



8-2008

## Acoustic correlates of fortis/lenis in San Francisco Ozolotepec Zapotec

Anita J. Leander

[How does access to this work benefit you? Let us know!](#)

Follow this and additional works at: <https://commons.und.edu/theses>



Part of the [Linguistics Commons](#)

---

### Recommended Citation

Leander, Anita J., "Acoustic correlates of fortis/lenis in San Francisco Ozolotepec Zapotec" (2008).  
*Theses and Dissertations*. 4470.  
<https://commons.und.edu/theses/4470>

This Thesis is brought to you for free and open access by the Theses, Dissertations, and Senior Projects at UND Scholarly Commons. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of UND Scholarly Commons. For more information, please contact [und.common@library.und.edu](mailto:und.common@library.und.edu).

ACOUSTIC CORRELATES OF FORTIS/LENIS IN SAN FRANCISCO  
OZOLOTEPEC ZAPOTEC

by

Anita J. Leander  
Bachelor of Arts, Northwestern College, St. Paul, MN, 1998

A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Arts

Grand Forks, North Dakota

August

2008

c 2008 Anita J. Leander

This thesis, submitted by Anita J. Leander in partial fulfillment of the requirements for the Degree of Master of Arts from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

John Clifton

---

Chairperson

Steve Parker

---

Joan Baart

This thesis meets the standards for appearance, conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

Joseph N. Benoit

---

Dean of the Graduate School

---

Date

PERMISSION

Title           Acoustic Correlates of Fortis/Lenis in San Francisco Ozolotepec Zapotec  
Department   Linguistics  
Degree        Master of Arts

In presenting this thesis in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the library of this University shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my thesis work or, in his absence, by the chairperson of the department or the dean of the Graduate School. It is understood that any copying or publication or other use of this thesis or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of North Dakota in any scholarly use which may be made of any material in my thesis.

Signature \_\_\_\_\_ Anita J. Leander \_\_\_\_\_

Date \_\_\_\_\_ July 17, 2008 \_\_\_\_\_

## TABLE OF CONTENTS

LIST OF FIGURES .....	viii
LIST OF TABLES .....	ix
ACKNOWLEDGEMENTS .....	xi
ABBREVIATIONS .....	xii
ABSTRACT .....	xiv
CHAPTER	
1 INTRODUCTION .....	1
1.1 The fortis/lenis question.....	2
1.2 Fortis/lenis analyses of Zapotec.....	3
1.2.1 Descriptions of fortis/lenis in various Zapotec languages ...	4
1.2.2 Hypothesis: fortis consonants as geminates.....	9
1.2.3 Nellis and Hollenbach (1980), a counterargument to fortis as geminates.....	11
1.3 Instrumental studies of fortis/lenis in Zapotec.....	14
1.3.1 Yateé Zapotec – Jaeger (1983) .....	14
1.3.2 Yalálag Zapotec – Avelino (2001).....	17
1.4 Fortis/lenis in SFOZ and SCXZ.....	20
2 SAN FRANCISCO OZOLOTEPEC ZAPOTEC .....	23
2.1 SFOZ Consonants .....	25
2.1.1 Stops.....	27
2.1.2 Affricates.....	30

	2.1.3	Fricatives.....	32
	2.1.4	Sonorants.....	32
	2.2	Vowels .....	33
	2.3	Glottal: neither consonant nor vowel.....	35
	2.4	Tone and intonation .....	37
	2.5	Syllable .....	40
	2.6	Stress.....	43
	2.7	Distribution of fortis/lenis segments.....	44
	2.7.1	Grammatical considerations.....	44
	2.7.2	Phonological considerations .....	46
	2.8	Impressionistic evaluation of fortis/lenis segments .....	46
3		PROCEDURES.....	48
	3.1	Scope of study.....	48
	3.2	Data selection.....	48
	3.3	Data recording.....	55
	3.4	Speaker selection, speaker characteristics and variation .....	57
4		DATA PROCEDURES, ANALYSIS, RESULTS .....	60
	4.1	Duration of VC segments and rime .....	60
	4.1.1	Word-final VC sequences.....	61
	4.1.2	Word-medial consonant duration.....	75
	4.2	Vowel quality.....	77
	4.3	Voicing and voice onset time (VOT).....	82
	4.3.1	Words used – word-final VOT .....	83
	4.3.2	Procedures – word-final VOT.....	84
	4.3.3	Results – word-final VOT.....	85

4.3.4	Words used – word-medial VOT .....	87
4.3.5	Results – word-medial VOT .....	87
4.3.6	Discussion/conclusion – VOT in all positions.....	89
4.4	Voice tail.....	90
4.4.1	Words used – voice tail.....	91
4.4.2	Procedures – voice tail .....	92
4.4.3	Results – voice tail .....	93
4.4.4	Discussion and conclusion.....	94
4.5	Intensity.....	95
4.5.1	Words used – intensity of sonorants .....	96
4.5.2	Procedures - intensity.....	97
4.5.3	Results of sonorant intensity.....	98
4.5.4	Discussion/conclusion.....	101
4.6	Pilot study: VOT and consonant duration of /p/, /b/, /t/ and /d/ in SFOZ and SCXZ.....	102
4.6.1	Initial consonant duration .....	104
4.6.2	Initial VOT.....	105
4.6.3	Discussion and conclusion.....	108
5	CONCLUSION.....	109
APPENDICES	114	
REFERENCES	125	



## LIST OF FIGURES

Figure	Page
1. Map of Oaxaca, Mexico.....	1
2. Languages and subgroupings of Southern Zapotec (Beam de Azcona) .....	5
3. Location and relationship of Southern Zapotec variants (Beam de Azcona) .....	20
4. Spectrogram and wave form segment boundaries .....	56
5. Illustration of the duration boundaries of vowel and consonant segments .....	63
6. Total rime duration (in ms) with vowel and consonant segments .....	65
7. Illustration of the consonant duration of fortis/lenis segments .....	68
8. Illustration of the duration of vowel /a/ preceding fortis/lenis consonants .....	70
9. Mean rime duration of vowels /i/ and /a/ before both fortis/lenis and obstruent/ sonorant consonants .....	72
10. Interaction between the vowel and consonant in fortis and lenis rimes .....	74
11. Formant values for high front and low back vowels.....	81
12. Percentage of consonant duration with voice tail .....	94
13. Spectrogram and wave file of creaky /a/ in the context of <i>kneʔgjaɬ ada inedl</i> as spoken by SFOZ Speaker three .....	124

## LIST OF TABLES

Table	Page
1. Phonetic correlates of fortis/lenis in various Zapotec languages.....	4
2. Inventory of fortis/lenis correlates in several Zapotec regions and variants .....	5
3. Inventory of SFOZ consonant phonemes .....	26
4. Contrast between /p/ and /b/ .....	29
5. Contrast between /t/ and /d/ .....	30
6. Contrast between /k/ and /g/ .....	30
7. Contrast between /ts/ and /dz/.....	31
8. Contrast between /s/ and /z/, /ʃ/ and /ʒ/.....	32
9. Inventory of vowel phonemes.....	34
10. Tone contrast between SFOZ and SCXZ.....	38
11. Word-final fortis/lenis pairs analyzed for VC duration (and V quality).....	62
12. Mean duration of fortis (F) and lenis (L) sonorants and obstruents (in ms).....	65
13. Mean (MN) and standard deviation (StDev) duration values of all word-final fortis/lenis consonants after /i/ and /a/ (in ms) (N=30 each).....	66
14. Mean and standard deviation of duration of vowels /i/ and /a/ before word-final fortis/lenis consonants (in ms) (N = 30 each).....	69
15. Mean rime duration and standard deviation of combined VC segments (in ms)..	73
16. Word-medial fortis/lenis pairs for analysis.....	75
17. Consonant duration of word-medial fortis/lenis /p/, /b/, /t/, /d/, /k/, and /g/ (in ms) (N = 18 each).....	76
18. ANOVA: word-medial point of articulation and length (fortis/lenis). .....	77

19.	Mean value of F1 and F2 before fortis/lenis obstruents and sonorants (in Hz)....	80
20.	Word-final stops /p/, /b/, /t/, /d/, /k/, /g/ following /i/ and /a/ .....	84
21.	VOT of word-final stops (in ms) .....	85
22.	Word-medial stops /p/, /b/, /t/, /d/, /k/, /g/.....	87
23.	VOT of word-medial /p/, /b/, /t/, /d/, /k/ and /g/ .....	88
24.	ANOVA: word-medial place of articulation, length (fortis/lenis), VOT.....	89
25.	Word-final stops /p/, /b/, /t/, /d/, /k/, and /g/ analyzed for voice tail.....	91
26.	Voice tail on word-final fortis/lenis consonants (in ms).....	93
27.	Fortis/lenis sonorants analyzed for intensity.....	97
28.	Mean intensity results of fortis/lenis sonorants following i/a (in dB) .....	98
29.	Mean intensity results of fortis/lenis sonorants (in dB).....	99
30.	Statistical <i>t</i> -test values for intensity of sonorants /l/, /l:/, /n/, /n:/ .....	99
31.	Univariate Analysis of Variance (ANOVA) values for sonorant intensity .....	100
32.	Words used in pilot study of SFOZ and SCXZ .....	103
33.	Mean consonant duration of /p/, /b/ and /t/, /d/ in SFOZ and SCXZ (in ms) .....	104
34.	Mean +VOT and % of -VOT of /p/, /b/, /t/, and /d/ in SFOZ and SCXZ.....	106

## ACKNOWLEDGEMENTS

My sincere gratitude is to the people of San Francisco Ozolotepec and Santa Catarina Xanaguía for sharing your lives and language with me. This thesis would not be possible without your generosity, and the cooperation of Renato Juarez Perez, Baltazar Perez Ramos, Alejandro Romero Lopez, Sibilino Perez Gallardo, and two other speakers from San Francisco Ozolotepec, along with Natanahel Valladarez Cruz, Cosme Valladarez Cruz, and two other speakers from Santa Catarina Xanaguía. *¡Laki ndzun xdi'dzda!*

Many thanks go to my committee members, John Clifton, Joan Baart, and Steve Parker. Each of you has contributed so much time, effort and experience. I am also indebted to Steve Marlett for helping me get started, and to Beth Merrill and Cheri Black for their insightful comments on previous drafts. It is hard to quantify just how very much each of you has taught me through this thesis experience. Thanks to countless others who have contributed along the way through published research, linguistic insights, and personal encouragement (Holly, Dustin, Becky, and Starbucks in Duncanville to name just a few). Research was conducted as project number IRB-200603-317.

Above and before all, my gratitude is to the Maker of us, our minds, and the languages we speak. You have given us language to communicate with you. How tenderly you want to speak to us; may we seek you and listen to your voice.

## ABBREVIATIONS

Adv.	Adverb
<b>ANOVA</b>	<b>Univariate Analysis of Variance</b>
1	First person
C	Consonant
CAUS	Causative
COMPL	Completive Aspect
dB	Decibels
F	Fortis
F1	First formant
F2	Second formant
F3	Third formant
FUT	Future aspect
<b>GPS</b>	<b>Global positioning system</b>
HAB	Habitual aspect
Hz	Hertz
ILV	<i>Instituto Lingüístico de Verano</i> [SIL]
IMP	Imperative aspect
L	Lenis
MN	Mean
ms	milliseconds
N	Number of tokens

n.	noun
Neg	Negator
NOM	nominalizer
PASS	Passive
pl	plural
PN	Pronoun
poa	Point of articulation
POSS	Possessive
POT	Potential aspect
SCXZ	Santa Catarina Xanaguía Zapotec
SFOZ	San Francisco Ozolotepec Zapotec
sg	Singular
Sp.	Spanish
StDev	Standard deviation
TBU	Tone bearing unit
V	Vowel
v.	verb
VOT	Voice onset time
ztg	ISO code 639-3 for the Zapotec variant considered in this thesis
( )	Loanword
-	Morpheme break
à (L)	Low tone
á (H)	High tone
ǎ (LH)	Rising tone
â (HL)	Falling tone

## ABSTRACT

Analyses of the Zapotec family of languages often divide consonants into categories of strong and weak consonants, more commonly known as fortis and lenis. These given categories usually correspond to voiceless and voiced, respectively. In San Francisco Ozolotepec Zapotec (SFOZ) and Santa Catarina Xanaguía Zapotec (SCXZ),<sup>1</sup> prior analyses describe the fortis/lenis distinction in terms of duration, voicing, and articulatory force. This description parallels other impressionistic descriptions in Isthmus-Valley and Southern Zapotec variants. However, no study has objectively identified the acoustic patterns of the fortis/lenis contrast in SFOZ or in any Southern, Valley, or Isthmus Zapotec language. A previous instrumental study of the northern Zapotec variant of Yateé describes the fortis/lenis contrast in terms of duration, glottal width, and closure width. A similar experimental study of the northern variant spoken in Yalálag describes the fortis/lenis contrast in terms of duration, voice onset time (VOT) and voicing, and amplitude. Both conclusions reject the terms fortis/lenis and point to characterization of the contrast in terms of geminate/single.

My intention in this thesis is to present acoustic analyses of recordings made by native Zapotec speakers of both SFOZ and SCXZ. I analyze the acoustic properties of the word-final fortis/lenis consonant contrast of SFOZ, with occasional reference to data from SCXZ. Parallel to instrumental results for Yalálag Zapotec (Avelino 2001) and Yateé Zapotec (Jaeger 1983), duration is a primary characteristic differentiating fortis and

---

<sup>1</sup> SFOZ and SCXZ are two language communities that speak mutually intelligible variants given the same ISO 639-3 code 'ztg' (Gordon 2005).

lenis consonants in SFOZ and SCXZ. Data from six adult male speakers of SFOZ reveal a second acoustic correlate of fortis and lenis segments in word-final position, quality of the preceding vowel. Voicing and VOT add to the phonetic contrast, but are not reliable cues in SFOZ. In contrast with Jaeger's results, which found that "fortis consonants have consistently higher...average amplitudes than those of the lenis consonants" (1983:183), I found no difference in the average amplitude of fortis/lenis sonorants. In contrast with variation in sonorants in Yalálag, SFOZ sonorants – both nasals and laterals – match the duration patterns of obstruents: fortis consonants are long and lenis consonants are short. In SCXZ, obstruents can be defined in terms of voicing; however this distinction is considerably less reliable in SFOZ.



## CHAPTER 1

### INTRODUCTION

Traditional analyses of many Zapotec languages divide consonants into two categories, fortis (strong) and lenis (weak) (Swadesh 1947; Pickett 1951, 1967; Fernández 1995). This fortis/lenis contrast has been described by a long list of phonetic correlates including duration, voice-onset-time or voicing, amplitude, articulatory force, glottal width, and closure width. In this instrumental study I identify the acoustic correlates of fortis and lenis consonants in San Francisco Ozolotepec Zapotec (SFOZ) and, to a lesser extent, in Santa Catarina Xanaguía Zapotec (SCXZ).<sup>2</sup>



Figure 1. Map of Oaxaca, Mexico

The Zapotec language spoken in the communities of San Francisco Ozolotepec (SFOZ) and Santa Catarina Xanaguía (SCXZ) belongs to the Zapotec family of the Otomanguean stock spoken primarily in Oaxaca, Mexico. The Zapotec family of

---

<sup>2</sup> SFOZ and SCXZ are classified by the ISO 639-3 code ‘ztg’ (Gordon 2005).

languages is divided into four groups: Northern, Central (or Valley-Isthmus), Western (also known as Papabuco), and Southern (Swadesh 1947:221). SFOZ and SCXZ are geographically situated in the eastern part of the Southern Zapotec group.

In this chapter, I present the general background of the fortis/lenis issue, summarize analyses of fortis/lenis in Zapotec languages, and outline the findings of two similar instrumental studies. In chapter two, I introduce the SFOZ community along with the basic phonological system and also the relevant phonetic variations of the neighboring SCXZ community. I describe the experimental procedure for data selection, recording, and speaker selection in chapter three, and present the findings on durations, vowel quality, voicing and VOT, and intensity in chapter four. In chapter five I summarize the findings and suggest areas for further research.

## **1.1 The fortis/lenis question**

The terms fortis and lenis label contrasting pairs of consonants. The terms imply reference to articulatory strength, one category being in some way stronger and the other weaker. Jaeger (1983) identifies three types of phonological systems that have been labeled fortis/lenis, dismissing the use of terms ‘fortis/lenis’ in the first two. Consonant contrasts in the first system, exemplified by English, can be explained in terms of voice onset time (VOT). The second system, exemplified by Korean, may be described in terms of tense voice and lax voice, with no durational difference between the two consonant types. In the third phonological system, VOT is not a reliable cue to the fortis/lenis contrast, and various phonetic properties give the impression of a difference in force of articulation. Zapotec fits into the third category, not able to rely fully on voicing or VOT,

quite unlike the Korean system of tense/lax, and consistently described on the basis of articulatory strength.

The fortis/lenis distinction is a descriptive tool that identifies a phonological contrast different from the typical voiced/voiceless distinction in other languages. It is useful as a simple name for what is a cluster of articulatory characteristics that varies phonetically in individual Zapotec languages. At the same time, Jaeger (1983) claims the terms over generalize, obscure the acoustic phonetic correlates unique to Zapotec languages, and leave much to be desired when it comes to truly understanding the articulatory quality of the consonant contrast. The following section is an overview of the varied analyses of Zapotec languages that use the categories fortis and lenis.

## **1.2 Fortis/lenis analyses of Zapotec**

Jaeger (1983) claims that the terms fortis/lenis have two basic uses: "...to characterize a basic phonological contrast in consonant systems which cannot be explained in terms of a voicing distinction", and ..."to add additional phonetic information to a contrast which is primarily characterized as voiced/voiceless" (p. 177). Since early analyses of Zapotec languages in Mexico, use of these terms is due in part to the insufficiency of voicing as a reliable cue, but even more to an impression of strength given by fortis consonants that they are unlike simple voiceless consonants found in other languages.

What is described as strength takes various phonetic realizations. In an attempt to describe fortis and lenis consonants in various Zapotec languages, linguists have used combinations of the following phonetic correlates in a variety of groupings: strength, articulatory force, amplitude, tension, duration, voicing and/or voice onset time (VOT),

glottal width, and closure width. See Table 1 for an overview of correlates used to describe the fortis/lenis contrast in several Zapotec variants.

Table 1. Phonetic correlates of fortis/lenis in various Zapotec languages

Phonetic correlates of fortis/lenis in Zapotec <sup>3</sup>	
strong	weak
greater articulatory force	
greater amplitude	
longer consonant	shorter consonant
geminate	single
shorter preceding V	longer preceding V
lax preceding V	tense preceding V
voiceless	voiced
	slight voicing
+VOT, aspirated	+/- VOT
	voiceless release
glottal width	
closure width (complete closure)	stops prone to friction

The variety of descriptions and analyses attests to the variation among Zapotec languages as well as the complexity of the contrast under consideration.

### 1.2.1 Descriptions of fortis/lenis in various Zapotec languages

The fortis/lenis distinction is present in each of the regions: Isthmus (Pickett), Western, or Papabuco, (Operstein 2004:107-116; Robinson 1963), Northern (Newberg 1987), Southern (Reeck 1991), and Valley (Jones and Knudson 1977). In the map of the state of Oaxaca, Mexico in Figure 2, Beam de Azcona (2008) identifies the geographic location of the Zapotec language regions. SFOZ and SCXZ are geographically situated in the region labeled ‘Southern Zapotec’. In Table 2 I present an inventory of fortis/lenis descriptions of a few Zapotec languages in each of the regions.

<sup>3</sup> This list is compiled from Swadesh 1947; Pickett 1967; Speck 1978:18; Nellis and Hollenbach 1980; Butler 1980; Jaeger 1983; Rendón 1995:16-17; Avelino 2001.

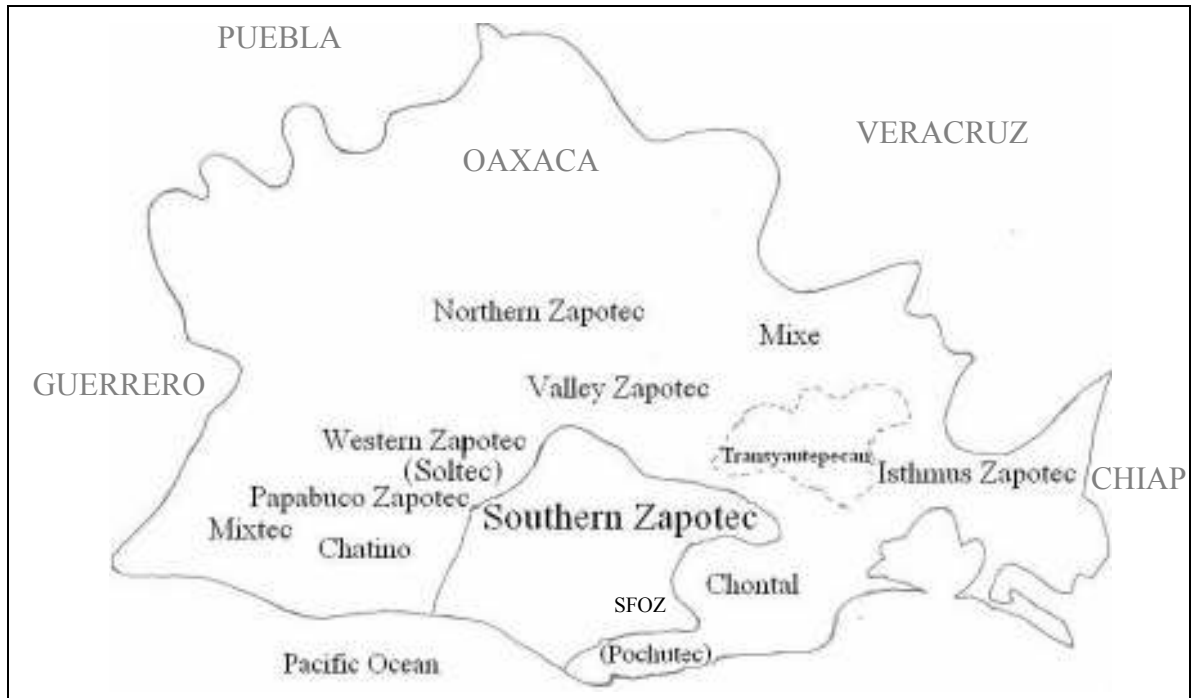


Figure 2. Languages and sub groupings of Southern Zapotec (Beam de Azcona)

Table 2. Inventory of fortis/lenis correlates in several Zapotec regions and variants

Region/Variant	tense	articulatory /strength	VOT aspiration	vowel	C duration	closure width/type	voicing	Reference
ISTHMUS		X		X	X			Pickett 1951
WESTERN								
Papabuco					X			Robinson 1963
Zaniza			X		X		X	Operstein 2004:107-116
NORTHERN								
Yatzachi del Bajo		X	X	X			X	Butler 1980:3-4;1997
Yalálag					X			Avelino 2001
SOUTHERN								
Cajonos	X	X		X	X		X	Nellis and Hollenbach 1980
Yateé			X		X	X	X	Jaeger 1983
San Juan Mixtepec	X	X			X		X	Reeck 1991
San Francisco Ozolotepec	?	?		X	X		X	Current study
VALLEY								
Tlacoahuaya		X			X		X	Rendón 1995
Guelavia	X		X	X	X		X	Jones and Knudson 1977
Chichicapam					X			Benton 1987
Tilquiapam					X		X	Merrill 2008a
Santo Domingo Albarradas					X		X	Kreikebaum 1987
Choapam			X			X	X	Lyman and Lyman 1977

Butler, writing about Yatzachi del Bajo Zapotec, a northern language, defines the basic consonant distinction as ‘strong’ and ‘weak.’ Strong obstruents are pronounced “with a puff or release of air”, and when pronounced one feels “more strength in the mouth” (translations mine). All strong consonants are voiceless except for /l/ and /n/. Weak obstruents are sometimes voiced, but often voiceless; even when voiceless, they are weaker (Butler 1980:3-4). Similar to the idea of articulatory strength, Nellis & Hollenbach (1980:92) describe Cajonos Zapotec fortis consonants as ‘tense’ and lenis as ‘lax’. After an experimental study of Yateé Zapotec, Jaeger (1983), instead of using terms ‘fortis’, ‘lenis’ and ‘force of articulation’, says that the consonant contrast is due to “timing of articulator gestures and glottal width” (p. 177).

Geographically closer to SFOZ, Chichicapam Zapotec, situated between valley and southern groups, is unique in that it reports a complete set of fortis/lenis nasals (mm/m, nn/n, nny/ny). In addition, the phonetic sequence [ld] fills the role of the fortis lateral phoneme<sup>4</sup> (Benton 1987:72-84).

