0.164	0.191	0.148	0.442
CL	CL = NA	0.040	-0.398	0.478	0.180	0.430
	CL = VA	-0.193	-0.713	0.328	-0.726	0.238
REP	REP = IIN	0.388	0.197	0.579	3.975	0.000
	REP = UNI	-0.064	-0.271	0.142	-0.608	0.275
T_1	$T_1 = H$	2.433	1.649	3.218	6.078	0.000
	$T_1 = L$	-0.578	-1.420	0.265	-1.344	0.097
T_2	$T_2 = H$	3.481	2.826	4.136	10.411	0.000
	$T_2 = L$	-3.024	-3.873	-2.174	-6.978	0.000
T_3	$T_3 = H$	1.064	0.405	1.723	3.165	0.002
	$T_3 = L$	0.552	0.005	1.099	1.978	0.031
VT	VT = I	0.689	0.273	1.104	3.250	0.002
	VT = U	0.372	-0.094	0.839	1.564	0.067
CT	CT = LAB + VC	0.013	-0.523	0.549	0.047	0.481
	CT = COR–VC	0.423	-0.057	0.903	1.726	0.050
	CT = DOR–VC	0.012	-0.502	0.525	0.044	0.483
$T_2 \times T_1$	$T_2 = H{:}T_1 = H$	-1.231	-2.223	-0.238	-2.430	0.012
	$T_2 = L{:}T_1 = H$	-1.290	-2.465	-0.115	-2.151	0.022
	$T_2 = H{:}T_1 = L$	-1.065	-2.108	-0.023	-2.003	0.029
	$T_2 = L{:}T_1 = L$	0.466	-0.614	1.547	0.846	0.204
CL $\times$ T_3	CL = NA:$T_3 = H$	-0.335	-1.079	0.410	-0.881	0.194
	CL = VA:$T_3 = H$	0.117	-0.783	1.017	0.255	0.401
	CL = NA:$T_3 = L$	-0.776	-1.519	-0.034	-2.050	0.027
	CL = VA:$T_3 = L$	-0.860	-1.764	0.045	-1.863	0.039
T_1 $\times$ TIME	$T_1 = H$:TIME	-0.147	-0.262	-0.032	-2.513	0.010
	$T_1 = L$:TIME	0.041	-0.058	0.141	0.811	0.214
T_2 $\times$ TIME	$T_2 = H$:TIME	0.145	0.014	0.277	2.164	0.021
	$T_2 = L$:TIME	-0.094	-0.247	0.059	-1.208	0.121
TIME $\times$ VT	TIME:VT = I	-0.006	-0.112	0.100	-0.116	0.454
	TIME:VT = U	0.014	-0.106	0.133	0.221	0.414
TIME $\times$ CT	TIME:CT = LAB + VC	0.003	-0.127	0.134	0.052	0.479
	TIME:CT = COR–VC	-0.192	-0.313	-0.071	-3.115	0.003
	TIME:CT = DOR–VC	-0.159	-0.285	-0.033	-2.465	0.011
TIME $\times$ CL	TIME:CL = NA	-0.119	-0.284	0.047	-1.407	0.087
	TIME:CL = VA	-0.086	-0.246	0.075	-1.045	0.154
TIME $\times$ T_3	TIME:$T_3 = H$	0.719	0.470	0.969	5.647	0.000
	TIME:$T_3 = L$	-0.338	-0.568	-0.108	-2.883	0.005
TIME $\times$	TIME:CL = NA:$T_3 = H$	-0.682	-0.971	-0.393	-4.627	0.000
CL $\times$ T_3	TIME:CL = VA:$T_3 = H$	-0.668	-0.952	-0.383	-4.603	0.000
	TIME:CL = NA:$T_3 = L$	0.427	0.141	0.714	2.921	0.004
	TIME:CL = VA:$T_3 = L$	0.300	0.018	0.581	2.089	0.025