In Guelavía Zapotec, which is a valley Zapotec, fortis/lenis consonants contrast in correlates of voicing, tense/lax, length. Fortis consonants are generally longer and are aspirated clause-finally, while lenis consonants cause preceding vowels to lengthen. Lenis consonants also have a voiceless release clause-finally and are predominantly fricative, except following a homorganic consonant (p. 168).<sup>5</sup> Jones and Knudson (1977) describe the fortis/lenis contrast as follows:

---

<sup>4</sup> This fortis /ld/ is also posited in another valley Zapotec spoken in Tilquiapan (Merrill 2008a).

<sup>5</sup> In Guelavía Zapotec it seems that duration of the consonant and duration and quality of the vowel are tied into the syllable structure (closed or open) and the stress (stressed or unstressed). A lax vowel only occurs after a glide and before a fortis consonant.

All fortis obstruents are voiceless. Stress lengthens a fortis consonant...[A] fortis consonant is more tense and generally longer than a lenis consonant...all fortis consonants are long when occurring intervocalically following a stressed vowel or before a pause. Fortis stops and nasals are also long following a stressed vowel when preceding a semivowel or voiced consonant. In addition to length, the fortis stops /ptk/ are aspirated before a pause (p. 166).

Lenis consonants are voiced. Lenis consonants cause the preceding vowel to lengthen...A lenis consonant is more lax, with stops tending towards fricative articulation...[with] a voiceless release before a pause...A lenis consonant also has a voiceless release before a pause (with the exception of the nasals /m/ and /n/). Lenis consonants also cause preceding stressed oral vowels to be lengthened (p. 163). (pp. 163, 166, and 173).

Voicing and VOT are common correlates of the fortis/lenis contrast between obstruents. The consonant contrast in Zaniza Zapotec, a western Zapotec variant, is orthographically represented as voiced/voiceless for obstruents and as double consonants for fortis nasals (Operstein 2004:107-116). In Santo Domingo Albarradas Zapotec, considered to be a valley Zapotec, the consonant contrast is represented by voiceless/voiced consonants for obstruents, and by double/single consonants for sonorants (excluding fortis /m/, /w/, and /y/) (Bickford 1985). Western Ixtlán Zapotec (in the northern group), also distinguishes between fortis/lenis obstruents and sonorants, with obstruent pairs represented as voiced/voiceless, and sonorants as short and long (Thiessen 1987:85).<sup>6</sup>

Choapan Zapotec is a variant in which just a voiced and voiceless distinction is sufficient to describe the consonant contrast. Lyman and Lyman (1977) report that “each has a counterpart distinguished by voicing.” Furthermore, all obstruent categories “exhibit the same voiceless-voiced pairing.” Sonorants are not noted for a durational difference and do not require special categorization. Lyman and Lyman give additional phonetic information for voiceless and voiced stops: “voiceless stops are unaspirated, and

---

<sup>6</sup>For Mixe, a non-Zapotec neighbor that also has a fortis/lenis contrast, “the primary phonetic cue for the fortis/lenis contrast in obstruents is susceptibility to voicing”...“However, [voice] does not work for sonorants, since both the fortis and lenis sonorants are voiced” (Bickford 1985:197).

both voiceless /k/ and voiced /g/ being subject to lenition to ‘spirantal allophones’” (pp. 137-138).

As noted above, duration of vowels preceding fortis consonants is an impressionistic cue to fortis/lenis in Guelavía Zapotec. In Guelavía, both vowel length and vowel quality are fortis/lenis correlates; the low [a] fluctuates with schwa [ə] before fortis consonants, predominantly before fortis nasals (Jones and Knudson 1977:173). Speck (1978) claims vowels are also longer before lenis consonants in Texmelucan Zapotec (western), while word-final consonants are voiceless. In Texmelucan, vowels are lengthened before lenis consonants to maintain the consonant distinction.

In a number of analyses, fortis/lenis consonants are said to interact with the preceding vowel. Pickett (1951:63) discovered a unique interaction between fortis consonants following two like vowels: “In a sequence of two like vowels the second is actualized...as the abstracted quality of the first vowel plus the first part of length of the following consonant, before a fortis consonant”. That is, the fortis consonant robs the vowel of its duration, so the rime duration is the same (i.e. has the same number of moras).

Santa Catarina Quioquitani Zapotec, a southern variant, divides obstruents into fortis/lenis categories, but with no mention of fortis sonorants (Ward 1987:26). In another Southern Zapotec Reeck (1991) summarizes a fortis/lenis distinction in San Juan Mixtepec Zapotec, which is closely related to SFOZ, and belongs to the same Cisyautepecan subgroup:

“Fortis consonants are articulated in a more forceful manner than are lenis consonants. Fortis obstruents are voiceless and more tensely articulated than their lenis counterparts...Fortis resonants (/m/, /n/, /l/, /r/, and /w/) are tensely articulated and phonetically longer than lenis resonants...Syllable-initial fortis resonants are limited to fortis consonant clusters...word-initial fortis sonorant is bimorphemic.” (Reeck 1991:263)



Unique to Zapotec languages, Rendón (1995:16-17) reports a three-way consonant contrast of ‘strong, weak, and double’ in Tlacoachahuaya Zapotec. This contrast interacts with acoustic correlates of voicing, articulatory force, and duration. Length consistently stands out as a correlate of the contrast.

### 1.2.2 Hypothesis: *fortis* consonants as geminates

Various authors posit that the fortis/lenis contrast finds its source in historic double/single consonants (Benton 1988; Swadesh 1947). Swadesh (1947) basing analysis on word lists from Zapotec variants from four regions<sup>7</sup> and concludes that fortis is geminate:

“In many cases, the modern weak-strong contrast simply reflects the old relation between single consonant and geminate group...the weak consonants represent the normal development from simple original consonants, and the strong ones usually stem from original consonant groups” (p. 221).

Swadesh attributes the stability of voicelessness and the added force to the additional consonant, and reports this weak-strong/single-double/lenis-fortis relationship for the Zapotec and Chatino languages alike. Likewise, Pickett (1951) considers fortis consonants to be geminate in Isthmus Zapotec.

The distribution of fortis consonants in Zapotec languages is important to note. Swadesh observes that “...[in the four variants] the reflex in word-initial [position] is simple and in medial position geminate” (p. 221). In the same way, the syllable structure, whether it allows consonant clusters or not, plays a role in the fortis/lenis contrast. “Word comparisons between the dialects seem to indicate that most original obstruent clusters were geminate. However, it is likely that many of them began as mixed clusters and were assimilated into geminates” (p. 223).

---

<sup>7</sup> The four regions referred to are 1) Ixtlán – Sierra de Juarez, northwest, 2) Yatzachi el Bajo – Sierra de Villa Alta, northeast, 3) Tehuantepec—Valley-Isthmus, central, and 4) Cuixtla – Miahuatlán, south.

In a reconstruction of Proto-Zapotec, Swadesh (1947) claims that the strong-weak consonant contrast in Zapotec derives historically from simple versus geminate consonants. Since then, application of the geminate theory to define the fortis/lenis contrast pervades current analyses (e.g. Pickett 1967). For example, Benton (1988) claims that duration—a single/double contrast—is the basis of the fortis/lenis distinction in Coatlán Zapotec.

The fortis/lenis contrast is also found in the Guichicovi variant of Mixe of the Mixe-Zoque family spoken in Oaxaca, Mexico, which has no relation to the Zapotec family of languages, but whose speakers interact in some communities. For example, speakers of Santo Domingo Albarradas Zapotec have contact with Mixe speakers from surrounding towns (Kreikebaum 1987:33). The phonetic realization of the fortis/lenis contrast in the Mixe language parallels acoustic correlates that found in instrumental studies of Zapotec. For instance, in an acoustic study, Bickford (1985) found vowel patterns in Mixe that are similar to Isthmus Zapotec (Pickett 1951): “long vowels preceding lenis consonants are consistently longer than vowels before fortis” (p. 203). Therefore, in the interest of a wider understanding of the fortis/lenis issue, it is worth presenting the results of Bickford’s study here.

Bickford (1985:195-207) considers amplitude, consonant and vowel length, and voicing in the Guichicovi variant of Mixe. Regarding amplitude, Bickford writes that while “amplitude may be useful as a phonetic cue of the fortis/lenis distinction for subclasses of consonants, it does not appear to provide a good basis for a characterization of the phonological nature of this contrast” (p. 201).

Bickford finds length to be the primary correlate of the fortis/lenis contrast. “In all six pairs of words, exemplifying all major classes of consonants in both positions where the

contrast occurs, the fortis/lenis contrast correlates directly with a phonetic difference in length” (p. 203). “Intervocalic and final fortis consonants are significantly longer” than lenis (p. 202). Bickford (1985:204) concludes that: “the fact that the Mixe fortis/lenis contrast can be identified with underlying gemination suggests that other cases where the fortis/lenis distinction has been claimed could also be the same phenomenon.”

Given the parallels between the fortis/lenis correlates in Mixe and Zapotec, two distinct language families, future investigation of the fortis/lenis consonant contrast in other Otomanguean languages such as Mazatec (Williams p.c.) and Pame (Berthiaume forthcoming) might increase our current understanding of the fortis/lenis issue.

In spite of the proposal that the fortis/lenis contrast in various Zapotec languages is rooted in geminate/single consonants, and in spite of frequent subjective descriptions of fortis consonants as having greater articulatory force, there are few thorough examinations of the fortis/lenis question in Zapotec languages. The three most thorough are by Nellis and Hollenbach (1980), Jaeger (1983), and Avelino (2001); the latter two represent the only two instrumental studies of Zapotec. It is interesting to point out that all three call into question the use of the terms ‘fortis’ and ‘lenis’ for Zapotec consonants. The following sections take a closer look at these three most thorough works on fortis/lenis in Zapotec.

### *1.2.3 Nellis and Hollenbach (1980), a counterargument to fortis as geminates*

Until the instrumental studies were done of northern Zapotec variants summarized in the section 1.3, the most thorough treatment of the fortis/lenis contrast was that of Cajonos Zapotec. Nellis and Hollenbach (1980) describe the fortis/lenis pairs (which contrast in all three word positions) in terms of consonant and vowel length, voicing and articulatory strength, and phonetic stability (particularly resistance to assimilation).

The most salient correlate of the contrast in Cajonos Zapotec is length. In the cluster of the phonetic correlates that form the contrast, the feature length is the primary distinction between fortis (longer) and lenis (shorter) sonorants. Nellis and Hollenbach hypothesize that, "...it would be possible to consider fortis consonants inherently long in their underlying form" (p. 95).

This duration difference is not isolated to the consonant segment. Consonant duration interacts closely with stress and the duration of the preceding vowel. While fortis and lenis both occur in stressed and unstressed syllables, the "fortis consonants are longer after a vowel with primary stress" (1980:93). The relationship of vowel and consonant length (long vowels before short lenis consonants, short vowels before long fortis consonants) holds true particularly in stressed syllables. Nellis and Hollenbach observe: "Simple vowels with primary or secondary stress are lengthened in open syllables and preceding lenis consonants" (p. 98). The result is that, "The interaction of vowel and consonant length preceding fortis and lenis consonants...maintain a fairly constant length for stressed syllables" (p. 93).

There is a noteworthy exception to this pattern, however. A vowel before /n/ does not realize length in the same manner as when it precedes other consonants. Rather, "a syllabic /n/ serves as a portmanteau realization of the second mora of the vowel and the following /n/. A fortis nasal in the onset of the following syllable also realizes the second mora of the vowel" (p. 98). The fortis nasal carries the length of the preceding vowel.<sup>8</sup> After observing patterns of consonant length, vowel length and stress, Nellis and Hollenbach conclude that, "vowel and consonant length is...not contrastive, but rather

---

<sup>8</sup> Pickett observed a similar interaction between vowel length and a following (stressed) fortis consonant. Fortis consonants, obstruents and nasals, absorb the length of the preceding vowel (1951:63).

conditioned by stress placement and by the occurrence of fortis and lenis consonants” (p. 100).

In words native to Cajonos Zapotec, lenis sonorants are weakly syllabic. Sonorants in loan words are often realized as fortis, or long, and “become strongly syllabic” (p. 95).<sup>9</sup> Considering this phenomenon in light of the interaction of vowels and nasals mentioned above, these long, so-called ‘fortis’ consonants from Spanish loanwords are quite possibly nasals with two moras, one from the deleted vowel and one from the nasal.

Without citing articulatory strength as a contrastive correlate as other linguists do, Nellis and Hollenbach use similar terminology to describe fortis as stronger and lenis as weaker. For example, they note the “lenis stop is always articulated more weakly than the corresponding fortis stop” (p. 92), and “affricates and fricatives are differentiated by ‘stronger friction’ for fortis than for lenis” (p. 92). The inferred reference to articulatory strength, however, is secondary to the contrast maintained by segment duration.

Adding to the bundle of acoustic correlates of fortis/lenis consonants, Nellis and Hollenbach’s description claims that fortis consonants have “inherently greater stability” (p. 95). Lenis consonants undergo various weakening processes, including lenition, place assimilation, and devoicing, while fortis consonants do not. The lenis consonant is unstable and susceptible to change, while the fortis consonant resists such change.

In spite of the fact that phonetic length is a primary characteristic of the consonant contrast, Nellis and Hollenbach (1980) object to an analysis of fortis/lenis as geminates. They present three counterarguments to fortis as geminates. The primary argument is that double consonants would put an undue burden on the syllable structure. Fortis consonants

---

<sup>9</sup> SFOZ sonorants in Spanish loanwords are the reflex of a syllable having undergone vowel deletion (e.g. Spanish *an.tonio* becomes *n:.ton*, *al.ver.ja* → *l:.berg* ‘pea’).

analyzed as a series of two like consonants result in clusters of eight to nine consonants. A second argument is that in Cajonos Zapotec, two like lenis consonants across morpheme boundaries do not become fortis. Thirdly, Zapotec speakers new to writing do not intuitively write double consonants (p. 103). Nellis and Hollenbach concede that for sonorants, “the analysis of fortis consonants as geminate clusters has more validity,” but conclude that it is better to treat all fortis consonants the same as they “behave alike with respect to lengthening rules” (p. 103). For these reasons, Nellis and Hollenbach reject the theory of fortis consonants as geminates for Cajonos Zapotec.

In the following sections, evidence from instrumental studies of two other northern Zapotec variants by Jaeger (1983) and Avelino (2001) supports consonant duration as the principal characteristic of the fortis/lenis contrast. Contrary to Nellis and Hollenbach, their acoustic studies point to Swadesh’s theory of geminates as a potentially feasible analysis.

### **1.3 Instrumental studies of fortis/lenis in Zapotec**

The study of Yateé Zapotec by Jaeger (1983) is the first instrumental investigation of the acoustic correlates of the fortis/lenis contrast in a Zapotec language. Avelino (2001) undertook a similar instrumental study of Yalálag Zapotec. Both of these studies focus on northern Zapotec languages, yet the similarities and differences of the results give insight into the fortis/lenis contrast in other languages in the Zapotec family. The following sections summarize the scope and results of the Yateé and Yalálag Zapotec studies, respectively.

#### *1.3.1 Yateé Zapotec – Jaeger (1983)*

Jaeger writes, “In order for the terms ‘fortis/lenis’ or ‘force of articulation’ to be considered phonetically accurate terms, it must be shown that they correspond to some

unitary and independently controlled phonetic parameter” (1983:186). In search of such a parameter, Jaeger considered consonant duration, voicing, closure type, VOT, and amplitude.

In both Jawan and Zapotec, consonant duration measured from spectrograms revealed that fortis consonants are consistently longer than lenis in all positions, with fortis consonants almost double the length of lenis consonants (p. 183). The durational difference in fortis/lenis languages is more distinct than that in prototypical VOT languages.

Jaeger also considered the parameters of voicing (whether the consonant was fully voiced, partly voiced or voiceless), and closure type (whether the consonant was a stop, affricate, or fricative). Since there is no contrast in voicing or manner of articulation for nasals and laterals in Yateé, Jaeger considered only obstruents in this study. The instrumental results show that fortis obstruents are voiceless (often with heavy aspiration word-finally) with complete closure while lenis obstruents vary in voicing and completeness of closure. Therefore, in Yateé, voicing and closure type (manner of articulation) are additional cues to the fortis/lenis contrast.

Jaeger (pp. 184-85) points out that data for Jawan and Yateé present a contrast inconsistent with VOT languages such as English. Both fortis and lenis consonants can be voiceless and unaspirated in Yateé, variation in closure type is rare in VOT languages, and the consistent durational difference is not present in prototypical VOT languages.

Given these results, Jaeger (p. 185) points to a connection between duration and the fluctuation in closure completeness (stop vs. affricate/fricative), and to the connection between duration and voicing. Short consonants are more likely to have incomplete closure than long consonants: they are also more likely to be voiced. In other words, both

voicing and closure type naturally correlate with consonant length, making duration a more critical characteristic of fortis versus lenis consonants.

Jaeger notes that researchers in Zapotec languages have a long tradition of encoding the fortis/lenis contrast in terms of ‘articulatory force.’ Phonetic phenomena used to explain this added force include pulmonic, articulatory, timing and glottal factors (Jakobson, Fant & Halle, 1951; Fischer-Jorgensen, 1969; Malécot, 1970; Catford, 1977:199-208; Jakobson & Waugh, 1979:135-9, as cited in Jaeger). Results of Jaeger’s study show that the impression that fortis consonants have greater force of articulation, or are somehow stronger, is in part true: fortis consonants have higher peak and average amplitudes than do lenis consonants (p. 183). However, this additional strength can be explained by higher oral air pressure due to complete closure and longer closure duration. Furthermore, Jaeger states that it is “not clear that the greater intensity of fortis consonants is related to some factor other than voicelessness, as fortis consonants are nearly always voiceless.”

After considering the phonetic correlates of duration, voicing and closure type, VOT and amplitude, Jaeger concludes that ‘force of articulation’ is not a phonetically accurate characterization of this contrast. Rather, “the prototypical fortis obstruent is long and voiceless, with no variation in closure type, and higher amplitude noise. The prototypical lenis consonant is short, usually voiced but often voiceless, has much variation in closure type, and lower amplitude noise” (p. 184). Thus she argues that the fortis/lenis contrast is not primarily correlated with ‘force of articulation’ but rather with independently controlled variables of timing of the articulator gestures and glottal width. She writes that “superimposing the notion of ‘force of articulation’ on the contrast by the use of the terms ‘fortis/lenis’ does not add to the explanation of the phonetic factors involved, but in



fact obscures them by the vagueness, and probably incorrectness, of the notion of ‘force’” (p. 187). In conclusion, Jaeger rejects the term ‘force of articulation’ and offers the alternative parameters of duration, glottal width and closure width.

### 1.3.2 *Yalálag Zapotec – Avelino (2001)*

Avelino (2001) conducted an instrumental study of the fortis/lenis contrast in the northern Zapotec variant spoken in Yalálag. Fortis/lenis contrasts are found in Yalálag between obstruents [p/b, t/d, k/g~χ, s/z, ʃ/ʒ~dʒ, tʃ ~ʒ] and nasals and laterals [n:/n, l:/l]. Avelino measured duration, voicing and voice onset time (VOT), and intensity or amplitude.

This study takes into consideration grammar and phonological factors relevant to the fortis/lenis issue. The syllable structure of Yalálag allows for consideration of both closed and open syllables, and mono- and disyllabic words. Avelino reports vowel alternation between [e~ε], and [o~u], as well as realization of tones and a three-way contrast of modal, checked and rearticulated vowels, respectively /a/, /a<sup>ʔ</sup>/, and /a<sup>ʔ</sup>a/. The causative infix affects the realization of fortis and lenis consonants in that non-causative stems have a lenis consonant, and causative stems have a fortis consonant.

Avelino first considers temporal properties of closure duration, duration of neighboring segments and VOT. Results are that “the chief characteristic differentiating fortis and lenis consonants is length.” In all environments, fortis consonants are statistically longer than lenis consonants, in line with the “cross-linguistic tendency” for voiceless stops to be longer than voiced stops (Lisker 1957, Lofqvist 1976, et. al as cited by Avelino 2001).

Avelino also considers duration of preceding consonant-vowel in both open and closed syllables (CVC<sub>F/L</sub> and CV·C<sub>F/L</sub>) (p. 39). Results show that a voiced, lenis obstruent

is accompanied by a longer preceding vowel and, surprisingly, a longer preceding consonant: “the scope of lengthening (preceding a lenis consonant) includes not only the immediately adjacent vowel, but also the consonant preceding the vowel.” Based on VOT data presented earlier in the study, Avelino posits that the feature [voice] triggers lengthening of the previous CV segments (p. 51).

Vowels preceding sonorants, however, do not show the same trend; there is no difference in vowel duration before sonorants. Avelino concludes, therefore, that “the absence of this vowel lengthening before lenis sonorants argues that fortis/lenis is not a valid phonological category” (p. 67).<sup>10</sup> Due to the lack of vowel lengthening before sonorants, Avelino claims that phonological vowel length is only consistent as far as the “universal phonetic tendency to lengthen vowels before voiced obstruents” (Maddieson 1997, as cited in Avelino 2001).

In Jaeger’s study, VOT data reveals a contrast inconsistent with strictly VOT languages: both fortis and lenis consonants can be voiceless aspirated. Avelino’s data, however, shows that VOT is significant to the fortis/lenis contrast in Yalálag Zapotec, and is “a reliable parameter in characterizing the fortis/lenis contrast in stops” (p. 42). Results find that “fortis stops are unaspirated voiceless, where lenis are voiced.” Furthermore, even where word-final lenis segments are devoiced, there are phonetic differences in voicing that cue fortis versus lenis consonants (e.g. “...small amount of voicing at the beginning of the closure distinguishes devoiced lenis from voiceless stops.”). For Yalálag Zapotec obstruents “the [fortis/lenis] difference is well defined and consistent along the VOT dimension” (pp. 41-42). In spite of this, VOT and voicing

---

<sup>10</sup> The interaction of a vowel and a following sonorant, as in Isthmus Zapotec (Pickett 1967) may be what obscures the typical pattern of vowel length (longer vowel before lenis consonants, shorter before fortis) before nasals in Yalálag Zapotec.

remain insufficient for describing the consonant contrast between sonorant segments, thus preventing VOT from standing as the cross-categorical definition of the fortis/lenis contrast.

Unlike Yateé Zapotec, in Yalálag Zapotec Avelino found no difference in amplitude of fortis/lenis consonants. While lenis stops had higher amplitude than fortis stops, there were discrepancies among speakers (p. 76). There was no significant correlation between the average amplitude of fricatives and fortis/lenis contrast (p. 78). Finally, “[t]here was no significant difference between fortis and lenis sonorants with respect to the average amplitude in the onset of the following vowel.” (p. 80). Further inconsistencies in amplitude results for sonorants include greater amplitude for lenis nasals, and greater amplitude for fortis laterals (p. 81). Amplitude, therefore, is either an inconsistent or non-significant correlate to the fortis/lenis contrast in Yalálag Zapotec.

In summary, Avelino found that the most salient characteristic of the fortis/lenis contrast is duration. While obstruents can be defined by parameters as VOT and voicing, sonorants cannot be, and there is no difference in amplitude. “In essence, the phonetic attribute most associated with the fortis/lenis contrast is duration” (pp. 35-6).

On the basis of these results, Avelino, like Jaeger, concludes that “fortis/lenis is not a valid phonological category” (p. 67). Rather, Avelino argues in support of Swadesh’s theory of geminates due to the ‘inalterability’ of fortis consonants in terms of place assimilation of nasals, and resistance to spirantization. “The phonetic evidence presented here and the phonological behavior of the fortis/lenis contrast in [Yalálag Zapotec] suggest that a characterization in terms of a geminate/single distinction might be appropriate” (p. 86).

### 1.4 Fortis/lenis in SFOZ and SCXZ

The studies and descriptions in sections 1.2 and 1.3 summarize the fortis/lenis discussion on which I based my own investigation of the fortis/lenis consonants in San Francisco Ozolotepec (SFOZ) and Santa Catarina Xanaguía Zapotec (SCXZ). In particular, similarities in the behavior of fortis/lenis consonants between SFOZ, Guelavía and other Valley Zapotec languages are to be anticipated. SFOZ, while geographically situated in the southern Zapotec region, is different from other southern Zapotec languages. According to theories of Zapotec emigration, a subgroup of Southern Zapotec languages, including SFOZ, has roots in Valley Zapotec (Beam de Azcona 2004). Beam de Azcona (2004) reports that Smith-Stark (2001) labels this subgroup ‘Cisyautepecan’. The Cisyautepecan languages, including Zapotec languages spoken in San Juan Mixtepec (SJMZ), SFOZ and SCXZ, are indicated by vertical stripes in Figure 3.

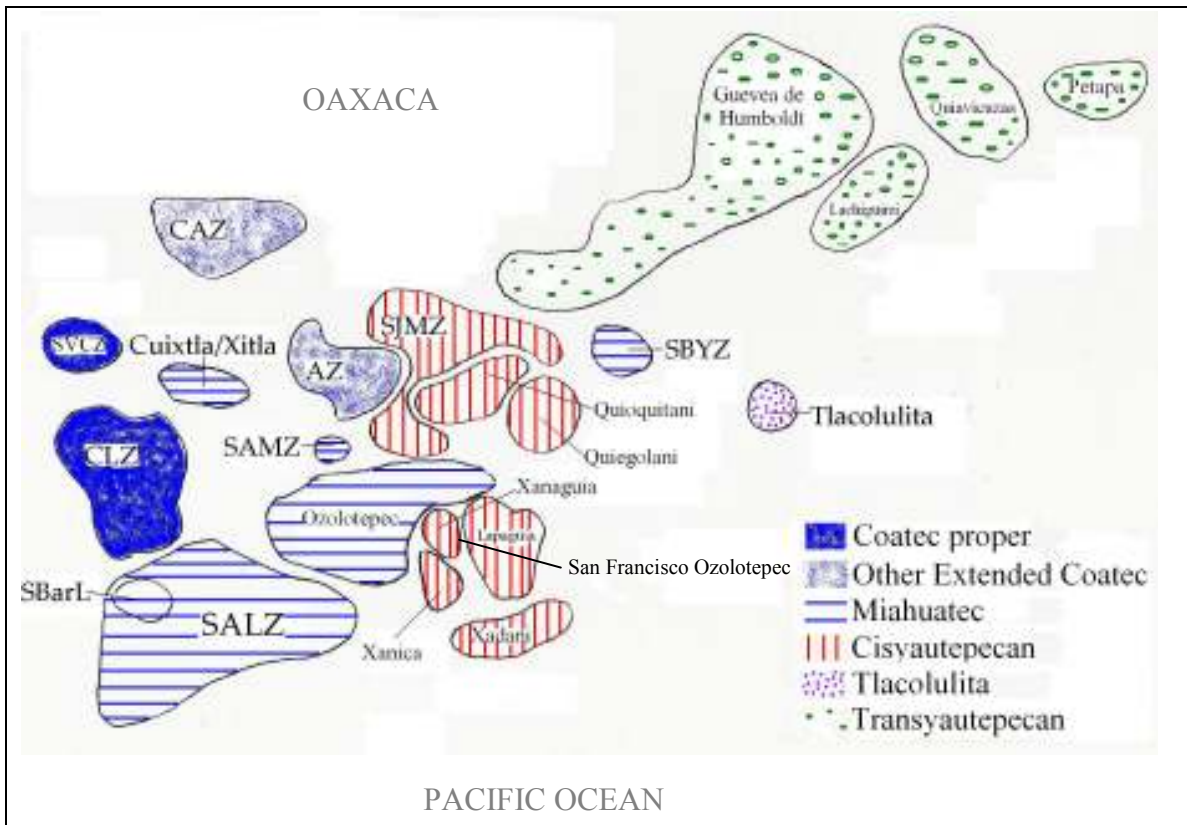


Figure 3. Location and relationship of Southern Zapotec variants (Beam de Azcona)

SFOZ is unlike other Zapotec languages in that the syllable structure is primarily one syllable roots in contrast with the disyllabic roots found more commonly in northern Zapotec, the focus of prior instrumental studies. Furthermore, the fortis/lenis contrast has a strictly limited distribution, with the most robust contrast found in the word-final position. This study of SFOZ offers additional insight into the fortis/lenis issue by presenting data from a primarily monosyllabic language in which voicing and VOT do not seem to be reliable cues to the fortis/lenis contrast.

An initial impression of the fortis/lenis distinction in SCXZ is that it is due to voicing and duration. Analysis by Olive and Hopkins (Hopkins p.c.) includes articulatory force as well. SFOZ, however, varies in that the voicing contrast is usually indistinct. In place of voicing, the salient cues are consonant duration and vowel duration, and quality of the preceding nucleus. Observe in example (1) the phonetic variation of phonologically identical words in SCXZ and SFOZ:

1)	SCXZ	SFOZ	gloss
	[nis]	[nɪs]	‘water’
	[niz]	[niz̥] <sup>11</sup>	‘Indian corn’

In SCXZ the fortis/lenis *s/z* contrast in voicing and the high-front vowel [i] preceding the fortis consonant /s/. But in SFOZ, the high-front vowel /i/ is pronounced [ɪ] preceding the fortis /s/, and the lenis consonant /z/ is devoiced. Therefore, in addition to the suggested correlates defining fortis/lenis (duration, VOT and voicing, and amplitude), this study includes vowel quality preceding fortis/lenis consonants.

An understanding of the fortis/lenis contrast in SFOZ as compared to SCXZ is important to the wider theoretical issue of consonant contrast and distribution. The purpose of this thesis is to identify the primary, consistent acoustic correlate(s) of the

---

<sup>11</sup>The lenis phoneme /z/ is phonologically voiced, but phonetically voiceless, hence I represent it with the IPA symbol for a voiceless /z/ instead of /s/, which is phonemically voiceless.

fortis/lenis phonological contrast as pronounced in SFOZ and SCXZ and its effect on vowel length and vowel quality.

This instrumental study sets out to add more data to the discussion, and to provide a clearer definition of ‘fortis/lenis’. To do so I will test the hypotheses that in SFOZ, the quality of a fortis consonant is realized by one or more of the following acoustic correlates: longer duration, voicelessness, complete closure, greater intensity (or greater force), phonetic stability, and laryngeal offset. These results should answer these questions: 1) What are the acoustic correlates of fortis/lenis in SFOZ? and 2) In SFOZ, do fortis/lenis consonants correspond to one unitary and independently controlled phonetic parameter?

This thesis sets out to present instrumental evidence in hopes of moving towards a greater understanding of the fortis/lenis contrast in SFOZ and of the greater fortis/lenis issue.

## CHAPTER 2

### SAN FRANCISCO OZOLOTEPEC ZAPOTEC

The language in focus, San Francisco Ozolotepec Zapotec, is also known as Xanaguía Zapotec, with variants spoken in the communities of Santa Catarina Xanaguía, San Francisco Ozolotepec, and San José Ozolotepec.<sup>12</sup> While their speech is mutually comprehensible, each language community varies slightly in pronunciation, tone, and lexical items. Of particular interest for this thesis are the phonetic correlates of the fortis/lenis consonant distinction in San Francisco Ozolotepec Zapotec (henceforth SFOZ), and Santa Catarina Xanaguía Zapotec (henceforth SCXZ), with primary attention given to SFOZ. San José Ozolotepec Zapotec will not be considered in this study.

These three communities are situated in a triangle in the southern mountain region of the district of Miahuatlán,<sup>13</sup> Oaxaca, Mexico, approximately thirty aerial miles from the Pacific coast.

The town of San Francisco Ozolotepec sits at an altitude of 2015 meters at GPS coordinates of N16°06'01.7", W96°13'15.2" (Joe Malda, p.c.). The 2000 census data reports a local population of 826 (INEGI 2000). An additional twenty percent of speakers of SFOZ (a very conservative estimate) live outside the language community. The local

---

<sup>12</sup> Politically, San Francisco Ozolotepec is the municipal head of San Jose Ozolotepec. Santa Catarina Xanaguía is an *agencia* of a different municipal head, San Juan Ozolotepec. The education system includes all three towns in the same jurisdiction.

<sup>13</sup> Miahuatlán de Porfirio Díaz is the market town for the Southern mountain region. It is located at an altitude of 1564 meters, and a GPS location of N16°20'16.6", W96°35'54.9" (Population, approximately 16,000).

population is approximately ninety-eight percent mother-tongue speakers of Zapotec. Approximately forty percent are monolingual Zapotec speakers. Oral bilingualism is increasing. In terms of literacy rates, I estimate that about twenty-five percent of the local population is increasingly literate in Spanish, the language of wider communication, and about five percent are literate in Zapotec.

Santa Catarina Xanaguía sits at an altitude of 2020 meters at GPS coordinates N16°05'20", W96°14'42" (Malda p.c.), an hour-and-a-half walk or drive from its closest neighbor, San Francisco Ozolotepec. The local population is 709 (2005 census data), with a considerable number of SCXZ speakers living elsewhere. There are fewer monolingual speakers in SCX, yet the Zapotec variant continues to be vital (INEGI 2006).

I collected general phonological information while living and doing language development in San Francisco Ozolotepec since December 2003 under the auspices of SIL International, known in Mexico as ILV. There is one published work on the discourse grammar of SFOZ (Heise 2003), and three published works on SCXZ that focus on pronouns (Marlett 1993), speech verbs (Olive 1995), and narrative peak in discourse (Hopkins 1995). There is no published account of the phonological system of SFOZ and SCXZ.

In this section I present a basic phonological sketch of San Francisco Ozolotepec Zapotec (SFOZ). This introduction is limited to what is relevant to a deeper understanding of the fortis/lenis issue, including the occurrence, distribution and contrast of phonemes in SFOZ, along with occasional comments regarding speech variations in SCXZ. I present the consonant inventory in section 2.1, vowels in section 2.2, the glottal feature in section 2.3, tone and intonation in section 2.4, the syllable in section 2.5, and stress in section 2.6. I discuss the distribution of fortis/lenis segments in section 2.7.



Finally, in section 2.8, I give a subjective evaluation of fortis/lenis segments and the hypotheses to be tested.

## **2.1 SFOZ Consonants**

The SFOZ phoneme inventory includes 25 consonants native to Zapotec,<sup>14</sup> plus three which occur in well-entrenched Spanish loanwords, and the glottal feature discussed in section 2.3. SFOZ obstruents include stops, affricates, and fricatives. Sonorants include nasals and laterals. Following Zapotec tradition and unpublished analyses by Hopkins and Olive, and Nelson and Heise, both obstruents and sonorants separate into categories of fortis and lenis. In this section, my use of the terms ‘fortis’ and ‘lenis’ does not subscribe to any particular analysis of fortis/lenis. Fortis consonants in Table 3 are represented by the voiceless counterpart of the voiced consonant for obstruents, or by the IPA diacritic for lengthening for sonorants. Phonemes that are only present in loan words are in parentheses.

---

<sup>14</sup> Fortis bilabial nasal /m:/ in /dam:/ ‘owl’, and glottal fricative /h/ in [haʔa] ‘take it’ (IMP) each occur in only one known word native to Zapotec. Due to the isolated occurrence of /h/, and lack of a known fortis or lenis counterpart, it is not listed on the phoneme chart.

Table 3. Inventory of SFOZ consonant phonemes

		Bilabial	Alveolar	Alveopalatal	Velar	Labialized velar	Glottal
Stops	fortis	p	t		k	k <sup>w</sup>	
	lenis	b	d		g	g <sup>w</sup>	ʔ <sup>15</sup>
Affricates	fortis		ts	tʃ			
	lenis		dz	dʒ			
	fortis	(f) [w̥] <sup>16</sup>	s	ʃ	(j) [x]		
	lenis		z	ʒ			
Nasals	fortis	m:	n:				
	lenis	m	n			ŋ <sup>w</sup>	
Laterals	fortis		l:				
	lenis		l				
Flap			(r) <sup>17</sup>				
Approximants-glide				j <sup>18</sup>		w	

Velar stops may be palatalized [g<sup>j</sup>]<sup>19</sup> or labialized /g<sup>w</sup>/, /k<sup>w</sup>/. Related Zapotec languages often include the labialized consonants as individual phonemes. While I follow that tradition, there is little internal evidence forcing a single phoneme analysis. Most examples are in loan words, or across morpheme boundaries. In SFOZ these consonants

<sup>15</sup> According to analysis by Heise and Nelson (n.d.), the glottal is a characteristic of the vowel. However, Hopkins (n.d.) analyzes it as a consonant in SCXZ when it follows a nasal /n/ or lateral /l/ (as in Choapan). I think it is a suprasegmental feature, capable of movement within a word or phrase, and a feature that may be assigned to a stressed segment, a word, or sometimes a phrase.

<sup>16</sup> Bilabial /f/ [w̥] and velar [x] are found only in Spanish loan words (i.e. *fok* [w̥ok<sup>h</sup>] from *foco* ‘flashlight’, and *konej* [konex] from *konejo* ‘rabbit’).

<sup>17</sup> Proto-Zapotec \*/r/ is realized as /dʒ/ in SFOZ and SCXZ (except for *mʒur* ‘curls’.) Different speakers pronounce flap~trill /r~r/ (in loanwords) in different places of articulation, always further back (velar~uvular) than the Spanish pronunciation of alveolar /r/.

<sup>18</sup> While vowel-like in quality, the word-initial potential and completive aspect markers /y-/ [j-] and /w-/ are analyzed as glides rather than vowels. This analysis, resulting in uncommon branching onsets, is preferred for the following reasons: The other aspect markers are consonants. Vowel onsets are rare, and often have an epenthetic glottal as the onset. The syllable structure already permits an extensive inventory of onset clusters. The inflected verbs are pronounced as one syllable, not two. In spite of the analysis as a consonant, the orthography represents these aspects with vowels, easier for new readers familiar with Spanish vowels.

<sup>19</sup> The palatalized /g<sup>j</sup>/ contrasts /g/ with in situations in which *gj* could be a consonant cluster (e.g. *gats* ‘break/hatch’ versus *gjat* ‘tortilla’). More often, however, /g/ and /g<sup>j</sup>/ are in free variation in the onset position as in *gjænd~gænd* ‘is not’ and *gjedz~gedz* ‘city’.

are limited to the word-initial position as in *kwded* ‘come in’, *kwa* ‘beside’, *kwál* ‘corn husks’; *gwa* ‘go!’; *gjat* ‘tortilla’, *gjal* ‘green corn stalk’, and *gja* ‘up’.

Three Zapotec phonemes in the consonant inventory occur without a fortis counterpart. Labialized velar nasals /ŋ<sup>w</sup>/ (*ŋ<sup>w</sup>laj* ‘priest’, *ŋ<sup>w</sup>tsan* ‘worm’, *ŋ<sup>w</sup>zizj* ‘lightening’)<sup>20</sup> are without fortis counterparts and are strictly limited to word-initial position. Likewise, glides /j/ and /w/ are without fortis/lenis counterparts, but occur both in initial and final positions, and as the second consonant of a consonant cluster (e.g. *jag* ‘tree’, *mej* ‘worm’, *gjàt* ‘tortilla’; *wæx* (LH) ‘clay griddle sweep’, *naw* ‘skirt’, *gwij* ‘look!’).

### 2.1.1 Stops

In SFOZ and SCXZ, stops contrast in three places of articulation: bilabial, alveolar, and velar. The distribution of stops and the interaction of stops with other morphemes raises some doubt as to their fortis/lenis phonemic contrast. Swadesh concludes that “strong stops /p/ /t/ /k/ are not very common in original native elements and have become more so by the addition of Spanish words” (1947:220). In a more recent study, Nellis and Hollenbach (Cajonos Zapotec) discover that “initial /p/ is found only in Spanish” (1980:93). As in other Zapotec variants, fortis stops in SFOZ have a limited distribution, particularly in the word-initial position.<sup>21</sup>

While there is vigorous contrast between bilabial stops /p/ and /b/ in Spanish loan words, in Zapotec words the contrast is weak at best. (In the following data, and throughout the thesis, a dash (-) marks a morpheme break unless otherwise stated.) In

---

<sup>20</sup> The phoneme /ŋ<sup>w</sup>/ is a velar nasal pronounced with rounded lips, perhaps previously a consonant cluster including the animate/deity morpheme /m-/. In Quiégolani Zapotec, this phoneme is realized as a cluster /ng<sup>w</sup>/ (Regnier 1993).

<sup>21</sup> Examples of consonant contrasts below are taken from SFOZ unless specifically stated otherwise.

SFOZ, word-initial /p/ occurs in voiceless clusters, and in the potential aspect of verbs, but in a simple onset /p/ occurs only once: before unstressed [ə] in the phrase *pə-'læ-l* ‘What’s your name?’. The lenis phoneme /b/, however, occurs word-initially in simple onsets and in voiced clusters. It is worth noting that in SFOZ, the only /p/ in a simple onset is in the morpheme *pe* ‘what,’ which occurs in other words as *be* ‘what’ (e.g. *bə kwan dʒunn-l* ‘What are you doing?’ and *be ju-l* ‘Are you home?’). The distribution of /p/ and /b/ differs between SFOZ and SCXZ. In SCXZ words, /b/ occurs word-initially before each vowel and in clusters [bg, by, bl, bz, bʒ, and (br)].<sup>22</sup> Word-initial /p/, however, precedes only the vowels /i/, /e/, /a/ in the question morpheme ‘what’ (See example (2)). Another difference between SFOZ and SCXZ is that in SCXZ, when not in a cluster, the word-initial bilabial is voiceless. This same phoneme, in the same word, is voiced in SFOZ as shown in example (2).

(2)	SFOZ	SCXZ	Gloss
	<i>ba-dze-ga</i>	<i>pa-dze-ga</i>	‘a while ago, the other day’
	<i>b{e,a,u}</i>	<i>pa</i>	‘which, what’
	<i>be</i>	<i>be</i>	‘if, question marker’

This is the opposite of the pattern seen in (1) in which SCXZ shows voiceless fortis consonants and voiced lenis consonants, while SFOZ shows voiceless fortis consonants, and preferred voiceless, or mildly voiced, lenis consonants. Due to these variations of the bilabial phoneme in the word-initial position, it is not clear if the [p] (SCXZ) and [b] (SFOZ) fit in the phonemic category of fortis or lenis.

In both communities, the voiceless stop /p/ occurs elsewhere as the first consonant in voiceless consonant clusters: [ptʃ, pk, (pl), (pr), ps, (pt)<sup>23</sup>, pts, pʃ]. In a cluster it follows

---

<sup>22</sup> Parenthesis indicate a loan from Spanish.

<sup>23</sup> The cluster /pt/ is suspected to be from old Spanish loan words (e.g. *ption* from Spanish “*pitona*,” or more commonly “*hierba buena*,” and *ptie* from “*epazote*”). However, other words are so ingrained in

only the phoneme /ʃ/ (e.g. *ʃpɪl: m-dʒɪ-doʔo* ‘numb and tingly’). The phoneme /p/ does not occur in the medial position of a root. It may, however, occur intervocalically across morpheme boundaries (*tʃop-u* ‘two things’), and in the word-final position (*nap* ‘later’).

Word-initially, /p/ and /b/ do not occur in any minimal pair contrasts, or even in similar environments, in either SFOZ or SCXZ. The patterns of distribution of /p/ and /b/ in SFOZ and SCXZ seem to vary unpredictably. In SFOZ clusters there is complementary distribution: /p/ occurs in voiceless clusters, and /b/ in voiced clusters. The bilabial stop contrast, therefore, is limited to the word-final position.

Table 4. Contrast between /p/ and /b/

Initial	(pal) <sup>24</sup> pə-læɪ	‘shovel’ Sp. <i>palo</i> ‘What’s your name?’	bal: bæg~k	‘sister of a girl’ ‘comb’
Medial	tʃop-u d-upaʔ-n	‘two things’ ‘my dad’	tib-u dubaʔn	‘one thing’ ‘rope’
Final	nɪp dʒap	‘corn liquor’ ‘has’	gɪb dʒab	‘look for’ ‘swallows’

Alveolar stops /t/ and /d/ present a similarly weak contrast in non-final position. Word-initial alveolar /t/ occurs only in numbers as seen in Table 5 below, in Spanish loan words, and in voiceless clusters. A word-medial contrast between /t/ and /d/, /k/ and /g/ is not found in monomorphemic noun roots, and there are few word-medial examples in verbs of the same aspect. Thus /t/ is limited to the word-final position. The voiced alveolar /d/ has a more robust distribution, particularly in the word-initial position.

---

the language as to be accepted as totally native (e.g. *ptoʔob* ‘‘maguey cactus’’ and *ptodz* ‘‘stubborn’’).

<sup>24</sup> Parentheses indicate a loanword from Spanish.

Table 5. Contrast between /t/ and /d/

Initial	<b>tib</b>	‘one’	<b>dik</b>	‘very small’
	<b>tap</b>	‘four’	<b>dad</b>	‘sir, man’
Medial	—		—	
	—		—	
Final	<b>git</b>	‘squash’	<b>gid</b>	‘leather’
	<b>gjat</b>	‘tortilla’	<b>dad</b>	‘sir, man’

The contrast between velar stops /k/ and /g/ is more common, but limited to verbs. Word-initial and word-medial contrast between /k/ and /g/ is not found in monomorphemic noun roots. The voiceless, or fortis, /k/ occurs frequently in the potential and imperative aspects, intervocalically across morpheme boundaries, and word-finally before both front and back vowels in the following word. The lenis counterpart /g/ occurs in all word positions.

Table 6. Contrast between /k/ and /g/

Initial	<b>kib</b>	‘POT.sew’	<b>giʔb</b>	‘metal, machine’
	<b>kaʔ-u</b>	‘IMP.buy it’	<b>gad</b>	‘IMP.give’
Medial	<b>w-ka</b>	‘COMPL.bought’	<b>w-gaʔ</b>	‘COMPL.caught’
Final	<b>gik</b>	‘head’	<b>(ʒig)</b>	‘gourd bowl’ Sp. <i>jicara</i>
	<b>blak</b>	‘How much?’	<b>blag</b>	‘leaf’

Given the particular distribution of fortis stops (their occurrence mostly limited to certain word classes (i.e. verbs), and conditioned by affixation), it would be difficult to compare the acoustic correlates of word-initial fortis/lenis consonants. The fortis/lenis contrast is much more salient in the word-final position, which is the focus of this thesis. Because labialized velars occur only word-initially (e.g. *kwa* ‘beside’, *gwa* ‘go’), they are not examined in this study.

### 2.1.2 Affricates

There are four affricates: /ts/, /dz/, /tʃ/, and /dʒ/. Alveolar affricates /ts/ and /dz/ contrast in both word-initial and word-final positions. See examples in Table 7:

Table 7. Contrast between /ts/ and /dz/

Initial	<b>tsiʔ-u</b>	‘ten-things’	<b>dzil</b>	‘comal/griddle’
	<b>ntsap</b>	‘lazy’	<b>ndzap</b>	‘young girl’
Medial	—		—	
	—		—	
Final	<b>gits</b>	‘paper’	<b>midz</b>	‘seed’
	<b>gats</b>	‘POT.break’	<b>gadz</b>	‘seven’

Contrast between the alveopalatal affricates /tʃ/ and /dʒ/, while it does exist, is less convincing. Most instances of contrast between /tʃ/ and /dʒ/ in like environments are due to the causative versus non-causative morphemes as shown in example

(3).

- (3) **w-tʃ-ug**      COMPL-CAUS-cut      ‘He cut.’  
**w-dʒ-ug**      COMPL-non.CAUS-cut      ‘It was cut.’

The phoneme /tʃ/ is most common in causative verbs; otherwise it is a relatively uncommon occurrence in Zapotec nouns. Two word-initial examples are *tʃen* ‘rust’ and *tʃog* ‘fingernail’; word-finally, /tʃ/ only occurs following high vowels (*gitʃ* ‘just now’). Before the fortis affricate /tʃ/, the vowel /i/ is pronounced as [ɪ] (e.g. [*bitʃ*] ‘cat’) instead of the expected [i].

In contrast to its fortis counterpart, the alveopalatal phoneme /dʒ/ has a robust presence as the word-initial habitual aspect marker on verbs (*dʒap* ‘has’).<sup>25</sup> The lenis phoneme /dʒ/ is also more common in nouns (*dʒob* ‘woven basket’) and other word categories. While this study focuses on the word-final contrast, it is interesting to note that in the word-initial position, /dʒ/ is in free variation with /ʒ/, as in the word [*dʒʊʃkwaʔ~ʒʃkwaʔ*] ‘make’.

---

<sup>25</sup> In related Zapotec languages (i.e. Lapaguía Zapotec), the habitual marker is /r/ (*rap* ‘HAB.has’ versus *dʒap* ‘HAB.has’ SFOZ).

### 2.1.3 Fricatives

There are four fricatives, an alveolar pair /s/ and /z/, and an alveopalatal pair /ʃ/ and /ʒ/. The four sibilants contrast phonemically. Phonetically, however, the pairs are often difficult to distinguish in terms of voicing, particularly the word-final alveopalatal /ʃ/ and /ʒ/. Alveolar fricatives contrast phonemically in word-initial and word-final contexts.