D.2 The timing of tone contours

Table D.6: Tone study CVV target words

Orthographic	Phonemic	Gloss	Category	Tones
ndyaa	$^{n}d^{j}aa$	dark blue	Adj	HH
kuii	$k^{w}ii$	clear	Adj	HH
kuaan	$k^{w}aa_{n}$	yellow	Adj	HH
nii	nii	whole	N	HH
ndyii	$^{n}d^{j}ii$	frigid	Adj	HH+L
yaa	ʒaa	tongue	N	HH+L
chiin	$ʧii_{n}$	nails	N	HH+L
mbaa	^{m}baa	compadre	N	HL
meloon	$miloo_{n}$	melon	N	HL
kuii	$k^{w}ii$	green	Adj	HL+H
xiin	$ʃii_{n}$	flank	N	HL+H
yii	ʒaa	husband	N	HL+H
jiin	xii_{n}	different	Adj	HM
nuu	nuu	cheap	Adj	HM
ndaa	^{n}daa	PL:STAT	V	HM
kaa	kaa	SG:STAT	V	HM
vii	vii	clean	Adj	MH
naa	naa	fight	V	MH
kuaa	$k^{w}aa$	blind	V	MH
ñuu	ɲuu	midnight	N	MH+L
kuaan	$k^{w}aa_{n}$	widdow	N	ML
nii	nii	corn ear	N	ML
kaa	kaa	stretch	V	ML
koo	koo	stone wall	N	ML+H
nii	nii	skin	N	ML+H
saan	saa_{n}	PROX.2	Pro	ML+H
yaa	ʒaa	pale	Adj	MM
kueen	$k^{w}ee_{n}$	IR:buy	V	MM
saa	saa	quickly	Adv	MM
chuun	$ʧuu_{n}$	work	N	MM+L
tyiin	$t^{j}ii_{n}$	grab	V	MM+L
kuun	kuu_{n}	crumble	V	MM+L
kuaan	$k^{w}aa_{n}$	yellowed	Adj	LH

Table D.6: Tone study CVV target words (continued)

Orthographic	Phonemic	Gloss	Category	Tones
jaa	xaa	later	Adv	LH
tyii	t^{j}ii	numb	V	LH
tuun	tuu$_n$	black	Adj	LH+L
saa	saa	new	Adj	LH+L
tyiin	t^{j}ii$_n$	mouse	N	LH+L
maa	maa	inside	N	LH+L
ndaa	^{n}daa	straight	Adj	LL
tyii	t^{j}ii	wrinkled	Adj	LL
yaa	ʒaa	ash	N	LL
saa	saa	arrive	V	LL
ndoo	^{n}doo	cane	N	LL+H
nii	nii	salt	N	LL+H
koo	koo	snake	N	LL+H
joo	xoo	shell	N	LL+H
vaa	vaa	bottom	N	LL+H
xii	ʃii	stiff	Adj	LM
vee	vee	heavy	Adj	LM
xaa	ʃaa	chin	N	LM
ndyii	^{n}d^{j}ii	dead	N	LM

Table D.7: Random effects in the model of μ_1 F0 in CVCV and CVV couplets

Groups	Term	Parameter	Variance	Std.Dev.
Instance		(Intercept)	0.3577927	0.598158
	Time	Time	0.0150908	0.122845
Target		(Intercept)	1.4604653	1.208497
	Time	Time	0.1248534	0.353346
	Cl	Cl = na	1.6537284	1.285974
		Cl = va	2.5560727	1.598772
	Rep	Rep = iin	0.0080291	0.089605
		Rep = uni	0.0177863	0.133365
	Time × Cl	Time:Cl = na	0.0967720	0.311082
		Time:Cl = va	0.1154993	0.339852
Residual			0.0876729	0.296096

Table D.8: Random effects in the model of μ_2 F0 in CVCV and CVV couplets

Groups	Term	Parameter	Variance	Std.Dev.
Instance		(Intercept)	0.739715	0.86007
	TIME	TIME	0.127458	0.35701
Target		(Intercept)	1.619414	1.27256
	TIME	TIME	0.144313	0.37989
	CL	CL = NA	2.359164	1.53596
		CL = VA	3.213247	1.79255
	REP	REP = IIN	0.020453	0.14301
		REP = UNI	0.097409	0.31210
	TIME × CL	TIME:CL = NA	0.135947	0.36871
		TIME:CL = VA	0.125093	0.35369
Residual			0.445784	0.66767