Table 8. Contrast between /s/ and /z/, /ʃ/ and /ʒ/<sup>26</sup>

Initial	sja ‘corn’	zja ‘left v.’	ʃun ‘eight’	ʒan ‘under’
	sil ‘morning’	zid ‘comes’ zak ‘can do’	ʃik ‘shoulder’	ʒij ‘nose’
Medial	—	—	—	—
	—	—	—	—
Final	nis ‘water’	niz ‘dried corn’	neʃ ‘fruit’	niʒ ‘delicious’
	dʒas ‘bathe’	dʒaz ‘chew’	gaʃ ‘close’	gaʒ ‘will be paid’

### 2.1.4 Sonorants

Sonorants include nasals, liquids and approximants/semivowels. Nasals occur with four possible points of articulation: bilabial, alveolar, alveopalatal and labialized velar. The lenis bilabial /m/ occurs word-initially (*minn* ‘3.sg/pl’, *man* ‘animal’). Most often the word-initial /m/ is the animate prefix remaining from the animal classifier *ma-* or *man*. Word-medial /m/ occurs in Spanish loan words (*tamaler* ‘kettle’ Sp. *tamalero*), and in compound numbers in which the /n/ assimilates to the following /p/ as in *tsiʔn: p tib-u* → *tsiʔmptibu* ‘fifteen-one-thing (sixteen things)’. Lenis /m/ does not occur word-finally, while occurrence of the fortis /m:/ is limited to only one example word-finally, *dam:* ‘owl’.

The lenis alveolar nasal /n/ occurs in the initial and final positions of a word (e.g. *neʔg* ‘here’, *nit* ‘cane liquor’, and *man* ‘animal’, *win* ‘small’). However, the fortis alveolar nasal /n:/ occurs only in the word-final position (e.g. *min:* ‘person’).

<sup>26</sup> A brief survey of local preference to these phonemes using the word [*zæʃta~ʒæʃta*] ‘not yet’ showed that half the people preferred /dʒ/ and half preferred /ʒ/.



Distribution of the alveopalatal nasal cluster /nj/, and labialized velar nasal phoneme /ŋ<sup>w</sup>/<sup>27</sup> is limited to the word-initial position. Examples are shown below in (4).

(4)	<b>njaz</b>	‘road’	<b>ŋ<sup>w</sup>tsan</b>	‘worm’
	<b>njag</b>	‘cold (liquid)’	<b>ŋ<sup>w</sup>laj</b>	‘priest’
	<b>njag</b>	‘yesterday’	<b>ŋ<sup>w</sup>zij</b>	‘lightening’

Lenis /l/ occurs in both word-initial and final positions, but the fortis /l:/ is strictly limited to the word-final position.<sup>28</sup> Therefore, fortis and lenis laterals /l:/ and /l/ contrast only in word-final position.

(5)	<b>SFOZ</b>	<b>SCXZ</b>	
	<b>pfil:</b>	<b>midz-gi</b>	‘spark’ (compound: <i>midz</i> ‘seed’ + <i>gi</i> ‘fire’)
	<b>pfil</b>	<b>bzil</b>	‘sugar cane’

Fortis nasals and laterals have the most distinct effect on the preceding high vowels /i/ and /e/ so that the vowels are pronounced in a more central vowel space, phonetically [ɪ] and [ɛ], respectively.

In SFOZ, glides occur frequently as aspect markers on the verb onset. Approximants may occur in simple as well as complex onsets, but only in simple codas (*gjat* ‘tortilla’, *naj* ‘woman’).<sup>29</sup>

## 2.2 Vowels

SFOZ has six vowel phonemes: /i/, /e/, /æ/, /a/, /o/, and /u/. The six modal vowels have laryngealized counterparts analyzed as a single vowel phonologically.

---

<sup>27</sup> All known words with the phoneme /ŋ<sup>w</sup>/ are animate and as such likely incorporate the animate morpheme *m-* (Reeck 1991:266).

<sup>28</sup> While sonorants are not perceived as longer or ‘stronger’ in the word initial position, a pilot study investigating length would be of value. I suspect the palatalized nasals and laterals in the onset position have fortis roots.

<sup>29</sup> I argue that an approximant in the onset is part of the consonant cluster rather than a diphthong vowel, preferring analysis of a branching onset rather than a branching nucleus (*gjat* versus *giat* ‘tortilla’). In Isthmus Zapotec, glides are analyzed as part of branching nucleus (Marlett and Pickett 1987:398).

Vowel length is not phonemically contrastive, but conditioned by four factors: 1) stress placement, 2) whether the tone is simple or contour, 3) whether the syllable is open or closed, and – relevant to this study – 4) whether the syllable is closed by a fortis or lenis consonant (see also Nellis and Hollenbach 1980:98). For example, vowels are lengthened phonetically when they take a rising tone. Before fortis consonants, vowels are shortened. In SFOZ, but not in SCXZ, the vowel phoneme is realized as a phonetically lax allophone preceding fortis consonants. For example, the high front vowel /i/ is lax [ɪ] before fortis consonants. In Table 9 below, vowel phonemes are listed first followed by their allophones in [brackets].

Table 9. Inventory of vowel phonemes

	Front		Back Unrounded		Back Rounded	
High	i [i, ɪ]	iʔi			u [u, ʊ]	uʔu
Mid	e [e, ɛ]	eʔe			o	oʔo
Low	æ [æ, ɛ]	æʔæ	a	aʔa		

While some Zapotec languages have just five vowels, SFOZ has contrast between six. SFOZ has contrast between back vowels /u/ and /o/, both in open and closed syllables as seen in example (6):

- (6)    **gu**    ‘potato’                      **nkub**    ‘new’  
          **go**    ‘where’                            **nkob**    ‘corn dough’

The minimal pairs in example (7) show contrast for the sixth vowel, the open front unrounded /æ/.

(7)	<b>næn</b>	‘appears’	<b>mæ</b>	‘beans’
	<b>nen</b>	‘lazy’	<b>me</b>	‘wind/spirit’
	<b>nan</b>	‘knows’	<b>man</b>	‘animal’
	<b>non</b>	‘worth’		

There is a two-way vowel contrast between simple and laryngealized vowels as seen in example (8).

(8)	Simple Vowel		Glottalized	
	<b>mæ</b>	‘black beans’	<b>mæʔæ</b>	‘moon’
	<b>mal:</b>	‘fish’	<b>maʔal</b>	‘snake’
	<b>ju</b>	‘house’	<b>duʔu</b>	‘rope’

The laryngealized vowel may be phonetically realized as an unreleased glottal stop, as a slight echo, or a complete echo (or *svarabhakti*). While Isthmus Zapotec has a contrast between checked and laryngealized vowels (Marlett and Pickett 1987:400), SFOZ has no such contrast. The phonetic variations of laryngealized vowels (checked or echoed) do not contrast phonemically as in other Zapotec variants.

In San Juan Mixtepec Zapotec, a closely related language, Reeck (1991) finds a correlation between glottal allophones and the fortis/lenis consonant contrast:

“allophones of [a] glottalized nucleus vary according to the character of the final syllable margin... There is an echo in open syllables and before lenis consonants, and no echo before fortis consonants. [The] glottal is on the primary stress of the word – *luʔu* ‘you’ when independent, *gaʔlu* ‘you bathe’ when clitic, or when the pronoun is part of the prosodic word” (pp. 264-5).

Due to this potential interaction between glottal and fortis/lenis pairs, the following section looks more closely at the glottal feature.

### 2.3 Glottal: neither consonant nor vowel

The nature of the glottal feature, affecting closure width, voicing and amplitude (among other things), is relevant (perhaps critical) to understanding the fortis/lenis issue. Likewise, the distribution of the glottal (in a stressed syllable nucleus, or word- or phrase-

finally) means that it is often in the same domain as the word-final fortis/lenis consonants studied here.

The glottal stop most commonly occurs as part of the stressed syllable nucleus, so that the sequence written CVʔV is considered to be one phonemic syllable (Pickett 1960:9). Because the glottal feature is most salient as part of the nucleus, it is reasonable to analyze the glottal as a feature of the vowel. However, there are instances when the vowel is deleted and the glottal remains even where there is no vowel host (e.g. *golʔ* ‘Where are you?’ and *ʃlanʔn* ‘I’m hungry’). In this manner the glottal acts much like suprasegmental tone does. The glottal is not deleted with the vowel, so it is not merely a feature of the vowel.

At times, the glottal /ʔ/ behaves like a consonant. For example, in the rare instance of a vowel onset (*ada* ‘or’) there is often a phonetic epenthetic glottal [ʔ]. However, the glottal /ʔ/ may also be assigned at the phrase level; the /ʔ/ occurs after a pause even when there is no glottal on the last word of the phrase. The distribution of the glottal /ʔ/ is such that it would be difficult to argue that it is strictly a consonant feature (i.e., the presence of a glottal between vowels in *duʔu* ‘rope’ does not represent a CV.CV sequence of syllables, but a single CV syllable). While Swadesh (1947:220) argues that, “The glottal stop is a consonant apart. It occurs only in syllable-final and in the position between vowels.” I think his observation regarding distribution of the glottal stop leads to a different conclusion: the glottal is a prosodic feature of the syllable (or word, which in SFOZ is one syllable). There is precedence for this analysis in Zapotec. For Isthmus Zapotec, the “glottal stop is analyzed here...as a laryngeal feature of the syllable rather than as a consonant restricted to a syllable final position” (Marlett and Pickett 1987). Macaulay and Salmons (1995) write that in Sierra Juarez Zapotec, the “glottal [is]

represented as a floating feature in the lexicon...[the] glottal is a syllable-level feature.” Thus considered, the glottal feature in SFOZ is more aptly analyzed as a suprasegmental feature linked to the syllable rather than as either a vowel or consonant feature.

Laryngealization, a complex Otomangean phenomenon, is seen in many of the related language families. For example, in Coatzospan Mixtec, “glottalization is realized only once, on the vowel of the syllable with the strongest stress” (Pike and Small 1974). Likewise, in Chalcatongo Mixtec, “glottal stops do not occur in affixes or clitics, but only in roots...glottal [is] a feature of the root” (Macaulay and Salmons 1995:45, 48-49). The pattern is also observed in Ñumí Mixtec, where glottalization is treated as a feature of syllables rather than vowels, and glottal only occurs on stressed syllables (Gittlen and Marlett 1985).

## 2.4 Tone and intonation

A basic understanding of tone is helpful in understanding the elements involved in the phonology of SFOZ, especially since the glottal and tone interact in Southern Zapotec. In SFOZ, the functional load of tone is low. A word with a mispronounced tone in isolation may not be understood, but Zapotec readers pronounce correct tones given the context of the word, without tone markings. An initial analysis of tone reveals two phonemic tones, low (L) and high (H), as shown in example (9), and a contour tone which I analyze as a sequence of low-high (LH), or rising, as shown in example (10).<sup>30</sup>

	L		H	
(9)	<b>blàg</b>	‘leaf’	<b>blák</b>	‘how many?’
	<b>sjà</b>	‘corn on the cob’	<b>sjá</b>	‘went’
(10)	LH		HL	
	<b>mæ:</b>	‘black beans’		
	<b>dăd</b>	‘sir’		

---

<sup>30</sup> This analysis is similar to Isthmus Zapotec: L, H, LH (Pickett 1960).

In open syllables the vowel length of a nucleus bearing a rising contour tone, LH, is almost double the length of a nucleus with a single tone. In SCXZ, both LH and HL tone contours exist (*měy* ‘flea’ LH, and *mêy* ‘letusa’ HL), indicating the possible existence of both LH and HL tones in SFOZ as well. However, to date I have not found evidence for HL in SFOZ.

In SFOZ, the category of words assigned L tone in isolation show two different patterns of behavior when put into frames, some H and some L. Future research should consider the analysis of Beam de Azcona attributing the difference in tone to the (historical) presence of a glottal (2004).

Of significant interest, tones in SFOZ and SCXZ are in most cases opposite, as seen in a few sample tokens in Table 10. The contour tones are reversed; most H tones become L, and the L tones branch into different tone patterns, some L, some H, and some contour. This alternation is true for vowels preceding both fortis and lenis consonants.

Table 10. Tone contrast between SFOZ and SCXZ

SFOZ	SCXZ	Gloss
ʒìk	ʒík	‘shoulder’
læts (L)	lâets	‘flat’
gál	gàl	‘POT.be born’
ʒíd	ʒìd	‘among, between’
dăd	dâd	‘sir’
gâl:	gâ:	‘twenty’
tʃên:	tʃê:	‘belongs to’

There are a few words that do not follow this pattern. Words with high front vowels followed by a fortis affricate, as in *bitʃ*<sup>31</sup> ‘cat’ and *gitʃ* ‘just now’ maintain H tones in both communities. Perhaps this is evidence of a contour tone cut short by a following fortis consonant.

<sup>31</sup> The word *bitʃ* ‘cat’ is rumored to be a loanword from Spanish *michi*.

Although a vowel is preferred as a tone bearing unit (Goldsmith 1990), nasals and laterals are also tone bearing units (TBU) in SFOZ, similar to the situation in other Zapotec variants (Pickett 1951:62). A syllabic consonant keeps its own tone following another obstruent in the coda (11). But when an open syllable accepts a tone bearing consonant as its coda, L and H tones linked to separate TBUs combine to make a LH contour on the vowel, taking the tone away from the syllabic consonant (12).

(11) L H  
       | |  
       *xik-n* ‘arm.my’

(12) L H  
       ∨  
       *nij-n* ‘foot.my’

Other observations about tones are that: 1) tones on unstressed tone bearing units are often realized as phonetically mid tones 2) H tones in a series are increasingly higher, and 3) phrase and sentence intonation is rising.<sup>32</sup>

Contour tones correlate with longer vowel length. Marks (1976:117) says of Sierra Juarez Zapotec, “vowels are phonetically lengthened to accommodate a contour tone and are thus written as geminate vowels.” In southern Zapotec as well, tone interaction affects segment length. And in Cajonos Zapotec, a northern variant, ‘surface tone’ or “tone sequences may be elided preceding fortis consonants” (Nellis and Hollenbach 1980:218). Further investigation of the interaction of tone and the fortis/lenis consonant is needed.

---

<sup>32</sup> See Nelson (2004) for a discussion of tone shift based on animacy in San Juan Mixtepec Zapotec, a southern Zapotec language.

## 2.5 Syllable

This section serves as a brief overview of the syllable structure and a springboard for future analyses. The prototypical SFOZ word, unlike varieties of Northern or Isthmus Zapotec, is monosyllabic and rich in consonant clusters. Consider first the obvious syllable types, CV and CVC, in example (13).

- 13)    CV        **gu**        ‘potato’  
      CVC       **mak**       ‘dog’

While assuming there is an obligatory onset, language universals claim exceptions for word-initial vowels, so that CV and CVC syllable types may license vowel onsets (Itô 1988). Some loanwords from Spanish (e.g. *or* ‘hour’ Sp. *hora*) are vowel initial. In words native to SFOZ, however, the word-initial syllable position is not exempt from an obligatory onset: there is only one exceptional instance of a word with a vowel onset is *a'da* ‘or’, which has an epenthetic glottal (?) onset following a pause. A monosyllabic, phonological word consists of an onset, a nucleus, and an optional (but preferred) coda; the minimal word is CV.

While Proto-Zapotec words are believed to be disyllabic (Swadesh 1947), SFOZ prefers closed, one-syllable words. Zapotec, southern Zapotec in particular, is well-known for vowel loss and a robust inventory of consonant clusters (e.g. Quiégolani Zapotec (Regnier 1993)). In the words of Nellis and Hollenbach (1980:95): “...vowel loss causes many clusters.” Similarly, SFOZ has a rich inventory of consonant clusters in both the onset and coda as shown in example (14).



(14)	CCV	<i>ʃni</i>	‘light’
	CCVC	<i>psan</i>	‘sibling of the opposite gender’
		<i>ptʃetʃ</i>	‘antsy’ (child)
	CVCC	<i>ʒeɲʃ</i>	‘grasshopper’

Onset clusters, including *lb*, *pt*, *bg* and *ʃk*, seem to have few restrictions. Lenis nasals are frequently part of consonant clusters. For example, a trace of the animal classifier prefix *ma-* has lost its vowel, but remains at the onset of most animal/deity words (e.g. *ngon* ‘cow,’ *mgin*: ‘bird’). Combinations of consonants in clusters are greatly restricted in coda position, allowing only a lenis nasal as the first consonant of a syllable-final, monomorphemic noun coda cluster (i.e. *mleɲʃ* ‘mosquito’).<sup>33</sup> This constraint, which follows the Sonority Sequencing Principle (SSP), may be represented as in example (15).

(15)	If		C	C]σ
	then		[	+ nasal]

Words with two syllables are often compounds formed from two roots (e.g. *lidz* + *giʔb* ‘house+iron’ becomes *lits.giʔb* ‘prison’), or a root hosting numerous affixes and/or clitics. Not uncommon are the multi-morphemic multi-syllabic words like *du.pa.gol.na* ‘POSS.father.old.my grandpa (my grandpa)’, *giʔ.ʒgab* ‘NOM.thought’, or *dʒap.dɲ* ‘I don’t have’. In these cases, perhaps extrametricality on word edges would be sufficient to explain CCVCC syllable types. However, a few multisyllabic words with no known morpheme breaks (e.g. *mi.tsank.ngid* ‘garlic’ and *ptʃok.ngeg* ‘shell’) indicate that a CVC syllable template may not be adequate. Extrametricality would not license the word-internal consonant clusters in both the coda and the onset: [CV.CVCC.CCVC] and [CCVC.CCVC], respectively.

---

<sup>33</sup> Fortis sonorants never occur in consonant clusters, either in word-initial, or word-final positions. Fortis obstruents often occur in clusters at the onset, but rarely in simple onsets (Nelson n.d.).

In the midst of so many consonants, the syllable nucleus consists of one vowel which may be simple or glottalized (phonetically varying from checked to echoed). In loanwords from Spanish that have a diphthong, the diphthong is reduced to a simple nucleus, deleting all vowels that do not have primary stress. For example, unstressed vowels delete in Spanish *maestro* resulting in *meftr* ‘teacher’, while *anteojos* becomes *ntoj* ‘eyeglasses’.

Potentially relevant to the fortis/lenis contrast in the onset, I interpret /w/ and /j/ as semi-vowels, or consonants, instead of vowels /u/ and /i/ (cf. Regnier 1993). Analysis of /w/ and /j/ as a consonant instead of a vowel feature does not increase the load on the syllable template, because labialized and palatalized consonants do not occur in clusters.<sup>34</sup> Nelson (n.d.) writes:

“The phonemes (or clusters) ky, gy, gw and ñ (or ny) do not occur in consonant clusters...it is likely that ky and gw are not single phonemes. It is surprising, however, to see that /gy/ and /ñ/, although seeming to function as single phonemes, do not occur in clusters.”

A syllable has an onset of one or two consonants; either the first or the second consonant may be labialized or palatalized, /w/ or /j/ respectively. See examples of Zapotec words in (16):

(16)	C <sup>l</sup> VC	<i>bjaʔal</i>	‘meat’
	jCV	<i>jnij</i>	‘banana’

Consonants /w/ and /j/ are also completive and potential aspect markers, respectively, at the onset of verbs, so that both occur as part of an onset cluster in which the first consonant is a glide, and the second is not.

---

<sup>34</sup> The only exceptions are in Spanish loanwords (e.g. *ptje* ‘epazote (herb)’ and *ptjon* ‘mint plant’ Sp. *pitonia* which result in CC<sup>l</sup>V and CC<sup>l</sup>VC, respectively).

Affixation also affects the syllable structure. Polymorphemic words allow extrametrical consonants in both the onset and the coda. Such consonants are often affixes with an omitted vowel as seen in example (17).

(17)	CVC-C	'dʒap-ŋ	'I have'
	CCVC-C-C	ʃlan-d-ŋ	'I don't want'
	C-C-CVC	ʃ-m-gij	'Her man'

On the basis of this initial analysis of the syllable, I propose the maximum template in SFOZ is [CCVCC].

## 2.6 Stress

As stated above, most words are one syllable roots. If a word is multi-syllabic, simply stated, stress falls on the root. Prefixes and clitics never receive primary stress. In compounds or phrases, the stress is usually on the last syllable: *gi:l:'giʔd* 'sandal', *ngit 'frit* 'roasted chicken' (*frit* 'fried' Sp. *frito*).

Vowels in unstressed roots or of suffixes move to a more central vowel space, are reduced phonetically to schwa [ə], and sometimes are deleted, making identification of the vowel phoneme difficult. Notice in example (18) the vowel variation in an unstressed syllable.

18)	<i>mbidz-lni</i>	→	[mɪbɪts-lni]	'dawn or evening' (?)
	<i>ʒan gjedz</i>	→	[ʃən~ʃɪn gjedz]	'below + town (a place name)'

It is often difficult to distinguish the phonemic vowel of clitics, prefixes and affixes as well (e.g. *ʃɪ~ʃə* '3POSS', *-chə~-cha* 'more'). This vowel reduction in SFOZ is also found in other Zapotec languages, to the extent of a total loss of the vowel: "In Yatzachi, unaccented vowels tended to be lost or converted into semi-consonant y or w" (Swadesh

1947:227).<sup>35</sup> An unstressed vowel will not show phonemic contrast, therefore, it is important to observe vowel correlates preceding fortis consonants in stressed roots.

## 2.7 Distribution of fortis/lenis segments

Fortis consonants have strict distribution patterns within the word and phrase. Within nouns, fortis consonants are mostly found in the word-final position. Word-initial contrast of single consonants in SFOZ is limited to /s/ and /z/ in monomorphemic nouns. For example, word-initially, the phoneme /p/ is only found in voiceless clusters (e.g. *pkuk* ‘pillow’) and in Spanish loanwords (e.g. *pat*, Sp. *pato*, ‘duck’). This is generally true of Zapotec languages as can be seen with the Isthmus and San Juan Mixtepec dictionaries (Reeck 1991). Single fortis consonants in the word-initial position are almost always: 1) across morpheme boundaries (i.e. verbs of the potential and imperative aspects), 2) adjectives (which are stative verbs), and 3) numbers which are lenis when morphemes are added (i.e. *tʃop* → *jdʒop* ‘two’ → ‘both’).

A few of the consonants in SFOZ have very limited distribution. The bilabial /m/ only occurs word-initially, most typically on animate nouns (e.g. *mak* ‘dog’, *mleŋf* ‘mosquito’) or preceding bilabial stops (e.g. *mban* ‘alive’). There is one instance of word-final bilabial nasal /m:/ (*dam*: ‘owl’), the only known instance of fortis /m:/.

### 2.7.1 Grammatical considerations

When a fortis consonant occurs word-initially, it is usually in a verb. The grammatical structure of the verb, therefore, is relevant to the understanding of fortis/lenis alternations of the stem. The basic stem construction of verbs in SFOZ is shown in (19).

(19) Aspect – (CAUS) – Root – (Neg) - Subject clitic

---

<sup>35</sup> Tones on unstressed affixes are also difficult to identify.

Unlike Cajonos Zapotec, in which Nellis and Hollenbach say that two lenis consonants do not equal a fortis consonant, in SFOZ the combination of two lenis consonants often results in a fortis consonant. Fortis consonants may be derived or produced in unstressed syllables of the root, and across morpheme boundaries. There seem to be at least three grammatical considerations for the distribution of fortis/lenis consonants in SFOZ. The first is that the root-initial consonant of causative voice is fortis, and that of the passive voice is lenis.

(20) a. *j-tʃop nis* ‘POT.CAUS.baptize’ (transitive, active)

b. *j-dʒop nis* ‘POT.PASS.baptize’ (lit. ‘with water’) (intransitive, passive)

The presence of the fortis consonant in example (20a) is most likely the result of a well-embedded prefix, the consequent consonant combination resulting in a long ‘fortis’ or voiceless consonant, as seen often in construction of the potential aspect (e.g. *k- + bif* = *pif* (POT + fall)). Positioning such a prefix between the aspect marker and the root for the transitive/active/causative verb stem is not without precedent (López & Newberg 1990, Merrill 2008b). In Sierra Juarez Zapotec, Bickmore and Broadwell (1998) find a transitive prefix *di-* in the same location in the stem. Vowel deletion that would result in a consonant prefix instead of a CV prefix is very common in SFOZ. Two consonants meeting at morpheme boundaries become voiceless fortis in SFOZ. This change could also be caused by a change in valence, or transitivity following Bickmore and Broadwell’s (1998:61-64) analysis of Sierra Juarez Zapotec. (See also Dixon and Aikhenvald (2000:5,166) “argument-adding derivation”.)

Another grammatical source of an apparent fortis/lenis consonant is the verb class of the potential mood/aspect that has root-initial consonants that vary from lenis to fortis: the future is lenis (*zjá* ‘will go’) and the potential is fortis (*sja* ‘may go’).

In a change from cardinal numbers to inclusive pronouns, the root-initial fortis consonant becomes lenis as seen in example (21) below:

(21)	Cardinal number	Pronoun	
	[tʃop] ‘two’	[j-dʒop-n]	‘both or us, together (just two)’
	[tson] ‘three’	[gjon-nu]	‘three of us’
	[tap] ‘four’	[j-dap-nu]	‘four of us’

The interaction of verbal and numeric/pronominal morphemes reveal phonological processes that may shed light on the fortis lenis consonant contrast, particularly in the root initial position.

### 2.7.2 Phonological considerations

Distribution of underived fortis consonants is limited to the root of the word, specifically in the word-final position. Similar to other Zapotec variants, “In inherently unstressed affixes, however, only lenis consonants occur” (Nellis and Hollenbach 1980:95). In SFOZ an exception is the possessive prefix *f- ~ f̥-* often found as part of a consonant cluster resulting from vowel deletion and the construction of the phonological word.

One instance of such a derived fortis consonant is found in compound words; however, a word-final consonant at the end of the first root is devoiced, appearing to be fortis.

(22)	lidz +	giʔb	→	[litsgiʔb]
	‘house’	‘iron’		‘jail’
	ʒob +	giʔn	→	[ʒopgiʔn]
	‘dough’	‘chile’		‘salsa’

## 2.8 Impressionistic evaluation of fortis/lenis segments

The Zapotec variants spoken in SFOZ and SCXZ are mutually intelligible, but differ impressionistically in the fortis/lenis correlates of consonant voicing and the quality of the vowel preceding a fortis consonant. Both fortis and lenis obstruents in SFOZ

generally seem to sound voiceless, while a difference in the preceding vowel formants helps cue the contrast. In contrast, fortis and lenis obstruents in SCXZ seem to show greater contrast in voicing, but little variation in the preceding vowel. Having recorded data in both language communities, I narrowed the scope of analysis in the instrumental study to include only SFOZ, the variant in which patterns of fortis/lenis consonants seem most unlike those of other Zapotec languages.

Categorizing consonants as fortis or lenis establishes a framework that signals a complex cluster of acoustic correlates that differs from phonological descriptions of languages with a simple voiced/voiceless distinction. Fortis obstruents (/p/ /t/ /k/ /ts/ /tʃ/ /s/ /ʃ/) are always voiceless, while the lenis counterparts vary between voiced and voiceless. However, voiced lenis obstruents are rarely fully voiced or fully devoiced. SCXZ is relatively stable in its voicing distinction between fortis and lenis consonants. In SFOZ, however, as in the Zapotec languages, Texmelucan Zapotec (Speck 1978:18) and Cajonos Zapotec (Nellis & Hollenbach 1980), there is a general word-level feature of word-initial and word-final consonant devoicing. Thus most oral lenis obstruents in word-initial and word-final positions are pronounced as voiceless (e.g. *mæg* [mæk] ‘scorpion’). Word-initially, there is also significant variation among native speakers of SFOZ observed in *kol kwij ~ gol gwij* ‘everybody look’. Some speakers voice onset obstruents, while others pronounce them as voiceless. Fortis sonorants are always voiced, making a strictly voiced-voiceless distinction between fortis/lenis pairs problematic.

Considering the factors discussed in this chapter, the fortis/lenis contrast seems least affected and most consistent in the word-final position. Therefore the acoustic study focuses on the investigation of fortis/lenis correlates in the word-final position. The following chapter describes the experimental procedures for this study.

## **CHAPTER 3**

### **PROCEDURES**

#### **3.1 Scope of study**

This experiment examines the perceived acoustic correlates of the fortis/lenis consonant contrast in SFOZ. The primary, most complete investigation is of duration of the VC rime and its individual vowel and consonant components. The second study is an analysis of the vowel quality (formant values) of the vowel preceding fortis/lenis consonants. Smaller studies investigate voice onset time (VOT) for stops, voicing and closure type/width of obstruents, and intensity of sonorants.

This chapter presents the procedures for selecting data, recording, and speaker selection. Chapter four will present the data used for specific studies, guidelines for analysis and the results of each study.

#### **3.2 Data selection**

I selected words for recording while living and collaborating in language development in San Francisco Ozolotepec since 2003 under the auspices of the SIL International. In addition to personal field notes, data were collected from numerous sources: Data from Santa Catarina Xanaguía transcribed and archived by Hopkins and Olive between 1985 and 1995, along with unpublished SFOZ field notes from Nelson and Heise, were initial data sources in the process of selecting fortis/lenis pairs for recording. SCXZ sources include organized language lessons, a manuscript of “501 Verbs” fully conjugated in all aspects (Hopkins, n.d.), and published and drafted texts. SFOZ sources



included language learning sessions, as well as published and drafted texts. At the time of recording, some speakers introduced additional target words to the experiment by informing me of other words that sounded the same as those being used. Speaker four, with unique awareness and command of the language, offered additional target words; a few of his suggestions were included in the data corpus.

To compare and contrast the fortis/lenis categories, target words with fortis/lenis pairs in initial, medial and final word positions were compiled from the data corpora of both SFOZ and SCXZ. The goal was to find fortis/lenis contrasts in the clearest, most uncomplicated context: monomorphemic, monosyllabic nouns with like tones and CVC syllable type. However, the difficulty in finding fortis-initial target words underscored the limited distribution of fortis consonants, as discussed in Chapter 2. Therefore this instrumental study is limited primarily to observation of the word-final position—the position with the most robust fortis/lenis contrast in SFOZ. Due to the limited distribution of fortis consonants in nouns, the study also includes verbs, quantifiers and modifiers in order to present a more complete picture of the word-final fortis/lenis contrast.

While preferring CVC nouns to avoid multiple morphemes and consonant clusters, I included some verbs which always inflect for aspect in the initial position, and some target words which have an onset cluster (e.g. *mbán*: ‘is quick’, or *gjàt* ‘tortilla’). To minimize potential variation between different word classes, when possible I compared fortis/lenis pairs belonging to the same grammatical category or verb aspect (e.g. *dʒas* ‘HAB.chew’ vs. *dʒaz* ‘HAB.bathe’). Consonant clusters, while generally avoided, were allowed in the onset of rare minimal pairs (e.g. *pʃil* ‘sugar cane’ vs. *pʃil*: ‘spark’, both with low tone). Since the focus of analysis is word-final and not word-initial, the interference, if any, is minimal. Contrastive pairs also have the same tone when possible.

Some pairs with dissimilar tone patterns are included due to lack of contrastive pairs with identical tones, particularly if the consonant segments contrast in identical environments (i.e. segmental minimal pairs).

The data corpus for recording consists mostly of words containing modal, unchecked vowels. Exceptions are word-medial occurrences of the fortis/lenis contrast (e.g. *wkaʔa* ‘bought’ vs. *wgaʔa* ‘caught’); these pairs were included even when they contain laryngealized vowels due to the rare occurrence of fortis/lenis in the word-medial position. A few exceptional pairs do not fit the general criteria, but were included in spite of a laryngeal feature, multiple morphemes, or different word classes (e.g. *d-upaʔa-n* ‘my dad’ vs. *dubaʔan* ‘rope’) because of their relevance to the fortis/lenis issue.

In order to reduce the variables affecting the consonant contrast, target words were grouped into four sets of words listed in example (23): Sets 1 and 2 represent fortis/lenis pairs in the word-initial position, while sets 3 and 4 include fortis/lenis pairs in word-final position.

- 23) Set 1: Initial fortis/lenis consonant followed by /i/.  
Set 2: Initial fortis/lenis consonant followed by /a/.  
Set 3: /i/ followed by final fortis/lenis consonant.  
Set 4: /a/ followed by final fortis/lenis consonant.

The vowel phonemes /i/ and /a/ are opposite ends in the range of vowels that may affect--or be affected by-- the fortis/lenis contrast (see Ladefoged 2003:4). To observe if fortis/lenis contrast is related to perceived vowel difference, or vice versa, the above word sets are controlled for vowel context: In Sets 1 and 3, fortis/lenis pairs are adjacent to the high front vowel /i/, and in Sets 2 and 4 the consonants are adjacent to the low back vowel /a/.

Selection of data for recording involved another research question: Do all vowels change before fortis and lenis consonants? Two additional sets of words, characterized

below in example (24), aim to show the allophonic vowel differences perceived before fortis and lenis consonants. Set 5 includes forms which should show the tense vowel allophones [i, e, æ, a, o, u] before each lenis consonant. Set 6 includes forms which show the lax vowel allophones [ɪ, e, ɛ, a, o, ʊ] before each fortis consonant.

- 24) Set 5: All vowels before all lenis consonants.  
Set 6: All vowels before all fortis consonants.

Sets 5 and 6 are different from Sets 1 through 4 in that Sets 1 through 4 group words according to fortis/lenis consonant pairs adjacent to only vowels /i/ and /a/. In contrast, set 5 includes only lenis consonants, and set 6 includes only fortis consonants following the complete range of vowels.

Data Sets 5 and 6 reveal gaps in the distribution of certain vowels preceding certain consonants (i.e. there is no /i/ before /dʒ/). Within Sets 5 and 6, there are four contrastive pairs for which there are more complete fortis/lenis corpora of target words. All vowel phonemes /i, e, æ, o, u, a/ occur before stop pairs /p b/ and /t d/; affricate pair /ts dz/, and nasal pair /n: n/. Set 5 (lenis) and Set 6 (fortis) combine and represent fortis/lenis pairs in only these four contrastive types of articulation. Thus, the data corpus for recording selectively includes a subset of target words from Sets 5 and 6.

A selective compilation of words from Sets 1 through 6 was test recorded. The time required for SCXZ Speaker one to record the full corpus was too long. Therefore, to reduce recording time, target data was limited to the best available pairs in each set (e.g. only one occurrence of /s/ before /i/ instead of three). There was helpful overlap between sets, so when possible, target words were chosen that matched the criteria of more than one set. For example, *git* ‘squash’ represents a lenis consonant in the onset, and a fortis consonant in the coda. As such, it meets the criteria for both Set 1 and Set 3 and was chosen over a word that belonged to only one set. In this way, fewer words showed more

instances of the consonant contrast. The final corpus from the six sets was approximately 120 target words. The addition of a few exceptional pairs brought the final data corpus recording to 130 target words representative of the fortis/lenis contrast.

With a carefully developed data corpus, three options for a recording environment are 1) in isolation, 2) in a natural context, and 3) in a frame, or carrier sentence. In isolation, word edges are often susceptible to devoicing, which could interfere with the fortis/lenis contrast in SFOZ. In the same way, tone patterns on words in isolation may be unpredictable. Target words in a natural context represent typical pronunciation patterns, but it would be more difficult to compare fortis/lenis consonants without control of the word edges, or word or phrasal stress. A frame controls for stress and rhythmic position, tone variation and intonation, and a vowel environment at both word edges.

In the data preparation stage of the experiment, the target words were elicited in a natural context of phrases or sentences. The female speaker of SFOZ recorded some of the target words in all three environments: in isolation, in the frame, and in a natural context. While an ideal study may record target words in every context, for the sake of time only one context could be chosen. Critically, a frame is “a better technique for producing stability in the pronunciation of each word” and “makes it easier to measure the lengths of the items that contrast” (Ladefoged 2003:7). Therefore, the remaining subjects recorded only words in a frame. Actual recording time for these target words in a frame was about one hour for each subject.

To analyze fortis/lenis consonants at the word edges, the ideal frame 1) controls for non-high, modal vowels both before and after the target word, 2) places the target word in a stressed position, and 3) is semantically coherent for natural elicitation. The original research design sought to compare the fortis/lenis contrast in SFOZ and SCXZ. The best

possible frame for both communities, shown in example (25) below, is the only known frame with a vowel environment for both word edges in both speech communities. It is semantically the most natural phrase for repetition of target words in an environment that offers the clearest definition of consonant boundaries and best control surrounding the target word. In example (25), ( - ) marks morpheme boundaries, ( ' ) marks primary stress in the phrase, and ( , ) marks secondary stress in the phrase.

- (25) *k-neʔe* ' \_\_\_\_ *ada* *j-ne-d-l* (SFOZ)  
*w-neʔe* ' \_\_\_\_ *oda* *j-ne-d-a* (SCXZ)<sup>36</sup>  
 IMP.say \_\_\_\_ or POT.say.NEG.2s  
 ‘Say \_\_\_\_ or don’t say it.’

The imperative aspect of the verb *kneʔe* ‘say’ includes an implied second person subject instead of the typical pronoun clitic which would have resulted in a consonant adjacent to the consonant onset of the target word. While it is not ideal that a laryngealized vowel precedes the onset of the target word, the laryngeal feature of the preceding vowel does not influence the analysis since the target consonants to be analyzed are at the word end. Furthermore, the verb *kneʔe* ‘say’ is still preferred over other verbs, because *kneʔe* ‘say’ is a semantically logical frame. The only native, non-high vowel initial word which can follow the target word, *ada~oda* ‘or’ (in fact, the only known non-high vowel initial word in all SFOZ), connects two parallel phrases.<sup>37</sup>

---

<sup>36</sup> The imperative aspect is often marked with a *k-* or a *ky-* more like a /k/ with lip rounding or a voiceless /u/. In contrast, the imperative marker in SCXZ is marked by a *u-*, or a *w-*, depending on the analyses suggested in Chapter 2.

<sup>37</sup> An alternate frame available for SFOZ is *kneʔe* \_\_\_\_ *or* *ki* ‘Say \_\_\_\_ now.’ However, *or* is a Spanish loan from *hora* ‘hour’. This same frame corresponds to *kneʔe* \_\_\_\_ *na or* in SCXZ, with nasal onset unacceptable for analysis of the preceding consonant.

The grammatical structure of the frame presents two problems for acoustic analysis of word-final fortis/lenis contrast, both related to the fact that speakers sometimes pause between the target word and the onset of the following vowel. First, the duration of a final consonant preceding a pause is likely to be longer than when there is no pause. The pause occasionally interferes with the segmentation of the final consonant, particularly when the stop burst is unclear. Such a pause was identified during analysis. When the consonant duration is unclear due to the pause, the token with an interfering pause is excluded from the results.

The second problem with the frame is that when there is a pause, a phrase-level glottal stop is inserted (see Beam de Azcona 1998), presumably to preempt a vowel onset and preserve the preferred CVC syllable structure.<sup>38</sup> This glottal may be realized at the end of the consonant (e.g. creaky /l/) or at the vowel onset as a glottal stop or as creakiness on the vowel /a/. See Appendix C for a spectrographic illustration of the creaky vowel spoken by SFOZ Speaker three. Both the pause and the glottal or creaky vowel, when present, preclude measurement of VOT. For this reason, VOT data has gaps.

In spite of the problems encountered due to the frame, the selected frame is sufficient for identifying the acoustic correlates of the fortis/lenis contrast. The target words are each pronounced in the same stress, tone and vowel context, uninfluenced by surrounding verb or pronoun morphemes. As such the frame is preferred to recording target words in isolation or in a natural context.

---

<sup>38</sup> Incidentally, a benefit of the pause is that it revealed a laryngeal pattern not previously observed in SFOZ phonology.

### 3.3 Data recording

Data was recorded between April and June of 2006 during research trips to the towns of San Francisco Ozolotepec and Santa Catarina Xanaguía. Each subject repeated the list of words five times in the context of the frame, *kne?e \_\_\_ ada jnédl* (SFOZ) and *wne?e \_\_\_ oda jnedala* (SCXZ) ‘Say \_\_\_ or don’t say it’. For recording, the order of the words in the list was changed each time through to avoid unnatural intonation and eliminate effects of adjacency. Tokens with interruptions or unusual background noises were excluded. If the interruption was noticed during the recording session, the subject was asked to record an additional repetition of the interrupted token.

Careful procedures were followed when recording the target fortis/lenis data, ensuring clear digital files for analysis. Tokens were recorded first on a Sony minidisk recorder. The microphone used for the first six speakers was a Sony head set with boom mike resting one to two inches from the mouth on the left side. After a rabbit chewed off the microphone cord, the remaining subjects spoke into a hand-held microphone held by a third party in the same position as the head set mike, approximately two inches from the mouth on the left side. No distinguishable difference was noted between recordings using the different microphones. Data from the minidisks was transferred onto a Dell Inspiron 8600 XP through an external sound card. Speech Analyzer 3.0<sup>39</sup> was used to save and label tokens in separate files.

Once tokens were saved in shorter segments, the wave files were analyzed using the speech analysis program PRAAT.<sup>40</sup> As a general rule, segment boundaries and values were first observed on spectrograms of the entire utterance as illustrated in Figure 4 of the word *gid* ‘leather’ as spoken by SFOZ Speaker three.

---

<sup>39</sup> Speech Analyzer is freeware available at [www.sil.org/computing/sa](http://www.sil.org/computing/sa).

<sup>40</sup> Praat is speech analyzer freeware available [www.praat.org](http://www.praat.org).

The boundaries and values were then adjusted using more focused wave forms, marking segment boundaries on the positive zero crossing. Further segmentation criteria are noted relevant to each acoustic correlate.

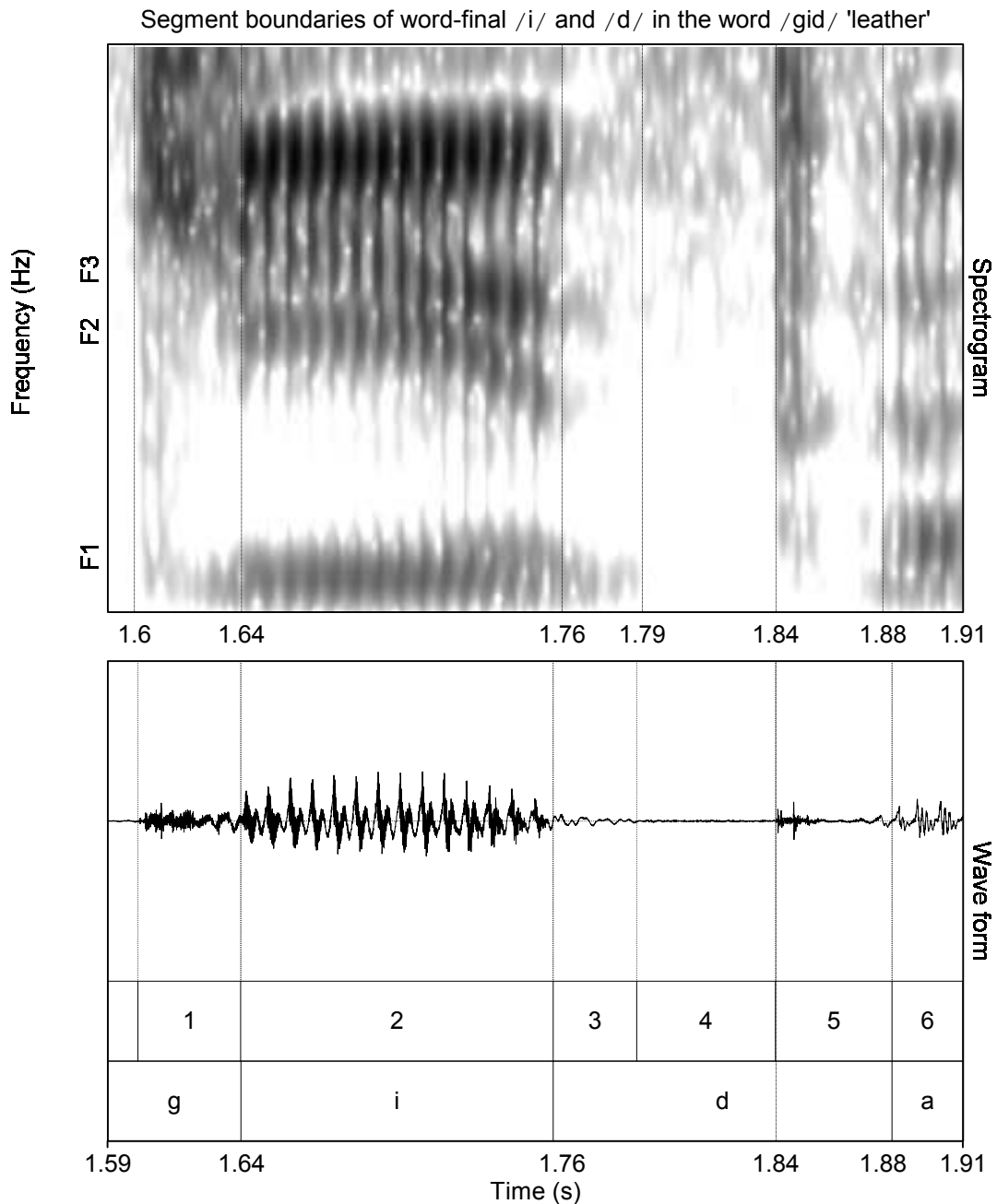


Figure 4. Spectrogram and wave form segment boundaries



### 3.4 Speaker selection, speaker characteristics and variation

The target population for recording includes adult native Zapotec speakers born, raised, and currently living in San Francisco Ozolotepec or Santa Catarina Xanaguía and with mature language development. While not a required criterion for subjects, during the recording process it was helpful for elicitation that each of the subjects be bilingual in Spanish. Subjects with speech impediments or particularly quiet voices were avoided. All speakers chosen for recording fit the subject criteria. Data recorded are from one female speaker and six male native speakers of SFOZ and four male native speakers of SCXZ. Due to time restrictions, primary attention is given to SFOZ and only data from the male speakers are analyzed for the fortis/lenis contrast in this investigation. **Each target word has five tokens per subject.** Given six male SFOZ speakers, thirty instances of each target word are available for analysis.

Speaker one is eighteen years old and in his final year of high school (local education being in Spanish, the language of wider communication). He speaks quickly and more quietly than other subjects. However, the faster rate of speech is consistent throughout the recording session, still giving an accurate representation of the fortis/lenis contrast.

Speaker two<sup>41</sup> is thirty-five years old with six years of formal education up through elementary school. Recorded speech is brisk, and clearly enunciated, and relatively loud. Speaker two consistently pauses after each target word in the frame. The pause separates the word-final consonant from the vowel onset of the following word, so VOT values are not available. Nonetheless, boundaries of the word-final consonant segments are still easily identified by the stop burst which precedes the pause.

---

<sup>41</sup> Apart from the recording, this speaker is a talented story-teller.

Speaker three is sixteen and has just recently left the language community to attend a Spanish school in a town where a different Zapotec language is spoken. There is no evidence in the data that either Spanish or the other Zapotec language has affected pronunciation of his mother tongue. The data is clear and natural.

Speaker four is thirty with formal schooling through primary school. He spent a few years working outside the language area, but worked primarily among SFOZ and Spanish speakers. The recording session lasted later than expected, so some of the recording is accompanied by crickets. There is no evidence that the background noise affected the acoustic measurements. Notably, this speaker has an overall rate of speech that is slow and intentional (e.g. the vowel /a/ is 358 ms long in the most extreme token, ‘58. *gadz* SM4a.wav’). Like Speaker one, the rate of speech is consistent throughout the recording session. While the contrast between fortis and lenis is still very evident, data from one fast speaker and one slow speaker result in greater standard deviations. This needs to be taken into consideration during analysis of the raw data.

Speaker five is forty, with little formal education but perhaps the highest level of bilingualism. A leader in the community, this speaker manages both SFOZ and Spanish well and in a broad range of contexts.

Speaker six is nineteen, a graduate of the local high school, and an enthusiastic author of SFOZ texts. Speakers five and six were the most variable in terms of rate of speech. VOT, voicing at the consonant onset and closure type also varied more for these two speakers.

This selection of six speakers<sup>42</sup> presents a relatively realistic spectrum of the population and of speech production in SFOZ: a wide range of ages, education, speech rates and styles, consistency and variability. In this way the data should give an accurate representation of the fortis/lenis contrast in SFOZ. While data presented here includes only male speakers, preliminary analysis of the recording of the one female SFOZ speaker indicates that the patterns of the fortis/lenis contrast can generalize to female speakers of SFOZ.

Data results from this study of SFOZ cannot generalize to speakers of SCXZ. It is true that the variants have very high mutual intelligibility, but further experimentation is necessary to determine which acoustic correlates are shared by SFOZ and SCXZ. On the basis of an initial glimpse at SCXZ data, I expect consonant voicing to be more salient for SCXZ, while the quality of the vowel preceding the final consonant will vary less.

---

<sup>42</sup> All of the speakers are literate in Spanish and at least minimally literate in Zapotec, after only recently becoming acquainted with the writing system in SFOZ.

## **CHAPTER 4**

### **DATA PROCEDURES, ANALYSIS, RESULTS**

In this chapter I present the specific procedures and results of the experiment described in Chapter 3. In section 4.1 I report the duration of rime segments and in section 4.2 the vowel quality preceding fortis/lenis consonants. Then I address voice onset time (VOT) in section 4.3, and the results for voice tail in section 4.4. In section 4.5, I present initial results of the study of sonorant intensity. Finally, in section 4.6, I include a pilot study comparing VOT and consonant duration in SFOZ and SCXZ.

To analyze the various acoustic properties, I used different subsets of fortis/lenis consonant pairs representing the consonant contrast. For example, one subset of target words, those with obstruents, is used to investigate the voicing contrast, and a different subset of words, those with sonorants, is used to explore the intensity correlation. Due to the fortis/lenis distinction and syllable structure of SFOZ discussed in Chapter 2, the core of the analysis is of word-final, utterance medial consonants and their effects on the preceding vowels /i/ and /a/.