Table D.9: Fixed effects in the model of μ_1 F0 in CVCV and CVV couplets

Term	Parameter	Estimate	CI.lower	CI.upper	t.value	p.75
	(Intercept)	0.455	-0.428	1.338	1.010	0.158
T_2	$T_2 = H$	0.104	-1.096	1.304	0.170	0.433
	$T_2 = L$	0.109	-1.009	1.228	0.191	0.424
T_1	$T_1 = H$	3.397	2.262	4.531	5.869	0.000
	$T_1 = L$	-2.112	-3.204	-1.020	-3.791	0.000
C_2T	$C_2T = –VC$	-0.634	-1.757	0.489	-1.107	0.136
	$C_2T = NO$	0.525	-0.463	1.513	1.042	0.150
TIME	TIME	-0.169	-0.269	-0.068	-3.301	0.001
CT	CT = –VC	-0.054	-0.470	0.363	-0.252	0.401
T_3	$T_3 = H$	-0.227	-0.856	0.402	-0.708	0.241
	$T_3 = L$	-0.055	-0.666	0.557	-0.175	0.431
CL	CL = NA	-0.356	-0.613	-0.098	-2.707	0.004
	CL = VA	-0.088	-0.401	0.225	-0.551	0.292
REP	REP = IIN	0.428	0.337	0.519	9.225	0.000
	REP = UNI	-0.107	-0.199	-0.014	-2.264	0.013
$T_2 \times T_1$	$T_2 = H{:}T_1 = H$	-0.571	-1.727	0.584	-0.969	0.168
	$T_2 = L{:}T_1 = H$	-1.197	-2.410	0.015	-1.936	0.028
	$T_2 = H{:}T_1 = L$	-0.409	-1.657	0.839	-0.643	0.261
	$T_2 = L{:}T_1 = L$	-0.282	-1.369	0.804	-0.509	0.306
$T_1 \times C_2T$	$T_1 = H{:}C_2T = –VC$	0.806	-0.447	2.060	1.260	0.106
	$T_1 = L{:}C_2T = –VC$	0.113	-1.118	1.345	0.181	0.429
	$T_1 = H{:}C_2T = NO$	-1.508	-2.661	-0.355	-2.564	0.006
	$T_1 = L{:}C_2T = NO$	-0.814	-1.951	0.324	-1.402	0.082
$T_2 \times C_2T$	$T_2 = H{:}C_2T = –VC$	0.515	-0.868	1.897	0.730	0.234
	$T_2 = L{:}C_2T = –VC$	0.263	-1.020	1.547	0.402	0.344
	$T_2 = H{:}C_2T = NO$	1.081	-0.232	2.394	1.614	0.055
	$T_2 = L{:}C_2T = NO$	0.484	-0.602	1.569	0.874	0.193
$C_2T \times$ TIME	$C_2T = –VC{:}$TIME	-0.242	-0.324	-0.159	-5.750	0.000
	$C_2T = NO{:}$TIME	0.015	-0.063	0.092	0.372	0.355
TIME:CT	TIME:CT = –VC	-0.113	-0.176	-0.050	-3.525	0.000
TIME:T_3	TIME:$T_3 = H$	-0.094	-0.173	-0.016	-2.353	0.011
	TIME:$T_3 = L$	0.132	0.051	0.212	3.209	0.001
TIME:CL	TIME:CL = NA	0.116	0.054	0.179	3.645	0.000
	TIME:CL = VA	0.075	0.008	0.143	2.182	0.016