#### **4.1 Duration of VC segments and rime**

Based on my perceptions, my hypotheses for duration are that 1) all word-final fortis consonants are significantly longer than their lenis counterparts, 2) a vowel preceding a fortis consonant is shorter than a vowel preceding the lenis counterpart, and 3) the fortis rime (VC:) is longer than the lenis rime (VC). The third hypothesis is based on the

assumption that if fortis consonants are historically geminate, geminates being almost twice as long as single consonants, the difference in vowel length would not be as extreme as the difference in the length of the consonant.

#### 4.1.1 *Word-final VC sequences*

To test these hypotheses for word-final fortis/lenis segments, I chose seventeen word-final consonant pairs from the recorded list of 130 target words. This data subset from six adult male speakers represents each manner and place of articulation of fortis/lenis contrast: stops, affricates, fricatives, nasals and laterals in the bilabial, alveolar, alveopalatal and velar places of articulation. For each type of articulation, there are two pairs: one with the consonant adjacent to the vowel /i/, and the other with the consonant adjacent to /a/.<sup>43</sup> The seventeen fortis/lenis pairs are listed in Table 11. Loan words well-entrenched in Zapotec phonology are in (parentheses).

---

<sup>43</sup> The phoneme /a/ occurs before fortis /ʃ/, as in *gaʃ* ‘close’, but there is no known instance of /a/ before lenis /ʒ/. Therefore this consonant pair was excluded from the analysis.

Table 11. Word-final fortis/lenis pairs analyzed for VC duration (and V quality)

	bilabial		alveolar		postalveolar				
stops	/p/	nìp <sup>44</sup>	‘cane’	/t/	gìt	‘rainbow’	/k/	ʃík	‘shoulder’
	/b/	gìb	‘iron’	/d/	gìd	‘leather’	/g/	(ʒìg)	‘bowl’ Sp. <i>jicara</i>
	/p/	dʒàp	‘has’	/t/	gjàt	‘tortilla’	/k/	blak	‘leaf’
	/b/	dʒab	‘swallows’	/d/	dǎd	‘sir’	/g/	blag	‘how much’
affricates				/ts/	gìts	‘paper’	/tʃ/	bítʃ	‘cat’
				/dz/	lídʒ	‘home’	/dʒ/	mèdʒ <sup>45</sup>	‘turkey’
				/ts/	gǎts	‘break’	/tʃ/	(kwatʃ) <sup>46</sup>	‘twin’
				/dz/	gádʒ	‘seven’	/dʒ/	ladʒ	‘clothing’
fricatives				/s/	nìs	‘water’	/ʃ/	jtíʃ	‘measure’
				/z/	níz	‘dried corn’	/ʒ/	níz	‘delicious’
				/s/	dʒas	‘chews’			
				/z/	dʒaz	‘bathes’			
nasals				/n:/	wdʒín:	‘arrived’			
				/n/	dʒìn	‘honey’			
				/n:/	mbán:	‘quick’			
				/n/	mbán	‘alive’			
laterals				/l:/	pʃíl:	‘spark’			
				/l/	pʃíl	‘sugar cane’			
				/l:/	gàl:	‘twenty’			
				/l/	gǎl	‘may be born’			

<sup>44</sup> Tone is marked á (H), à (L), ǎ (LH), â (HL). Tones on words vary in isolation, in a frame, and in a natural context. Further research is needed to identify tones on the roots, as well as patterns of tone sandhi.

<sup>45</sup> There is no known instance of /i/ before /dʒ/.

<sup>46</sup> I did not recognize *kwatʃ* ‘twin’ as a loan word until it was identified by Steve Marlett as taken from Spanish *cuate* ‘buddy’. There is no other known native word with an – *atʃ* rime.

#### 4.1.1.1 VC Segmentation

To measure the duration of the rime components of the word-final data on Table 11, I placed segment boundaries at the vowel onset, between the vowel and consonant of the rime, and at the end of the consonant/onset of the following vowel in the frame. As noted in section 3.3, segment boundaries were first indicated on zoomed-out spectrographs. The boundaries were then adjusted on the basis of the zoomed-in wave forms, to the closest positive zero crossing. The wave file in Figure 5 shows the boundaries for duration measurements of the VC segments in the word *gid* 'leather'. Numbers one through five identify the specific segments: Number one (1) is the onset consonant, two (2) is the vowel duration, three (3) is the voice tail/closure voicing, three and four (3-4) combined are the consonant duration, and five (5) is the VOT.

Segment boundaries for duration of word-final /i/ and /d/ in the word /gid/ 'leather'

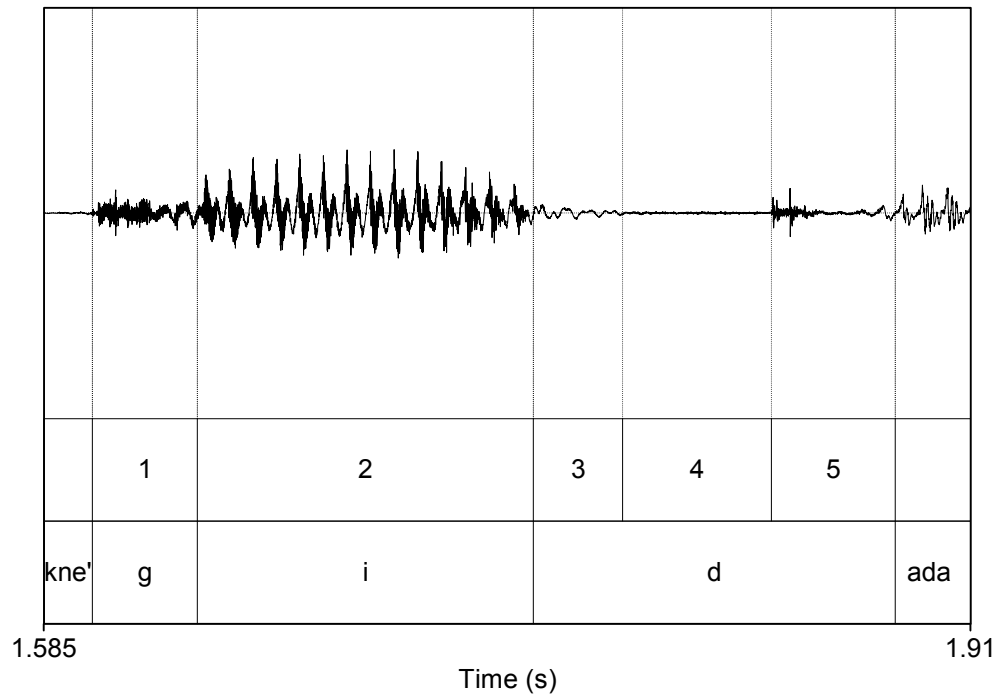


Figure 5. Illustration of the duration boundaries of vowel and consonant segments

The initial boundary for the vowel onset is marked where the formants are darkened and at a point closest to where the periodicity begins (the boundary to the left of section 2). The boundary between the vowel and consonant is marked where vowel intensity, periodicity and darkness of formants diminish; the boundary is marked after a complete waveform cycle, at positive zero crossing. A secondary indicator of this boundary is situations in which F2 and F3 seem to be converging.

For stops, the end of the consonant boundary is at the spike of the burst onset (the boundary between sections 4 and 5). Measurement of the consonant duration does not include the burst, as in several cases the following vowel is delayed by a pause or interrupted by a glottal causing greater ambiguity for measurement.<sup>47</sup> If there is no clear burst, and no obvious pause, the segment end is marked where the consonant releases into the vowel. This latter measurement, when there is no burst, results in a longer consonant duration than when there is a burst. Duration is recorded in milliseconds and rounded to the nearest tenth.

Identifying boundaries in this way, word-final VC results show the same overall pattern for both sonorants and obstruents: lenis consonants are shorter than fortis, and vowels preceding lenis consonants are longer than vowels preceding fortis consonants. For an overview of the results, see Table 12 for the average duration of all lenis and fortis sonorant and obstruent pairs, the average duration of the preceding vowel, and the total

---

<sup>47</sup> Due to the grammatical structure of the frame (a parallel structure sometimes interrupted with a pause), the transition from consonant closure to vowel onset of the following word/parallel structure often involves low amplitude bursts and creaky glottal pulses. It is not clear if the creakiness is from the consonant or the vowel. I suspect that it is a phrasal indicator of a pause preceding the vowel (e.g. *dad* SM6cd.wav). An additional observation was an unexpected creakiness in the nucleus of vowels that are not known to have a glottal feature. (Tokens with examples with a pause/creaky: 117. *gyat* SM1c.wav; 78. *blag* SM1d.wav; 117. *gyat* SM3b.wav.)



duration of the rime. (Mean duration values accompanied by the standard deviations of individual fortis/lenis consonant pairs are listed in Table 13.)

Table 12. Mean duration of fortis (F) and lenis (L) sonorants and obstruents (in ms)

	Sonorants							Obstruents						
	N	V	StDev	C	StDev	Rime	StDev	N	V	StDev	C	StDev	Rime	StDev
L	119	<b>151.9</b>	39.9	<b>85.2</b>	21.9	<b>237.1</b>	54.9	389	<b>167.8</b>	41.8	<b>126.1</b>	45.9	<b>293.9</b>	74.2
F	119	<b>94.3</b>	30.9	<b>126.5</b>	40.7	<b>220.8</b>	58.8	393	<b>105.7</b>	33.4	<b>162.0</b>	48.8	<b>267.7</b>	67.2

The contrast in vowel duration before fortis versus lenis consonants, the contrast in fortis versus lenis consonant duration, and the contrast in duration of fortis versus lenis rimes, are all illustrated in Figure 6:

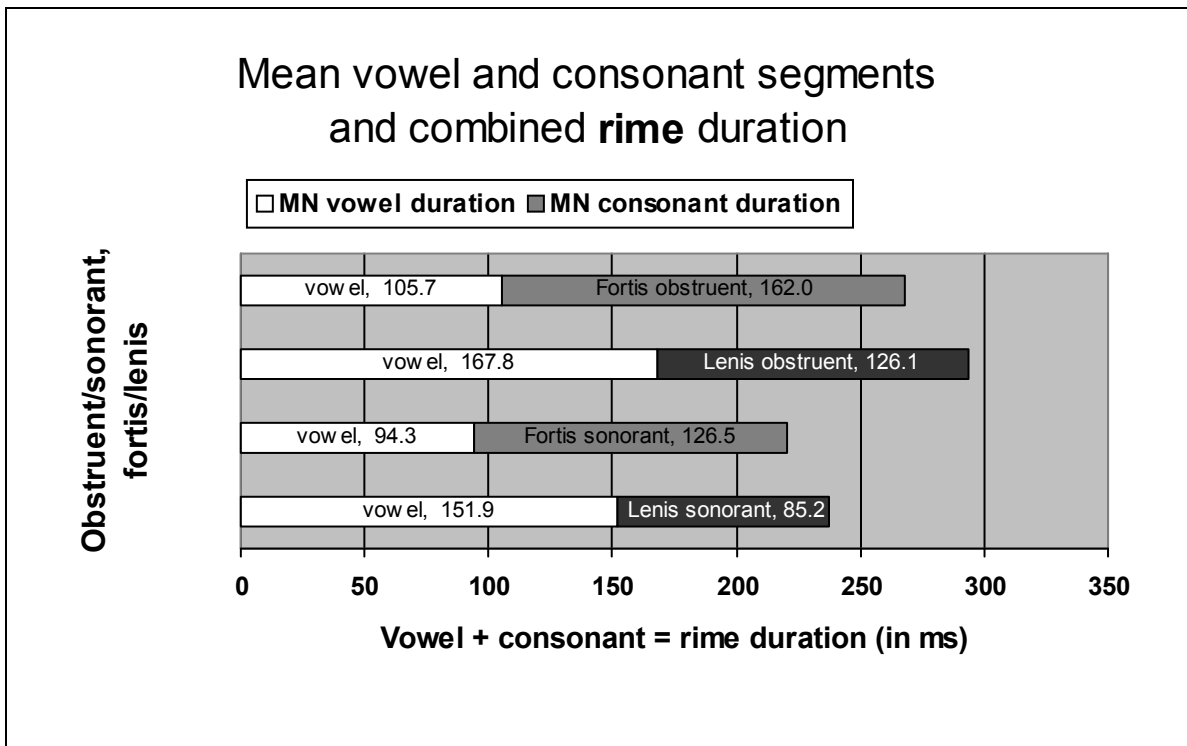


Figure 6. Total rime duration (in ms) with vowel and consonant segments

Observe that, while there is a difference in obstruent and sonorant rimes (obstruent rimes are longer), the fortis/lenis distinction is consistent in both consonant categories.

This summary provides strong support for two of the hypotheses: 1) lenis consonants are shorter than fortis consonants, and 2) vowels before lenis consonants are longer than

vowels before fortis consonants. My third hypothesis, that the fortis rime would be longer, is refuted. In fact, the lenis rime is actually significantly longer than the fortis rime for both obstruents and sonorants. For example, a lenis sonorant rime is 237.1 milliseconds compared to 220.8 milliseconds for a fortis rime (the duration of VC combined). Duration of consonants, vowels, and total rimes are discussed in greater detail in sections 4.1.1.2, 4.1.1.3, and 4.1.1.4, respectively.

#### 4.1.1.2 Consonant duration

This section presents the specific duration results for the consonant portion of the rime. In Table 13, observe the mean word-final consonant duration and standard deviation of thirty tokens of each fortis/lenis pair (five repetitions each by six speakers). For each segment, the upper row of values is the consonant duration following the vowel /i/; the lower row of values presents the mean consonant duration after the vowel /a/. The upper set of segments includes stops and fricatives; the lower set includes affricates, nasals, and laterals.

Table 13. Mean (MN) and standard deviation (StDev) duration values of all word-final fortis/lenis consonants after /i/ and /a/ (in ms) (N=30 each)

		stops						fricatives			
		<b>p</b>	<b>b</b>	<b>t</b>	<b>d</b>	<b>k</b>	<b>g</b>	<b>s</b>	<b>z</b>	<b>ʃ</b>	<b>ʒ</b>
/i/	MN	157.1	112.4	165.2	106.7	130.7	103.3	184.8	148.2	162.4	135.6
	StDev	38.8	36.6	23.8	29.7	29.6	28.2	39.9	46.8	45.9	50.2
/a/	MN	127.6	102.9	137.8	99.2	111.8	87.3	166.1	142.0	-	-
	StDev	31.9	36.3	40.3	39.7	26.6	27.0	42.0	44.5	-	-

		affricates				nasals		laterals	
		<b>ts</b>	<b>dz</b>	<b>tʃ</b>	<b>dʒ</b>	<b>n:</b>	<b>n</b>	<b>l:</b>	<b>l</b>
/i/	MN	203.9	158.0	178.4	146.3	124.3	80.2	122.3	82.1
	StDev	50.2	46.4	45.5	42.2	36.6	23.1	42.1	21.6
/a/	MN	207.7	153.2	172.3	143.3	124.0	87.5	135.5	90.8
	StDev	55.2	47.5	49.1	46.5	36.5	19.6	47.6	22.4

Observe the mean values of the duration of fortis /p/ compared to lenis /b/ following the high vowel /i/ in the top left corner of the chart. Given thirty tokens of each segment, the average duration of /p/ in the word-final position is 157.1 ms. In contrast, the average duration of /b/ is 112.4 ms. The standard deviation for /p/ is 38.8 ms, and the standard deviation for /b/ is 36.6 ms. While this standard deviation is high, consider that the data were not controlled for rate of speech of individual speakers. Standard deviations are greater because a fortis consonant /p/ spoken by Speaker four is longer than the same fortis consonant spoken by Speaker three, due to the consistently slower rate of speech of Speaker four.

The duration of the fortis phoneme /p/ is roughly thirty percent (exactly 28.5%) longer than the lenis phoneme /b/. The contrast is highly significant, as illustrated by a *t*-test ( $t(58) = 4.59$  and  $p(\text{two-tailed}) = .000$ ). This fortis/lenis duration is true of other consonant pairs as well, though decreasingly so as place of articulation moves back in the mouth. Note that  $b > d > g$  due to volume/pressure differences, ascribable to Boyle's law of aerodynamics, as discussed in Zemlin (1997).

Consonant duration consistently correlates with the fortis/lenis contrast across consonant categories and all manners of articulation. Figure 7 charts the duration of fortis/lenis consonants following the vowel /i/, data that is presented numerically above in Table 13. Fortis consonants have light gray bars, and lenis consonants have dark gray bars. Starting at the top of the bar graph, fortis stop /p/ with a consonant duration of 157.1 ms is followed by lenis stop /b/ with a consonant duration of 112.4 ms, etc.

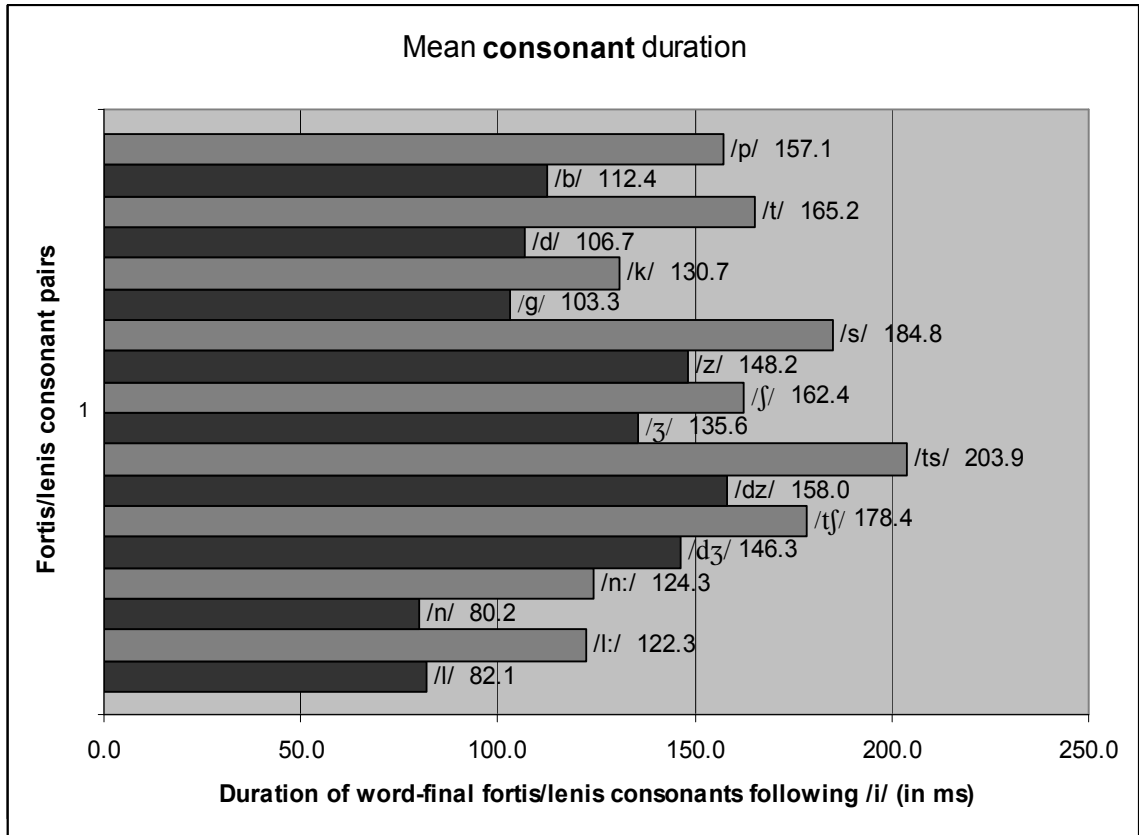


Figure 7. Illustration of the consonant duration of fortis/lenis segments

The *t*-test results (two-sample assuming unequal variance) for the duration of all fortis versus all lenis consonants indicate exceedingly high significance. Fortis consonants—stops, fricatives, affricates, nasals and laterals—are significantly longer than their lenis counterpart:  $t(960) = 12.314$  and  $p(\text{two-tail}) = .000$ . Simply stated, consonant duration is a reliable correlate of the word-final fortis/lenis contrast in all consonant categories in San Francisco Ozolotepec Zapotec.

#### 4.1.1.3 Vowel duration

The significant difference in fortis/lenis consonant duration is complemented by the duration of vowels before fortis and lenis consonants. Table 14 presents the mean duration and standard deviation of the vowels /i/ and /a/ preceding fortis and lenis

consonants. In this table, the mean value is the duration of the vowel, given thirty tokens. For example, in the top left corner of Table 14, the vowel /i/ has an average duration of 77.7 milliseconds before fortis /p/, and an average duration of 144.7 milliseconds before lenis /b/. The duration of the high front vowel /i/ before a fortis consonant is just over half (53.7%) the duration of /i/ before the lenis counterpart.

Table 14. Mean and standard deviation of duration of vowels /i/ and /a/ before word-final fortis/lenis consonants (in ms) (N = 30 each)

		stops						fricatives			
Before:		p	b	t	d	k	g	s	z	ʃ	ʒ
/i/	MN	77.7	144.7	73.5	142.6	66.8	144.5	94.0	163.6	120.7	161.6
	StDev	19.1	26.3	16.6	28.5	14.6	26.9	19.6	39.7	19.0	35.7
/a/	MN	125.1	181.1	124.1	190.8	115.6	159.4	145.3	206.5	-	-
	StDev	19.2	28.3	34.0	33.0	19.6	41.8	31.2	41.6	-	-

		affricates				nasals		laterals	
Before:		ts	dz	tʃ	dʒ	n:	n	l:	l
/i/	MN	75.9	138.7	105.7	170.4	76.4	133.2	61.1	129.9
	StDev	20.5	33.0	17.4	42.1	14.8	35.6	12.2	34.6
/a/	MN	132.1	199.3	125.7	177.7	118.4	168.6	121.2	175.1
	StDev	24.7	48.1	23.7	40.4	17.6	31.0	20.6	37.3

Vowels preceding a fortis consonant are significantly shorter than vowels preceding the lenis counterpart. A *t*-test gives the following results:  $t(928) = -25.307$ ;  $p(\text{two-tailed}) = .000$ . Table 14 also shows a significant phonetic difference between vowel durations of /i/ and /a/. The back open vowel /a/ is always longer than the high front vowel /i/ when compared in like contexts. While /i/ and /a/ differ in length, both still pattern the same before fortis/lenis (shorter vowel before fortis, longer vowel before lenis). The relationship of the preceding vowel and consonant duration seems to be bi-directional: voiced (lenis) and voiceless (fortis) stops following /a/ are longer than they are following

/i/.<sup>48</sup> It is clear that vowel length is not phonemic, but conditioned by the place of articulation (front versus back or high versus low) and most importantly, by whether the following consonant is fortis or lenis.

Duration of the preceding vowel is clearly one characteristic of the fortis/lenis contrast in the word-final position. As one example of the highly significant contrast between mean vowel duration before fortis/lenis consonants, Figure 8 illustrates the mean duration of /a/ preceding each fortis/lenis pair. For example, the mean duration of vowel /a/ before fortis bilabial /p/ is 125.1 ms, in contrast to the mean duration of 181.1 ms before the lenis bilabial /b/.

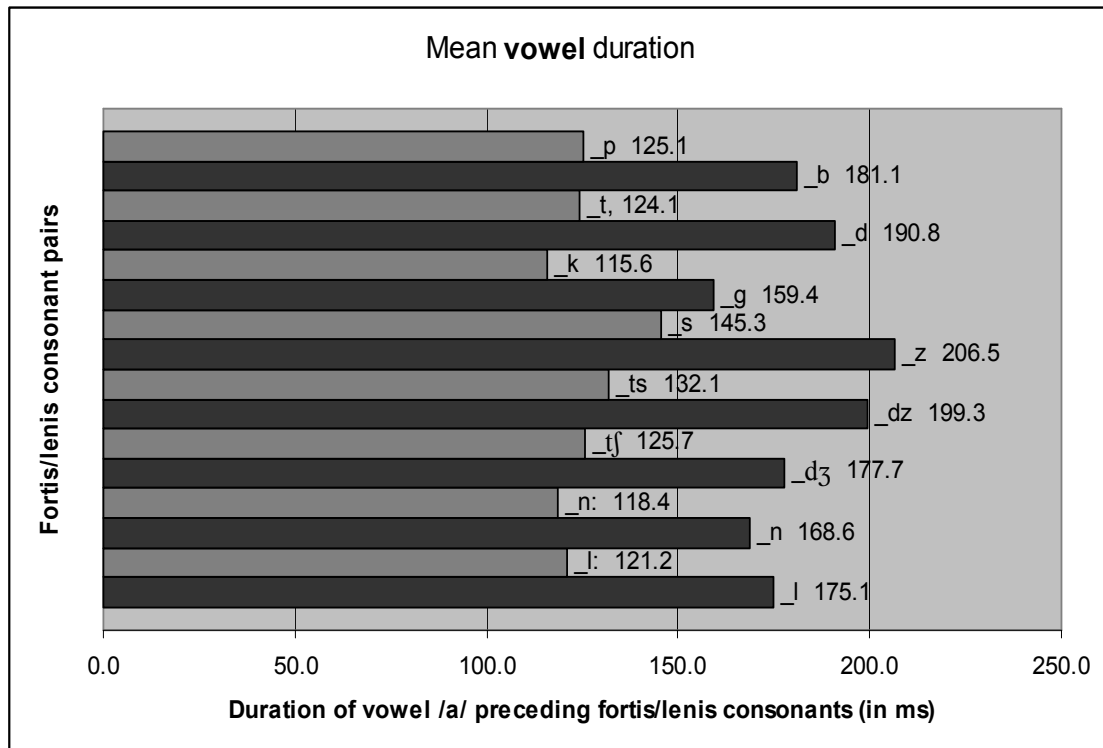


Figure 8. Illustration of the duration of vowel /a/ preceding fortis/lenis consonants

<sup>48</sup>An additional observation is that the duration of a vowel preceding a fortis consonant is always less than the duration of the consonant, except before a fortis velar (e.g. the duration of /a/ in *blak* ‘leaf’, is 115.2 ms, and /k/ is 111.0 ms). The reverse is true for a lenis coda; vowels are longer than the following lenis consonant.