Table D.10: Fixed effects in the model of μ_2 F0 in CVCV and CVV couplets

Term	Parameter	Estimate	CI.lower	CI.upper	t.value	p.69
	(Intercept)	-0.161	-1.004	0.683	-0.373	0.355
T_2	$T_2 = H$	2.507	1.348	3.667	4.238	0.000
	$T_2 = L$	-3.740	-4.849	-2.631	-6.610	0.000
T_1	$T_1 = H$	1.655	0.523	2.787	2.865	0.003
	$T_1 = L$	-1.213	-2.306	-0.121	-2.177	0.016
C_2T	$C_2T = –VC$	-0.165	-1.284	0.955	-0.288	0.387
	$C_2T = NO$	0.601	-0.380	1.582	1.201	0.117
TIME	TIME	-0.051	-0.183	0.082	-0.750	0.228
CL	CL = NA	0.264	-0.158	0.685	1.226	0.112
	CL = VA	0.200	-0.280	0.680	0.816	0.209
T_3	$T_3 = H$	1.214	0.443	1.985	3.086	0.001
	$T_3 = L$	0.931	0.176	1.686	2.417	0.009
REP	REP = IIN	0.442	0.317	0.567	6.939	0.000
	REP = UNI	-0.033	-0.167	0.102	-0.478	0.317
$T_2 \times T_1$	$T_2 = H{:}T_1 = H$	-0.431	-1.590	0.729	-0.728	0.235
	$T_2 = L{:}T_1 = H$	-1.063	-2.278	0.152	-1.714	0.046
	$T_2 = H{:}T_1 = L$	0.181	-1.065	1.428	0.285	0.388
	$T_2 = L{:}T_1 = L$	0.818	-0.272	1.908	1.470	0.073
$T_1 \times C_2T$	$T_1 = H{:}C_2T = –VC$	0.449	-0.812	1.710	0.698	0.244
	$T_1 = L{:}C_2T = –VC$	0.635	-0.595	1.864	1.012	0.158
	$T_1 = H{:}C_2T = NO$	-0.632	-1.775	0.511	-1.084	0.141
	$T_1 = L{:}C_2T = NO$	-1.802	-2.939	-0.664	-3.103	0.001
$T_2 \times C_2T$	$T_2 = H{:}C_2T = –VC$	0.290	-1.076	1.655	0.416	0.339
	$T_2 = L{:}C_2T = –VC$	0.158	-1.132	1.448	0.240	0.405
	$T_2 = H{:}C_2T = NO$	0.057	-1.219	1.333	0.087	0.465
	$T_2 = L{:}C_2T = NO$	1.704	0.619	2.789	3.078	0.001
$C_2T \times$ TIME	$C_2T = –VC$:TIME	-0.157	-0.266	-0.048	-2.814	0.003
	$C_2T = NO$:TIME	0.126	0.024	0.229	2.415	0.009
CL $\times T_3$	CL = NA:$T_3 = H$	-0.166	-0.946	0.614	-0.417	0.339
	CL = VA:$T_3 = H$	0.099	-0.796	0.995	0.218	0.414
	CL = NA:$T_3 = L$	-1.458	-2.256	-0.659	-3.577	0.000
	CL = VA:$T_3 = L$	-1.214	-2.132	-0.296	-2.592	0.006
TIME × CL	TIME:CL = NA	-0.149	-0.272	-0.027	-2.385	0.010
	TIME:CL = VA	-0.132	-0.251	-0.013	-2.166	0.017
TIME $\times T_3$	TIME:$T_3 = H$	0.656	0.450	0.862	6.233	0.000
	TIME:$T_3 = L$	0.007	-0.203	0.216	0.061	0.476
TIME × CL $\times T_3$	TIME:CL = NA:$T_3 = H$	-0.705	-0.934	-0.476	-6.039	0.000
	TIME:CL = VA:$T_3 = H$	-0.667	-0.891	-0.443	-5.834	0.000
	TIME:CL = NA:$T_3 = L$	0.356	0.124	0.588	3.007	0.002
	TIME:CL = VA:$T_3 = L$	0.270	0.042	0.497	2.323	0.012

Table D.11: Random effects in the model of total vocalic duration

Groups	Terms	Parameter	Variance	Std.Dev.
Target		(Intercept)	2.2162e-03	0.0470762
	CL	CL = NA	3.0231e-03	0.0549828
		CL = VA	3.1524e-03	0.0561459
	REP	REP = IIN	6.7002e-05	0.0081855
		REP = UNI	1.5267e-04	0.0123558
Residual			2.7900e-03	0.0528206

Table D.12: Random effects in the model of couplet duration

Groups	Terms	Parameter	Variance	Std.Dev.
Target		(Intercept)	1.8165e-03	0.0426204
	CL	CL = NA	2.5169e-03	0.0501686
		CL = VA	3.2687e-03	0.0571725
	REP	REP = IIN	5.2045e-05	0.0072143
		REP = UNI	7.5739e-05	0.0087028
Residual			2.0642e-03	0.0454333