This instrumental examination of individual fortis/lenis rime segments supports the typical description of the fortis/lenis contrast: fortis consonants are longer than their lenis counterparts, and vowels preceding fortis consonants are shorter than vowels preceding lenis consonants.

#### 4.1.1.4 Rime duration

If fortis is geminate, I would expect that the fortis rime (VCC) would be longer than a lenis rime (VC), regardless of the difference in vowel duration. If the fortis rime does not have a geminate, I would expect the duration of fortis and lenis rimes (VC) to be relatively constant in a language in order to maintain a constant word prosody (i.e. lenis [V:C] rime equals fortis [VC:] rime). To test this aspect of the geminate hypothesis, I calculate the rime duration by combining the values of individual vowel and consonant segments. The actual mean rime durations shown in example 26 do not support either hypothesis.

26)

	Sonorant			Obstruent		
	N	Rime	<i>StDev</i>	N	Rime	<i>StDev</i>
Fortis	120	220.8 ms	58.8	384	267.7 ms	67.2
Lenis	119	237.1 ms	54.9	390	293.9 ms	74.2

Contrary to my expectations, the fortis rime is shorter than the lenis rime. The difference, while not as great as the difference between mean consonant segments, is consistent and significant for both sonorant and obstruent categories.

The mean duration of the fortis sonorant rime (220.8 ms), has a significant contrast with the lenis sonorant rime mean duration (237.1 ms). As reported in example (27), the *p* value is .03, nearing the alpha .05, but still below it. It is possible, however, that significance would increase with more data, confirming the well-established contrast.

27)	Sonorant rime:	$t(236) = 2.15$	$p(\text{two-tail}) = .033$
	Obstruent rime:	$t(773) = 4.90$	$p(\text{two-tail}) = .000$
	Combined rime:	$t(966) = -5.23$	$p(\text{two-tail}) = .000$

Example (28) below illustrates this overall duration of fortis/lenis rime segments pictorially.

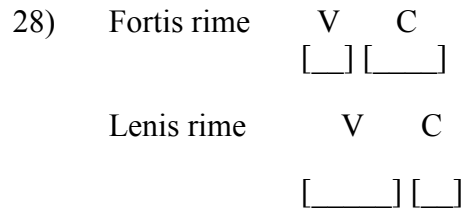


Figure 9 compares specific mean durations of fortis/lenis rimes with an obstruent coda, and fortis/lenis rimes with a sonorant coda. Obstruent rimes are longer than sonorant rimes, and fortis rimes are shorter than lenis rimes.

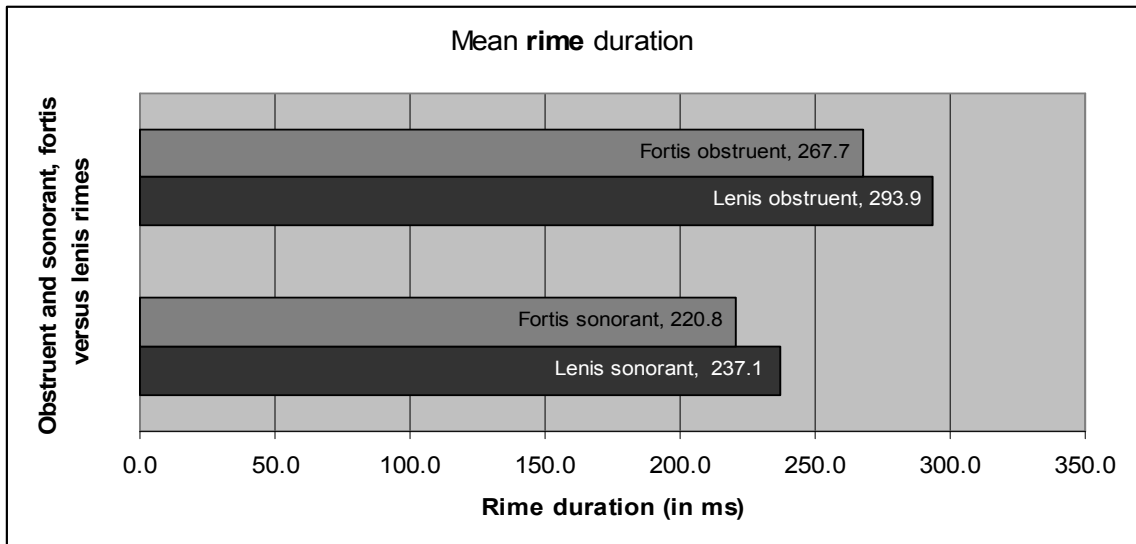


Figure 9. Mean rime duration of vowels /i/ and /a/ before both fortis/lenis and obstruent/sonorant consonants

The mean rime duration of 30 tokens each from six SFOZ speakers is enumerated in Table 15. Individual fortis and lenis consonant pairs are arranged adjacently.



Table 15. Mean rime duration and standard deviation of combined VC segments (in ms)

		stops					fricatives				
plus:		<b>p</b>	<b>b</b>	<b>t</b>	<b>d</b>	<b>k</b>	<b>g</b>	<b>s</b>	<b>z</b>	<b>ʃ</b>	<b>ʒ</b>
<b>/i/</b>	MN	234.8	257.1	233.2	245.7	197.5	247.9	278.8	311.8	283.0	247.2
	<i>StDev</i>	<i>51.0</i>	<i>51.9</i>	<i>45.0</i>	<i>47.7</i>	<i>39.1</i>	<i>47.6</i>	<i>54.4</i>	<i>70.4</i>	<i>55.1</i>	<i>56.9</i>
<b>/a/</b>	MN	252.7	284.0	261.9	286.7	227.4	246.7	311.5	348.5	-	-
	<i>StDev</i>	<i>47.0</i>	<i>54.9</i>	<i>69.0</i>	<i>67.2</i>	<i>42.5</i>	<i>61.2</i>	<i>65.8</i>	<i>64.5</i>	-	-

		affricates				nasals		laterals	
plus:		<b>ts</b>	<b>dz</b>	<b>tʃ</b>	<b>dʒ</b>	<b>n:</b>	<b>n</b>	<b>l:</b>	<b>l</b>
<b>/i/</b>	MN	279.8	286.8	284.1	316.7	200.8	213.4	183.4	204.9
	<i>StDev</i>	<i>67.3</i>	<i>85.4</i>	<i>54.3</i>	<i>75.4</i>	<i>47.3</i>	<i>50.7</i>	<i>44.9</i>	<i>62.9</i>
<b>/a/</b>	MN	339.8	352.5	298.0	320.9	242.4	256.1	256.7	265.9
	<i>StDev</i>	<i>71.4</i>	<i>83.0</i>	<i>67.6</i>	<i>65.7</i>	<i>49.5</i>	<i>46.8</i>	<i>61.6</i>	<i>50.8</i>

The row of mean values to the right of the phoneme /i/ is the rime duration in which the vowel nucleus is /i/. For example, the mean rime /ip/ is 234.8 milliseconds and the standard deviation of the thirty tokens is 51.0. The row of mean values to the right of the phoneme /a/ is the rime duration in which the vowel nucleus is /a/. There is a difference in rime duration in that a rime with the low back vowel /aC/ is longer than a rime with a high front vowel /iC/. This particular difference is not a correlate of the fortis/lenis contrast, but rather a phonetic realization of either front versus back vowels or perhaps high versus low vowels.

Figure 10 is a bar graph of the combined duration of fortis and lenis rimes. The vowel duration is the left-most segment; the consonant duration is the right-most segment. Observe that in a lenis rime the vowel duration is longer than the consonant duration (long vowel, short consonant). The reverse is true of fortis rimes: vowels are shorter and consonants are longer (short vowel, long consonant). The duration of the combined segments in the fortis rime is shorter than the duration of combined segments in the lenis

rime. The fortis/lenis sonorant rimes (nasal and lateral) at the bottom of the figure show the narrowest margin of durational difference. Yet, as mentioned above, even this contrast of least distinction is still significant, with a *p* value of .033.

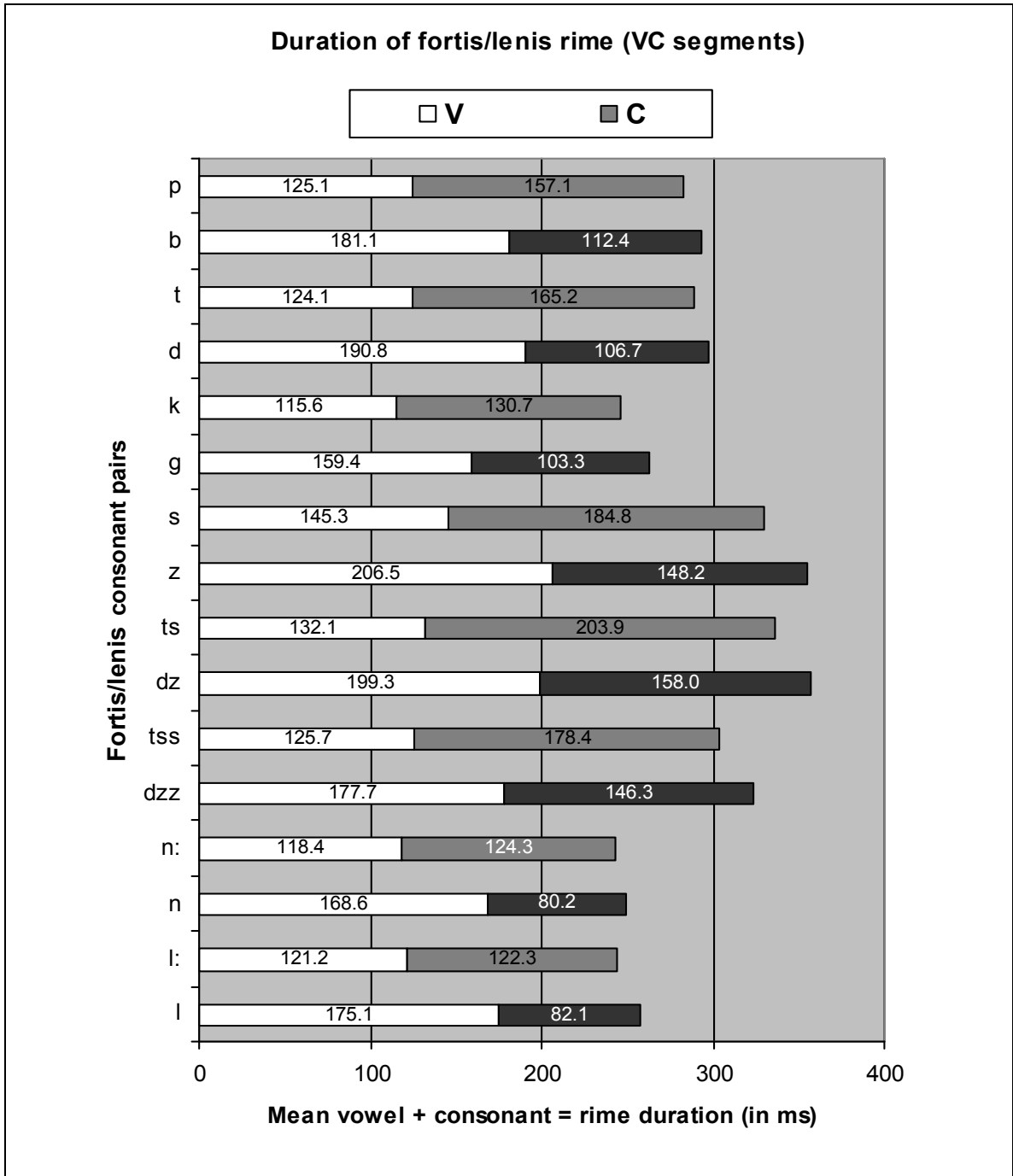


Figure 10. Interaction between the vowel and consonant in fortis and lenis rimes

The word-final data supports the hypothesis of long fortis and short lenis consonants and of shorter vowels before fortis consonants and longer vowels before lenis consonants. Contrary to my third hypothesis, however, a fortis rime is shorter than a lenis rime. The results are summarized in (29).

(29)		Fortis	Lenis
	Consonant duration	long	short
	Vowel duration	short	long
	Rime duration	shorter	longer

#### 4.1.2 Word-medial consonant duration

While the focus of this experiment is the fortis/lenis contrast in the word-final position, I also tested the three hypotheses concerning consonant, vowel, and overall rime duration with recordings involving the three word-medial fortis/lenis pairs (p/b, t/d, k/g). Six target words represent word-medial contrast between stops. Each word is repeated three times by six SFOZ speakers for a total of eighteen tokens. I list words used for the word-medial study in Table 16. Morpheme breaks are identified with a dash (-), stress is marked by ( ' ), and the laryngeal feature is represented by a glottal (?).

Table 16. Word-medial fortis/lenis pairs for analysis

		bilabial		alveolar		velar
stop	/p/	d-u'paʔa-n	/t/	j-tiʃ	/k/	w-kaʔa
		POSS-dad-1s		POT-measure		COMP-buy
	/b/	du'baʔan	/d/	j-dib	/g/	w-gaʔa
		'rope'		POT-finish		COMP-catch

The small sample of target words is due to extremely limited options given the constraints on distribution in SFOZ. Word-medial bilabial stops contrast in only one known noun pair: *dupaʔan* 'my dad', and *dubaʔan* 'rope.' The former word is polymorphemic, but the morphemes at the word edges are unlikely to affect the labial

stop /p/ in the middle; the latter is possibly polymorphemic as well, as the first syllable may stand on its own (*du?u* ‘rope’)<sup>49</sup>. This pair /p/ and /b/ is not controlled for identical morphemes (i.e. constituency) or grammatical category, but neither stop is adjacent to a consonant morpheme boundary.

While instances of an intervocalic fortis/lenis contrast are rare in nouns, the fortis/lenis contrast may be observed in verbs following aspect markers /j-/ ‘potential’ and /w-/ ‘completive’. Regardless of whether the onset of the verbs in Table 16 are analyzed as vowels /i/ and /u/ or consonants /j/ and /w/, the vowel-like quality of the segments allows us to measure the adjacent consonants /t/ and /d/, /k/ and /g/.

Results of the word-medial study are shown in Table 17. For each consonant, the mean consonant duration is from eighteen tokens (six speakers, three repetitions each) of each given in milliseconds.

Table 17. Consonant duration of word-medial fortis/lenis /p/, /b/, /t/, /d/, /k/, and /g/ (in ms) (N = 18 each)

Segment	Dur (ms)	St Dev	Dur (ms)	St Dev	Dur (ms)	St Dev		
/p/	98.4	24.0	/t/	127.8	26.8	/k/	109.7	31.0
/b/	75.9	21.6	/d/	76.7	17.7	/g/	74.6	28.5

Analysis of word-medial fortis/lenis stops /p/, /b/, /t/, /d/, /k/ and /g/ strongly support the correlation between fortis/lenis consonants and duration; the word-medial fortis consonant is longer than lenis. Furthermore, duration of both fortis and lenis segments is generally shorter in the word-medial position than in the word-final position.

An ANOVA analysis of the word-medial results confirms that the word-medial fortis/lenis contrast is statistically significant, as shown in Table 18.

---

<sup>49</sup> If *duba?an* ‘rope’ is two morphemes, it is an opaque compound. The gloss of the latter, *-ba?an*, is unknown.

Table 18. ANOVA: word-medial point of articulation and length (fortis/lenis).

ANOVA Duration		
point of articulation (poa)	F(2,102) = 3.30	$p = .041$
length (fortis/lenis)	F(1,102) = 55.29	$p = .000$
poa x length	F(2,102) = 2.88	$p = .061$ (ns)

The difference in length between word-medial fortis versus lenis consonants is highly significant, with a  $p$  value of .000. The effect of point of articulation on length of the consonant, that is whether the word-medial stop is a /p/, /t/, /or /k/, is also significant with a  $p$  value of .041.

The conclusions of the instrumental study of duration of fortis/lenis segments are:

- 1) Fortis consonant segments are significantly longer than their lenis counterpart.
- 2) Vowels preceding fortis consonants are significantly shorter than vowels preceding lenis consonants.
- 3) The lenis rime is longer than the fortis rime.

Given these three observations, it is clear that duration is a consistent and significant correlate of the fortis/lenis contrast in all consonant categories and manners of articulation.

## 4.2 Vowel quality

The fortis/lenis contrast in SFOZ is also linked to an impressionistic difference in the quality of the preceding vowels, particularly in high front vowels. In other words, the fortis/lenis consonant seems to condition vowel allophones, allowing for phonetic variation among speakers and tokens. The allophonic conditioning is more noticeable for high front vowels. For example, in the two minimal pairs shown in (30), both word-final fortis/lenis consonants are impressionistically voiceless. The lenis consonant is sometimes voiceless. It is represented here by adding the voiceless diacritic to the lenis symbol [z̥] in order to distinguish from the fortis phoneme /s/, which is always voiceless.

- (30) [nɪs] ‘water’                      [ɡɪt] ‘rainbow’  
       [nɪz] ‘dried corn’                [ɡɪd] ‘skin/leather’

The vowel /i/ is pronounced [i] preceding lenis consonants /z/ and /d/, and [ɪ] before fortis /s/ and /t/. Likewise, the phoneme /e/ is [e] preceding lenis /n/ and [ɛ] preceding fortis /n:/ as seen in example (31).

- (31) [tʃɛn] ‘rust’  
       [tʃɛn:] ‘belonging to’

Based on my perception, I hypothesize that in SFOZ vowels before fortis consonants will be pronounced in a more central vowel space than vowels preceding lenis consonants. The vowels preceding lenis consonants will be pronounced in a more extreme vowel space identified by lower first formants and higher second formants. If this hypothesis is supported, in addition to the correlate of vowel duration discussed in section 4.1, the correlate of vowel quality would also be a characteristic of the fortis/lenis contrast. I tested this hypothesis with data from six adult male speakers of SFOZ, using the target words in Table 11 on page 62 that were analyzed for word-final duration. Due to the nature of formant analysis, male and female speech could not be analyzed together; therefore I did not include the recordings from the one female speaker.

Segment boundaries for the vowel were determined as described in section 4.1.1.1. The speech analysis program *Praat* ([www.praat.org](http://www.praat.org)) was used for analysis of the acoustic data. For male speakers, the maximum formant value was set at 5000Hz. On occasion, this setting still produced an unusual formant reading. For example, SFOZ Speaker one has consistently low F1 values for the vowel /a/, in the high 400’s to 500’s instead of the expected values in the 600’s. The computer seemed to be reading a lower value and splitting the difference. In this situation I change the number of formants viewed from 5

to 6, and a more realistic F1 was given. I also change the number of formants viewed for a few tokens produced by Speakers two and three.

The formant value was identified by eyeballing the center point of the vowel, and then selecting at least three cycles to the left and three cycles to the right, to include approximately the middle fifty percent of the vowel. By analyzing a middle portion, the mean formant values were less skewed by transitions into and out of the vowel. Some speakers occasionally pronounced nasalized vowels near nasals, which interfered with formant values. For this reason I intentionally did not use a script to identify the exact fifty percent because I wanted to avoid any influence palatalization and nasalization may have had on formant values. Also, unpredictably, some data showed nasalized or creaky vowels even when no nasal or glottal is apparent in the isolated CVC word. In these situations I selected a smaller section of the vowel to avoid effects of creakiness and antiformants.

The result of the study is that the fortis/lenis contrast for both obstruents and sonorants in the coda position correlates with the quality of the preceding vowel as shown in Table 19.

Table 19. Mean value of F1 and F2 before fortis/lenis obstruents and sonorants (in Hz)

		Preceding obstruents					Preceding sonorants				
		F1			F2		F1			F2	
		N	MN	<i>St Dev</i>	MN	<i>St Dev</i>	N	MN	<i>St Dev</i>	MN	<i>St Dev</i>
/i/	fortis	214	341	56.2	1995	190.6	60	395	57.1	1704	191.8
	lenis <sup>50</sup>	179	311	49.2	2176	184.9	60	312	51.8	2125	150.3
/a/	fortis	180	602	65.5	1504	115.3	60	646	69.5	1409	96.3
	lenis	180	639	79.4	1490	79.2	60	650	77.3	1450	93.8

Before a lenis consonant, the high front vowel /i/ is high and tense, reaching a more extreme point of pronunciation. The first vowel formant is lower and the second formant is higher before a lenis consonant than before a fortis consonant. Taking an example from the data in Table 19, the mean F1 value of /i/ before a lenis obstruent is 311 Hz, and the mean F2 is 2176 Hz, that is, phonetic [i]. In contrast, the high front vowel /i/ before a fortis consonant has a slightly higher first formant (341 Hz) and slightly lower second formant (1995 Hz), resulting in a more centralized vowel, phonetic [ɪ].

Vowel quality may be conditioned by whether the following consonant is voiced or voiceless. However, in SFOZ, the contrast in vowel quality before fortis/lenis consonants occurs before voiceless fortis stops (/p/, /t/, /k/), as well as before voiced fortis sonorants (/l:/, /n:/). Figure 11 presents the fortis/lenis vowels in two general places of articulation. The high front /i/ before lenis sonorants is in the upper left corner, while the high front lax allophone [ɪ], conditioned by the following fortis consonant, is lower and further to the right, representing a more central vowel space. The contrast between vowel /i/ before both fortis/lenis obstruents and fortis/lenis sonorants is highly significant.<sup>51</sup> The low back

<sup>50</sup> The lenis target word *niz* ‘water’ has an unusually high first formant, perhaps due to the nasal onset. This affected the mean value, bringing it closer to the F1 value of /i/ before fortis consonants.

<sup>51</sup> Both *t*-tests have *p* values of .000.



vowel /a/, with less of a distinction, still has a fortis/lenis contrast in either F1 or F2, but not both. Before obstruents, the F1 difference for /a/ is significant,<sup>52</sup> but the F2 difference is not.<sup>53</sup> The pattern is reversed before sonorants: The F1 difference for /a/ is not significant,<sup>54</sup> but the F2 contrast is.<sup>55</sup> The mean formant values (in Hz) of vowels /i/ and /a/ before fortis/lenis obstruents and sonorants are plotted in Figure 11.