Table D.13: Fixed effects in the model of total vocalic duration

Term	Parameter	Estimate	CI.lower	CI.upper	t.value	p.72
	(Intercept)	2.455	2.419	2.491	133.976	0.000
C_2T	C_2T = –VC	-0.056	-0.104	-0.008	-2.297	0.012
	C_2T = NO	0.173	0.130	0.215	7.994	0.000
T_1	T_1 = H	-0.059	-0.105	-0.013	-2.514	0.007
	T_1 = L	-0.009	-0.053	0.036	-0.391	0.349
T_2	T_2 = H	-0.013	-0.064	0.038	-0.502	0.309
	T_2 = L	0.024	-0.033	0.080	0.820	0.208
T_3	T_3 = H	0.010	-0.043	0.063	0.374	0.355
	T_3 = L	0.022	-0.034	0.078	0.778	0.220
CL	CL = NA	-0.214	-0.243	-0.185	-14.651	0.000
	CL = VA	-0.237	-0.266	-0.208	-15.909	0.000
REP	REP = IIN	0.002	-0.006	0.010	0.494	0.311
	REP = UNI	-0.016	-0.024	-0.008	-3.891	0.000
$T_2 \times T_1$	T_2 = H:T_1 = H	0.037	-0.011	0.085	1.504	0.069
	T_2 = L:T_1 = H	0.018	-0.032	0.067	0.705	0.241
	T_2 = H:T_1 = L	0.000	-0.051	0.051	0.012	0.495
	T_2 = L:T_1 = L	-0.003	-0.047	0.042	-0.124	0.451
$T_2 \times C_2T$	T_2 = H:C_2T = –VC	-0.028	-0.092	0.037	-0.836	0.203
	T_2 = L:C_2T = –VC	-0.013	-0.082	0.056	-0.371	0.356
	T_2 = H:C_2T = NO	0.008	-0.054	0.071	0.266	0.396
	T_2 = L:C_2T = NO	-0.026	-0.086	0.035	-0.826	0.206
$T_1 \times C_2T$	T_1 = H:C_2T = –VC	-0.008	-0.061	0.044	-0.308	0.380
	T_1 = L:C_2T = –VC	0.000	-0.050	0.050	0.001	0.500
	T_1 = H:C_2T = NO	0.003	-0.044	0.051	0.143	0.443
	T_1 = L:C_2T = NO	-0.008	-0.055	0.038	-0.355	0.362
CL $\times$ T_3	CL = NA:T_3 = H	-0.007	-0.039	0.025	-0.422	0.337
	CL = VA:T_3 = H	0.001	-0.032	0.034	0.062	0.475
	CL = NA:T_3 = L	0.040	0.008	0.072	2.420	0.009
	CL = VA:T_3 = L	0.042	0.009	0.075	2.494	0.007
C_2T $\times$ CL	C_2T = –VC:CL = NA	-0.004	-0.038	0.029	-0.259	0.398
	C_2T = NO:CL = NA	-0.068	-0.100	-0.037	-4.210	0.000
	C_2T = –VC:CL = VA	0.022	-0.013	0.057	1.248	0.108
	C_2T = NO:CL = VA	-0.117	-0.149	-0.084	-7.041	0.000
$C_2T \times T_3$	C_2T = –VC:T_3 = H	-0.083	-0.152	-0.014	-2.372	0.010
	C_2T = NO:T_3 = H	-0.038	-0.100	0.024	-1.205	0.116
	C_2T = –VC:T_3 = L	-0.012	-0.077	0.053	-0.361	0.360
	C_2T = NO:T_3 = L	-0.037	-0.103	0.029	-1.111	0.135

Table D.14: Fixed effects in the model of couplet duration

Term	Parameter	Estimate	CI.lower	CI.upper	t.value	p.77
	(Intercept)	2.612	2.583	2.640	181.670	0.000
S	S = CVV	0.005	-0.037	0.048	0.249	0.402
T_1	T_1 = H	-0.045	-0.088	-0.003	-2.082	0.020
	T_1 = L	-0.031	-0.074	0.013	-1.386	0.085
T_2	T_2 = H	-0.024	-0.058	0.010	-1.361	0.089
	T_2 = L	0.020	-0.020	0.060	0.986	0.164
T_3	T_3 = H	-0.035	-0.069	-0.000	-1.966	0.026
	T_3 = L	0.003	-0.029	0.035	0.185	0.427
CL	CL = NA	-0.166	-0.185	-0.147	-17.123	0.000
	CL = VA	-0.182	-0.203	-0.162	-17.347	0.000
REP	REP = IIN	0.003	-0.004	0.009	0.740	0.231
	REP = UNI	-0.016	-0.023	-0.009	-4.550	0.000
S × T_1	S = CVV:T_1 = H	-0.003	-0.066	0.060	-0.099	0.461
	S = CVV:T_1 = L	0.046	-0.018	0.109	1.410	0.081
S × T_2	S = CVV:T_2 = H	0.037	-0.025	0.098	1.161	0.125
	S = CVV:T_2 = L	-0.003	-0.066	0.060	-0.094	0.463
T_2 × T_1	T_2 = H:T_1 = H	0.032	-0.024	0.088	1.126	0.132
	T_2 = L:T_1 = H	0.009	-0.054	0.071	0.273	0.393
	T_2 = H:T_1 = L	0.047	-0.009	0.102	1.650	0.051
	T_2 = L:T_1 = L	0.033	-0.020	0.086	1.233	0.111
CL × T_3	CL = NA:T_3 = H	-0.003	-0.032	0.026	-0.208	0.418
	CL = VA:T_3 = H	-0.003	-0.034	0.028	-0.195	0.423
	CL = NA:T_3 = L	0.037	0.008	0.066	2.475	0.008
	CL = VA:T_3 = L	0.048	0.016	0.080	2.933	0.002
S × CL	S = CVV:CL = NA	-0.116	-0.140	-0.093	-9.811	0.000
	S = CVV:CL = VA	-0.171	-0.196	-0.146	-13.182	0.000
S × T_3	S = CVV:T_3 = H	0.008	-0.037	0.053	0.362	0.359
	S = CVV:T_3 = L	-0.025	-0.070	0.021	-1.067	0.145
S ×	S = CVV:T_2 = H:T_1 = H	-0.000	-0.088	0.087	-0.010	0.496
T_2 × T_1	S = CVV:T_2 = L:T_1 = H	-0.006	-0.096	0.085	-0.124	0.451
	S = CVV:T_2 = H:T_1 = L	-0.088	-0.175	-0.001	-1.981	0.026
	S = CVV:T_2 = L:T_1 = L	-0.080	-0.161	0.002	-1.919	0.029

D.3 The interaction of tone and glottalization

Table D.15: Tone study CVˀV target words

Orthographic	Phonemic	Gloss	Category	Tones
vi'i	viˀi	a bit	Adv	HH
yo'o	ʒoˀo	you (FAM)	Pro	HH
tu'un	tuˀu$_{n}$	alone	Adj	HH
xa'an	ʃaˀa$_{n}$	hawk	N	HH
kua'a	kʷaˀa	red	Adj	HH + L
jo'o	xoˀo	deaf	Adj	HH + L
ni'i	niˀi	chicken	N	HH + L
ye'e	ʒeˀe	door	N	HH + L
ndyi'i	^{n}dʲiˀi	short	Adj	ML + H
ka'a	kaˀa	butt	N	ML + H
ñu'u	ɲuˀu	earth	N	ML + H
yo'o	ʒoˀo	rope	N	ML + H
tu'un	tuˀu$_{n}$	yank	V	MM
nda'a	^{n}daˀa	fatten	V	MM
ko'o	koˀo	drink (POT)	V	MM
ve'e	veˀe	house	N	MM
kua'an	kʷaˀa$_{n}$	go (IPFV)	V	LL
yu'u	ʒuˀu	I	Pro	LL
ni'i	niˀi	receive	V	LL
se'e	seˀe	trash	N	LL
yo'o	ʒoˀo	twisted	Adj	LL + H
kua'a	kʷaˀa	many	Adj	LL + H
ndo'o	^{n}doˀo	basket	N	LL + H
sa'a	saˀa	foot	N	LL + H
ji'in	xiˀi$_{n}$	leg	N	LM
nu'u	nuˀu	tooth	N	LM
xa'an	ʃaˀa$_{n}$	lard	N	LM
yo'o	ʒoˀo	root	N	LM

Table D.16: Random effects in the model of F0 in level tone patterns

Groups	Name	Variance	Std.Dev.
Instance	(Intercept)	3.5330e-07	0.00059439
Target	(Intercept)	1.4301e+01	3.78167355
	CL = NA	7.9685e+00	2.82285548
	CL = VA	4.7617e+00	2.18214105
	TIME = M	9.4785e+00	3.07871461
	TIME = F	1.8064e+01	4.25023134
	REP = IIN	6.3311e-01	0.79568135
	REP = UNI	7.8419e-01	0.88554463
	CL = NA:TIME = M	8.1164e+00	2.84892796
	CL = VA:TIME = M	1.2779e+01	3.57481322
	CL = NA:TIME = F	8.9870e+00	2.99783338
	CL = VA:TIME = F	1.3435e+01	3.66539561
Residual		7.9579e+00	2.82096943

Table D.17: Fixed effects in the model of F0 in level tone patterns

	Estimate	CI.lower	CI.upper	t.value	p.21
(Intercept)	85.395	84.323	86.466	156.21	0.000
T = H	3.242	2.079	4.404	5.46	0.000
T = L	-3.525	-4.590	-2.461	-6.49	0.000
S = CVˀV	1.594	0.162	3.026	2.18	0.020
TIME = M	-0.992	-1.744	-0.240	-2.584	0.009
TIME = F	-0.904	-1.857	0.050	-1.857	0.039
CL = NA	-1.187	-1.900	-0.473	-3.260	0.002
CL = VA	-0.666	-1.311	-0.022	-2.026	0.028
REP = IIN	0.553	0.178	0.927	2.893	0.004
REP = UNI	-0.143	-0.508	0.221	-0.771	0.225
T = H:S = CVˀV	1.500	-0.225	3.226	1.70	0.052
T = L:S = CVˀV	-0.924	-2.572	0.724	-1.10	0.142
S = CVˀV:TIME = M	-0.516	-1.203	0.171	-1.473	0.078
S = CVˀV:TIME = F	-0.088	-0.970	0.793	-0.196	0.423
TIME = M:CL = NA	1.017	0.143	1.891	2.281	0.017
TIME = F:CL = NA	0.633	-0.200	1.467	1.489	0.076
TIME = M:CL = VA	1.106	0.161	2.051	2.295	0.016
TIME = F:CL = VA	0.480	-0.323	1.283	1.172	0.127

Table D.18: Random effects in the model of CPP in level tone patterns

Groups	Name	Variance	Std.Dev.
Instance	(Intercept)	3.5330e-07	0.00059439
Target	(Intercept)	1.4301e+01	3.78167355
	CL = NA	7.9685e+00	2.82285548
	CL = VA	4.7617e+00	2.18214105
	TIME = M	9.4785e+00	3.07871461
	TIME = F	1.8064e+01	4.25023134
	REP = IIN	6.3311e-01	0.79568135
	REP = UNI	7.8419e-01	0.88554463
	CL = NA:TIME = M	8.1164e+00	2.84892796
	CL = VA:TIME = M	1.2779e+01	3.57481322
	CL = NA:TIME = F	8.9870e+00	2.99783338
	CL = VA:TIME = F	1.3435e+01	3.66539561
Residual		7.9579e+00	2.82096943

Table D.19: Fixed effects in the model of CPP in level tone patterns

	Estimate	CI.lower	CI.upper	t.value	p.21
(Intercept)	25.216	23.647	26.785	31.51	0.000
T = H	0.928	-0.113	1.969	1.75	0.048
T = L	-4.358	-5.297	-3.418	-9.09	0.000
S = CVˀV	-1.580	-3.225	0.065	-1.88	0.037
TIME = M	2.496	1.222	3.770	3.84	0.000
TIME = F	-0.692	-2.388	1.003	-0.80	0.216
CL = NA	-0.814	-1.982	0.354	-1.37	0.093
CL = VA	-1.414	-2.436	-0.391	-2.71	0.007
REP = IIN	0.036	-0.403	0.476	0.16	0.436
REP = UNI	-0.200	-0.662	0.262	-0.85	0.203
T = H:S = CVˀV	-1.071	-2.667	0.525	-1.32	0.101
T = L:S = CVˀV	2.503	1.007	3.998	3.28	0.002
S = CVˀV:TIME = M	-5.271	-6.474	-4.068	-8.59	0.000
S = CVˀV:TIME = F	-3.033	-4.673	-1.393	-3.62	0.001
TIME = M:CL = NA	1.306	0.000	2.612	1.96	0.032
TIME = F:CL = NA	4.781	3.316	6.247	6.39	0.000
TIME = M:CL = VA	0.016	-1.419	1.450	0.02	0.492
TIME = F:CL = VA	3.594	2.031	5.156	4.51	0.000

Table D.20: Random effects in the model of HNR in level tone patterns

Groups	Name	Variance	Std.Dev.
Instance	(Intercept)	0.35830	0.59859
Target	(Intercept)	14.82667	3.85054
	CL = NA	4.74718	2.17880
	CL = VA	6.89718	2.62625
	TIME = M	12.89824	3.59141
	TIME = F	14.57641	3.81791
	REP = IIN	0.26984	0.51946
	REP = UNI	0.72842	0.85348
	CL = NA:TIME = M	8.56234	2.92615
	CL = VA:TIME = M	11.46089	3.38539
	CL = NA:TIME = F	14.63375	3.82541
	CL = VA:TIME = F	26.41517	5.13957
Residual		8.00510	2.82933

Table D.21: Fixed effects in the model of HNR in level tone patterns

	Estimate	CI.lower	CI.upper	t.value	p.21
(Intercept)	13.728	11.539	15.917	12.29	0.000
T = H	-1.454	-3.758	0.851	-1.24	0.115
T = L	-7.952	-10.072	-5.832	-7.35	0.000
S = CVˀV	-5.881	-8.822	-2.941	-3.92	0.000
TIME = M	5.513	3.975	7.052	7.02	0.000
TIME = F	2.935	1.269	4.601	3.45	0.001
CL = NA	-1.149	-2.241	-0.058	-2.06	0.026
CL = VA	-1.417	-2.588	-0.247	-2.37	0.014
REP = IIN	-0.007	-0.472	0.458	-0.03	0.488
REP = UNI	-0.144	-0.662	0.374	-0.54	0.296
T = H:S = CVˀV	2.054	-1.354	5.462	1.18	0.125
T = L:S = CVˀV	6.227	2.959	9.495	3.73	0.001
S = CVˀV:TIME = M	-5.383	-7.006	-3.760	-6.50	0.000
S = CVˀV:TIME = F	-3.708	-5.397	-2.020	-4.30	0.000
TIME = M:CL = NA	-1.066	-2.420	0.288	-1.54	0.069
TIME = F:CL = NA	1.218	-0.468	2.904	1.42	0.086
TIME = M:CL = VA	-1.835	-3.273	-0.397	-2.50	0.010
TIME = F:CL = VA	1.373	-0.588	3.335	1.37	0.092

Table D.22: Random effects in the model of H1–H2 in level tone patterns

Groups	Name	Variance	Std.Dev.
Instance	(Intercept)	0.61826	0.78629
Target	(Intercept)	4.09728	2.02417
	CL = NA	4.12140	2.03012
	CL = VA	6.01572	2.45270
	TIME = M	6.15934	2.48180
	TIME = F	7.46046	2.73138
	REP = IIN	0.72435	0.85109
	REP = UNI	0.78999	0.88882
	CL = NA:TIME = M	18.13234	4.25821
	CL = VA:TIME = M	6.09105	2.46801
	CL = NA:TIME = F	8.68481	2.94700
	CL = VA:TIME = F	5.67067	2.38132
Residual		15.99323	3.99915

Table D.23: Fixed effects in the model of H1–H2 in level tone patterns

	Estimate	CI.lower	CI.upper	t.value	p.17
(Intercept)	-0.992	-2.915	0.931	-1.01	0.163
V = E	0.465	-1.256	2.185	0.53	0.302
V = I	4.749	3.437	6.061	7.10	0.000
V = O	-0.578	-1.957	0.801	-0.82	0.211
V = U	4.446	2.438	6.455	4.34	0.000
T = H	4.502	2.513	6.492	4.43	0.000
T = L	-3.046	-4.892	-1.200	-3.23	0.002
S = CVˀV	-1.244	-3.541	1.052	-1.06	0.152
TIME = M	-0.032	-1.377	1.314	-0.05	0.482
TIME = F	0.176	-1.402	1.753	0.22	0.415
CL = NA	0.902	-0.432	2.235	1.33	0.101
CL = VA	1.292	-0.079	2.664	1.85	0.041
REP = IIN	0.339	-0.247	0.925	1.13	0.136
REP = UNI	0.177	-0.438	0.793	0.57	0.290
T = H:S = CVˀV	-2.067	-4.820	0.686	-1.47	0.080
T = L:S = CVˀV	-0.976	-3.622	1.671	-0.72	0.240
S = CVˀV:TIME = M	0.137	-1.193	1.467	0.20	0.421
S = CVˀV:TIME = F	1.619	-0.059	3.296	1.89	0.038
TIME = M:CL = NA	-2.509	-4.418	-0.600	-2.58	0.010
TIME = F:CL = NA	-1.763	-3.555	0.029	-1.93	0.035
TIME = M:CL = VA	-2.424	-3.964	-0.885	-3.09	0.003
TIME = F:CL = VA	-2.490	-4.185	-0.796	-2.88	0.005

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