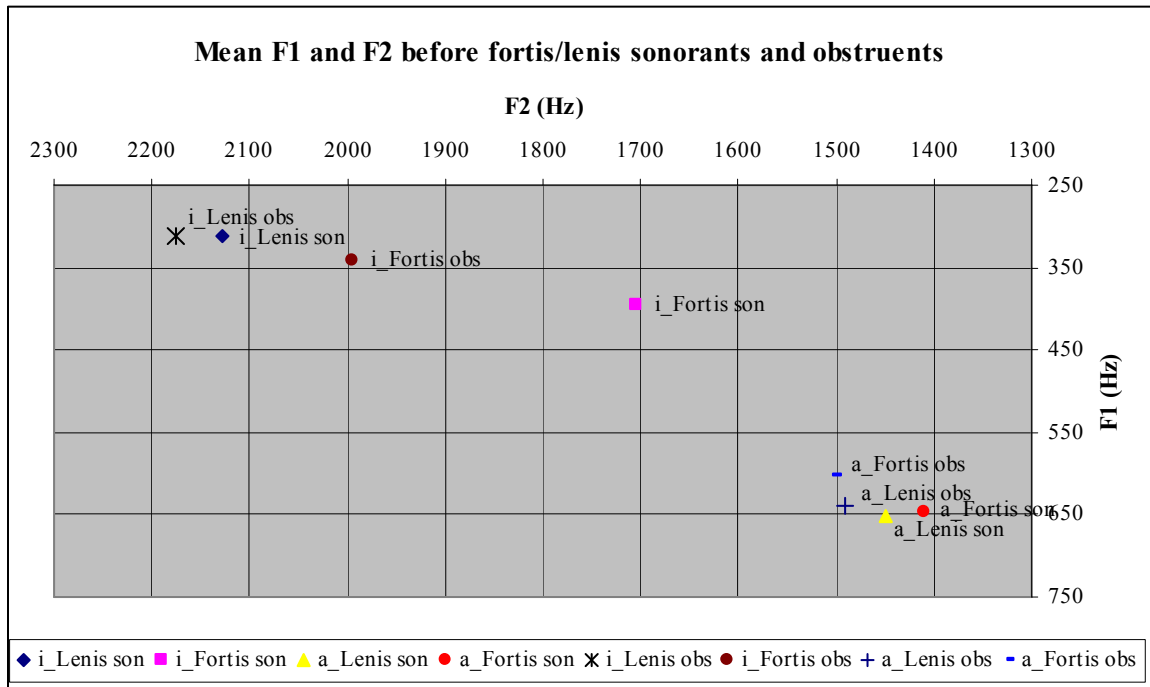


Figure 11. Formant values for high front and low back vowels before obstruents and sonorants

Pronunciation of the high front vowel /i/ is one characteristic of the fortis/lenis consonant contrast. The nature of /a/ does not lend itself to significant movement to a more central vowel space before fortis consonants. Nonetheless, the quality of the low back vowel /a/, while less obvious, still correlates with the fortis/lenis consonant contrast.

<sup>52</sup>  $t(345) = 4.78; p(\text{two tail}) = .000$

<sup>53</sup>  $t(189) = .30; p(\text{two tail}) = .76$

<sup>54</sup>  $t(117) = .33; p(\text{two-tail}) = .74$

<sup>55</sup>  $t(118) = 2.38; p(\text{two-tail}) = .019$

Unstressed vowels preceding fortis/lenis consonants do not follow the same pattern of change in formant values or duration. Only stressed vowels show consistent contrast.

The mean formant values indicate a statistically significant difference between vowels before fortis and lenis consonants. The data supports my hypothesis that a consistent difference in vowel quality correlates with the fortis/lenis contrast. Further analysis of all vowel allophones [i, ɪ, e, ε, æ, u, ʊ, o, a] preceding fortis and lenis consonants would be useful for testing the hypothesis that vowels [ɪ, ε, ʊ] are allophones of the phonemes /i, e, u/ in syllables closed by a fortis consonant or a glottal.

### **4.3 Voicing and voice onset time (VOT)**

Voicing of a segment, where voicing begins and ends, is a cue to the fortis/lenis consonant contrast in many Zapotec languages. Fortis obstruents are described as voiceless, and lenis consonants fluctuate between voiced and voiceless. In SFOZ, the voicing contrast is less salient at word edges, often making it difficult for Zapotec writers to distinguish between stops /k/ and a /g/, or fricatives /s/ and a /z/ in the word-final position.<sup>56</sup> To determine if voicing is a correlate of the fortis/lenis contrast, this instrumental study investigates two elements of voicing: 1) VOT, or the voicing at the onset of the following vowel, is discussed in this section, and 2) voice tail, or voicing at the onset of the consonant (at the consonant closure).

VOT, or the time it takes for speakers to resume voicing after a stop, is more specifically defined as “a measure of the time between a supraglottal event and the onset of voicing; for stops, VOT is the interval between release of the stop (usually determined acoustically as the stop burst) and the appearance of periodic modulation (voicing) for a following sound” (Kent and Read 2002:306).

---

<sup>56</sup> SCXZ maintains the voicing distinction lost at word edges in SFOZ.

The onset of voicing may begin at various stages of the consonant articulation. According to Ladefoged (1971), voice onset has phonetic, non-binary oppositions: “voicing throughout articulation, voicing during part of articulation, voicing starts immediately after, voicing starts shortly after, voicing starts considerably later.” If voicing starts at the exact moment the consonant is released (at the stop burst), the VOT is 0 milliseconds. If the onset of voicing is after the stop burst, the VOT is positive. If voicing begins before the consonant is released, the VOT is negative. “Smaller (more negative) VOT measures will thus correspond to earlier transition from voiceless to voiced during the articulation of a semi-voiced fricative” (p. 408).

For speakers of SFOZ, VOT is relevant to the fortis/lenis distinction in obstruents if the fortis consonants have a longer delay between the stop release and the resumption of sonorance (i.e. later VOT) than do lenis consonants. At best, however, VOT could only be a correlate for fortis obstruents, and not a unitary characteristic of the fortis consonant category, since fortis sonorants are voiced. Furthermore, while lenis consonants are sometimes voiced, the devoicing of word-final segments makes it unlikely that VOT is a salient characteristic of the fortis/lenis contrast (in this case, the resumption of sonorance in the vowel onset of the following word). Therefore, the hypothesis tested here is that, contrary to the VOT patterns in other Zapotec variants, in word-final position VOT will not be a significant correlate of the fortis and lenis consonant segments in SFOZ.

#### *4.3.1 Words used – word-final VOT*

Although word-final, utterance-medial consonants present unique issues in voicing and voice onset, the word-final position offered the most extensive contrast inventory for study. Words used for investigation of VOT, listed in Table 20 include three word-final

stop pairs (/p/ and /b/, /t/ and /d/, /k/ and /g/) in two vowel environments (preceding vowels /i/ and /a/).

Table 20. Word-final stops /p/, /b/, /t/, /d/, /k/, /g/ following /i/ and /a/

	bilabial		alveolar		postalveolar	
/i/	/p/	nìp ‘cane’ n.	/t/	git ‘rainbow’ n.	/k/	ʃik ‘shoulder’ n.
	/b/	gìb ‘iron’ n.	/d/	gìd ‘leather’ n.	/g/	(ʒìg) ‘bowl’ n. Sp.jicara
/a/	/p/	dʒàp ‘has’ HAB.v	/t/	gjàt ‘tortilla’ n.	/k/	blák ‘leaf’ n.
	/b/	dʒab ‘swallows’ HAB.v	/d/	dǎd ‘sir’ n.	/g/	blág ‘how much’ Adv.

#### 4.3.2 Procedures – word-final VOT

Following Avelino (2001): “VOT was measured from the point of release of the stop (starting at the burst and ending at the onset of voicing) to the onset of F2 and higher formants in the following vowel as seen in a wideband spectrogram and supplemented with observation of the waveform.” VOT was measured first looking broadly at the spectrogram, then more closely at the waveform to find the closest positive zero wave crossing. The first glottal pulse seen in the spectrogram was used to mark the beginning of voicing.

For consonants that have a discernible stop and a resumption of sonorance it was possible to measure the time between the stop release and the beginning of sonorance in milliseconds. In cases in which VOT measurements are not possible—whether due to a pause, the occurrence of a glottal, or a creaky vowel between the consonant and vowel onset—a value of -999 was assigned to indicate an impossible measurement, and the token was excluded from the statistical analysis.<sup>57</sup> Negative VOT in this study usually reflects voicing for the complete duration of the consonant. The negative VOT, therefore, is not

---

<sup>57</sup> One challenge to segmentation I encountered was laryngeal interference that preempted identification of the VOT. Occasionally voiced stops released into the onset of a glottal pulse, either with clear voicing during the pulse or with voiceless creaky pulses.

representative of an early onset of voicing, but of no end to voicing from the previous vowel. That is to say, a negative VOT value for SFOZ data usually reflects a completely voiced obstruent for which the onset of voicing is indistinguishable from the end of the voice tail, and does not necessarily represent the early onset of voicing as a negative VOT is typically understood.

#### 4.3.3 Results – word-final VOT

Data in Table 21 are mean VOT values (in milliseconds) of word-final fortis/lenis stops /p/, /b/, /t/, /d/, /k/, and /g/ following vowels /i/ and /a/ of the nucleus, and preceding /a/ in the following word. The upper section in the table details VOT after /i/, and the lower section after /a/. The data include only positive VOT values, as negative VOT values would have skewed the mean value. Because some tokens had negative VOT, or were otherwise not applicable, the number of tokens (N) is reported in the column to the left of the mean (MN) VOT. To the right of the mean value is the standard deviation (StDev).

Table 21. VOT of word-final stops (in ms)

Stop	N	MN	St Dev		N	MN	St Dev		N	MN	St Dev	after:
p	19	25.8	21.7	t	21	27.8	13.4	k	23	34.4	10.4	i
b	13	14.6	13.4	d	17	29.6	13.1	g	16	24.9	21.8	
p	18	24.3	15.2	t	24	25.1	9.9	k	21	42.0	46.8	a
b	13	15.5	12.9	d	15	24.4	12.1	g	21	30.5	29.2	

Of the positive VOT for both fortis and lenis consonants, fortis VOT is usually longer than the lenis VOT. For example, before /i/, the mean VOT of fortis /p/ is 25.8 ms while the mean VOT of lenis /b/ is 14.6 ms. However, that is not always the case. Fortis/lenis /t/ and /d/ have very similar VOT, and /d/ before /i/ has a longer VOT than fortis /t/ in the

same environment.<sup>58</sup> The high standard deviations attest to the wide variation in VOT for both fortis and lenis consonants in the word-final/utterance-medial position.

In addition to the mean positive VOT in Table 21, lenis stops occasionally have negative VOT. (Fortis VOT is always positive.) Place of articulation affects whether VOT is positive or negative for lenis stops. Of the tokens available for analysis, in addition to the twenty-six /b/ tokens with positive VOT (thirteen before /i/ plus thirteen before /a/), the lenis bilabial had seventeen fully-voiced tokens with ‘negative’ VOT. Alveolar /d/ had nine tokens with negative VOT. Voicing (or negative VOT) was more common for lenis bilabials than for lenis alveolars or velars. Lenis velar phoneme /g/, for instance, had only three tokens with negative VOT (and thirty-seven with positive VOT). Ladefoged (2003:98) identifies a relationship between voicing and place of articulation: “It is generally true that VOT for stops in the front of the mouth (/p/ and /b/) are shorter [and] stops that are made further back in the mouth usually have a longer VOT.”

To summarize, a fortis consonant in the word-final position has a zero or positive VOT. A lenis consonant may have a negative VOT (is fully voiced), or a positive VOT. Positive VOT for a fortis consonant is usually later than a positive VOT for a lenis consonant. A lenis consonant is more likely to have a negative VOT if it is in the front of the mouth (/b/) than if it is in the back of the mouth (/g/). This being said, there remains a wide variation in the VOT of both fortis and lenis consonants in the word-final/utterance-medial position; data show more of a trend than a statistically significant contrast. While VOT in this environment sometimes cues the fortis/lenis contrast, it is not a reliable correlate.

---

<sup>58</sup> The following vowel is unstressed in the frame making the VOT contrast less consistent. The word-final/utterance-medial consonant will always be unstressed because of the patterns of stress placement in SFOZ.

#### 4.3.4 Words used – word-medial VOT

While the focus of this study is the fortis/lenis contrast in the word-final position, I present here results of a smaller study of VOT in the word-medial position. I predict that, different from VOT on word edges in SFOZ, VOT will be a more salient cue to the fortis/lenis contrast in word-medial position. To test VOT of word-medial segments, I analyze a subset of three fortis/lenis pairs (p/b, t/d, k/g). Table 22 shows the fortis/lenis target words selected for analysis of VOT for word-medial stop pairs p/b, t/d and k/g.

Table 22. Word-medial stops /p/, /b/, /t/, /d/, /k/, /g/

	bilabial		alveolar		postalveolar				
stops	/p/	dupaʔn	‘my dad’	/t/	jtix	‘may measure’	/k/	wkaʔa	‘bought’
	/b/	dubaʔn	‘rope’ n.	/d/	jdib	‘may finish’	/g/	wgaʔa	‘caught’

Four of the words containing word-medial fortis/lenis pairs also contain glottalized vowels following the consonant in focus. While glottalization on vowels is avoided when considering fortis/lenis pairs in other word positions, the only bilabial and velar pairs with word-medial fortis/lenis contrast also contained a glottal.

The ‘word-medial’ segments in Table 22 are in a unique vowel environment: The target consonant is before a stressed vowel (which allows a more typical observation of VOT) and after an unstressed glide. While the alveolar and velar pairs are not a truly word-initial or truly word-medial environment (glides /w/ and /j/ are analyzed as consonants), data from these pairs support the word-final correlation of fortis/lenis with VOT.

#### 4.3.5 Results – word-medial VOT

Word-medial fortis stops always have a positive VOT. VOT for lenis stops, on the other hand, is sometimes positive and sometimes negative. Since VOT for all eighteen fortis tokens is always positive, the overall mean values and standard deviations for each

stop are reported in Table 23. Mean VOT values for lenis stops, on the other hand, are reported in three ways. First, the left-most lenis mean values include all tokens. The standard deviations are high because the averages include both positive and negative VOT. To the right are mean values of only positive VOT, then only negative VOT. The mean negative VOT for lenis is approximately the mean duration of the lenis tokens, as mentioned in section 4.3.3 and discussed further in section 4.3.

Table 23. VOT of word-medial /p/, /b/, /t/, /d/, /k/ and /g/

Fortis: (all VOT)				Lenis:	(all VOT)			(+ VOT)		
	N	MN	<i>StDev</i>		N	MN	<i>StDev</i>	N	MN	<i>StDev</i>
/p/	18	18.6	9.7	/b/	18	-42.5	37.1	6	16.8	11.7
/t/	18	27.0	8.5	/d/	18	-35.4	49.4	6	31.6	9.2
/k/	18	51.2	13.1	/g/	18	11.6	41.0	15	28.4	14.2

The overall mean VOT values are shorter for lenis and longer for fortis. The variability in VOT for lenis stops suggests that some speakers do not use VOT to cue the fortis/lenis contrast. For instance, all VOT values for non-final consonants as pronounced by Speakers one and four are positive—both fortis and lenis. Speakers two, three, and six have negative VOT values (completely voiced) for /b/ and /d/, but positive VOT for /g/. For Speaker five, all lenis consonants (/b/, /d/, /g/) are fully voiced.

Word-medial fortis consonants correlate with positive VOT. Compared to VOT of word-final/utterance-medial consonants, both positive and negative VOT values for word-medial consonants are more extreme, or distinct, before a stressed nucleus. Particularly, positive VOT values of both word-medial fortis and lenis consonants are longer than the VOT of word-final consonants. Lenis consonants are more susceptible to voicing after a glide and before a stressed nucleus. Voicing duration is longer at the onset of the consonant, and shows a key distinction between the patterns of voicing and voice onset time (VOT).



An ANOVA of word-medial point of articulation, length (fortis/lenis), and VOT illustrate the significance of the relationship of VOT and place of articulation, and VOT and whether a consonant is fortis/lenis. Both place of articulation and the fortis/lenis contrast significantly correlate with VOT, with  $p$  values of .000.

Table 24. ANOVA: word-medial place of articulation, length (fortis/lenis), VOT

ANOVA	VOT		
poa		F(2,102) = 17.271	$p = .000$
length		F(1,102) = 71.565	$p = .000$
poa x length interaction		F(2,102) = 1.323	$p = .271$ (ns)

#### 4.3.6 Discussion/conclusion – VOT in all positions

In both word-final and word-medial positions, both fortis and lenis consonants may have positive VOT values. The contrast is that fortis VOT values are always positive while lenis consonants are inconsistent: they are sometimes voiceless with a positive VOT and sometimes completely voiced with no break in voicing and no measurable VOT.

The fortis consonant /t/ is consistently voiceless, with little or no voice tail, and a positive VOT. Lenis word-initial /d/ varies in its phonetic realization in three basic ways: fully voiced with no complete closure (no stop burst), partially voiced due to voice tail (section 4.4), and voiceless aspirated with a positive VOT value sometimes as long as the VOT of its fortis counterpart /t/.<sup>59</sup>

VOT is a characteristic of the fortis/lenis contrast in obstruents only. The analysis of VOT reveals that VOT patterns only sometimes cue the fortis/lenis obstruent contrast. Fortis VOT values are always positive, with little or no voice tail from the preceding vowel. Lenis consonants have inconsistent VOT and regularly have long voice tails and

---

<sup>59</sup> Incidentally, for a given speaker, the /t/ /d/ contrast is more readily observed with VOT values. However, the phonetic realization of lenis /d/ is inconsistent and fluctuates (e.g. tokens /d/ SM6.21b, and /t/ SM1.19a have similar VOT, but differ in vowel duration, consonant duration, and voice tail durations).

less complete closure (i.e. no stop burst). However, this VOT contrast does not extend to the fortis/lenis sonorant pairs, and therefore cannot be a primary correlate of the fortis/lenis consonant categories.

#### 4.4 Voice tail

In section 4.3 I raised a problem in identifying the VOT due to voicing that continues from the preceding vowel into the consonant closure. After initial data analysis the source of voicing of lenis consonants was usually unclear, whether it was a continuation of the preceding vowel, or from the onset of the consonant. Data samples of intervocalic /d/ and /g/<sup>60</sup> reveal that the voicing of lenis consonants is more often due to continued voicing from the preceding vowel, and not an early onset of voicing on the consonant (i.e. negative VOT).

The term ‘voice tail’ as used here refers to voicing at the onset of the consonant beginning closure. The source of voicing is the preceding vowel. Often in fluid speech, the voicing never stops from the preceding vowel to the following one – and this is speaker dependent variation. For example, in the token (*dik* ‘very small’) pronounced by Speaker five (SM5.8b), the consonant /d/ is completely voiced with an apparent VOT of -112.4 ms, the complete duration of the consonant. It cannot be determined if voicing is from the previous vowel, or from an early voice onset of /d/. There is a continuation of voicing pulses, as well as a transition of 15 ms after the burst which looks much like VOT. Thus it is unclear if there is a long voice tail or negative VOT, and whether the VOT value is -112.4 ms or 15 ms. This is a common occurrence; only three tokens have a negative VOT value which is less than the full duration of the consonant.<sup>61</sup>

---

<sup>60</sup> I.e. tokens/wave files ‘125. idib SM2b.wav’, ‘125. idib SM3c.wav’, and ‘65. uga’ SM6ab.wav’

<sup>61</sup> These three tokens are shown in wave files SM6.105a, SM2.8b, XM1.21a.

Therefore, one of the distinguishing differences between /t/ and /d/ is not VOT and the onset of voicing, but rather voice tail, the continuation of voicing from the preceding vowel into the consonant. The voice tail from vowels preceding a fortis /t/ quickly ends, while the voicing of lenis /d/ is not necessarily due to early or negative VOT, but is more likely due to the long voice tail from the preceding vowel (e.g. /d/ in the token *dik* ‘very small’ SM6.8b). In this example, /d/ in *dik* has a VOT of 10.5 ms, but the prevoicing is 39.5 ms, giving the impression of a voiced consonant, even while there is a positive VOT.<sup>62</sup>

As a result, I hypothesize that voice tail (voicing from the preceding vowel) is relevant to the fortis/lenis consonant contrast. My purpose in this study of voice tail is to discover if the percentage of voicing during consonant closure is significantly different for fortis and lenis consonants.

#### 4.4.1 Words used – voice tail

Table 25 lists the target words selected for analysis of voice tail for word-final stop pairs /p/ and /b/, /t/ and /d/, /k/ and /g/ following the vowels /i/ and /a/.

Table 25. Word-final stops /p/, /b/, /t/, /d/, /k/, and /g/ analyzed for voice tail

bilabial		alveolar		postalveolar	
/p/	nip ‘cane’ n.	/t/	git ‘rainbow’ n.	/k/	ʃik ‘shoulder’ n.
/b/	gib ‘iron’ n.	/d/	gid ‘leather’ n.	/g/	(ʒig) ‘bowl’ n. Sp. <i>jitara</i>
/p/	dʒap ‘has’ HAB.v	/t/	gʒat ‘tortilla’ n.	/k/	blak ‘leaf’ n.
/b/	dʒab ‘swallows’ HAB.v	/d/	dad ‘sir’ n.	/g/	blag ‘how much’ Adv.

---

<sup>62</sup> It is uncertain if the VOT is -130.4ms or 14.5ms. In this situation, I identify the voice tail as -130.4 ms and VOT as 14.5ms. While common for /d/, the phoneme /t/ usually does not allow this type of voice tail.

#### 4.4.2 Procedures – voice tail

Voice tail is segmented in milliseconds from the end of the vowel/beginning of the consonant up to the end of voicing, indicated by the fading of periodic waves and the end of the voice bar at the bottom of the spectrogram. The voicing pulses in Praat confirmed the duration of voicing in consonant segments.<sup>63</sup>

Parallel to the voice tail issue is whether the type of consonant closure is a stop [b] or a fricative [β]. SFOZ fortis/lenis consonants, like those in Yateé Zapotec, may contrast in the manner of articulation. A fortis stop always has complete closure, including a stop burst. In contrast, while usually pronounced with complete closure and a stop burst, the lenis stop in SFOZ may be pronounced as a fricative. For example, there are instances in which it appears that the lenis /d/ does not actually stop (21. dad SM1a ‘man’). For this reason, I observed both the duration of the voice tail and the closure type of the fortis/lenis stop segments.

In instances with voice tail, there may be regular formant lines throughout the duration of the consonant, unlike a typical stop. In cases where the stop is produced as a fricative, there is little high frequency noise and no significant darkening of the spectrogram, a typical characteristic of fricatives. There were only a few instances of word-final stops pronounced as fricatives, by only a few speakers. The pilot study of ‘word-medial’ consonants shows similar results, with a greater tendency for lenis stops to be produced without complete closure. Only lenis stops may be produced as fricatives; fortis stops are always produced with complete closure.

---

<sup>63</sup> Nonetheless, I ignore the blue voice pulses in the few instances of *tib* ‘one’ and *tap* ‘four’ where the voicing pulses are in the middle of ‘voiceless’ /t/. (SM6.7ab, SM6.19b). The only three instances are from the same speaker.

#### 4.4.3 Results – voice tail

Measurement of voice tail supports the hypothesis that it is a characteristic of the fortis/lenis obstruent contrast in word-final position, more consistent than VOT. Nonetheless, the results in Table 26 show an unexpected pattern of voice tail in word-final stops. Fortis stops allow longer actual voice tail than lenis stops. Note in Table 26 that the mean duration of voice tail on fortis /t/ is 61.9 ms, while the mean duration of voice tail on lenis /d/ is 47.6 ms.<sup>64</sup>

Table 26. Voice tail on word-final fortis/lenis consonants (in ms)

	N	<b>MN</b>	<i>StDev</i> <sup>65</sup>	<b>%</b>	<i>StDev</i>
p	40	<b>52.1</b>	<i>36.7</i>	<b>0.41</b>	<i>0.34</i>
b	50	<b>48.7</b>	<i>24.4</i>	<b>0.53</b>	<i>0.37</i>
t	26	<b>61.9</b>	<i>36.4</i>	<b>0.45</b>	<i>0.30</i>
d	41	<b>47.6</b>	<i>26.5</i>	<b>0.56</b>	<i>0.37</i>
k	37	<b>38.6</b>	<i>31.2</i>	<b>0.32</b>	<i>0.25</i>
g	48	<b>36.3</b>	<i>25.8</i>	<b>0.42</b>	<i>0.31</i>
ptk	103	<b>49.7</b>	<i>35.6</i>	<b>0.39</b>	<i>0.30</i>
bdg	139	<b>44.1</b>	<i>26.0</i>	<b>0.50</b>	<i>0.35</i>

The voicing contrast between fortis and lenis stops, therefore, is in relation to the duration of the consonant. A fortis stop has a lesser percentage of voicing than lenis stops. For example, in Table 26 the mean voice tail of fortis /t/ is forty-five percent of the mean closure duration of /t/. In contrast, the voice tail of lenis /d/ is fifty-six percent of

---

<sup>64</sup> Not evident from the voice tail data is the fact that more fortis stops than lenis stops have voice tail durations of 0 ms. Lenis stops rarely have a voice tail of zero. For example, the phoneme /d/ allows an extended voice tail from the preceding vowel while /t/, with rare exceptions, does not.

<sup>65</sup> The high standard deviation is due in part to the variation of voicing of the consonants (i.e. the range of voice tail from /i/ into /p/ is 0-142 ms; some tokens had no voice tail, while another token had a voice tail of 142 ms). The standard deviation is also due, in large part, to the variation among speakers. Speaker six allowed more voice tail on word-final consonants.

the consonant duration. Voicing during consonant closure is thirty-nine percent of fortis stops (/p/ /t/ /k/), but fifty percent of lenis stops (/b/ /d/ /g/) – a statistically significant contrast ( $t(234) = 2.70$ ;  $p$  (two-tail) = .007). Figure 12 illustrates the percent of voicing in fortis/lenis stop pairs, followed by the combined value of all fortis (/p/ /t/ /k/) versus lenis (/b/ /d/ /g/) stops.

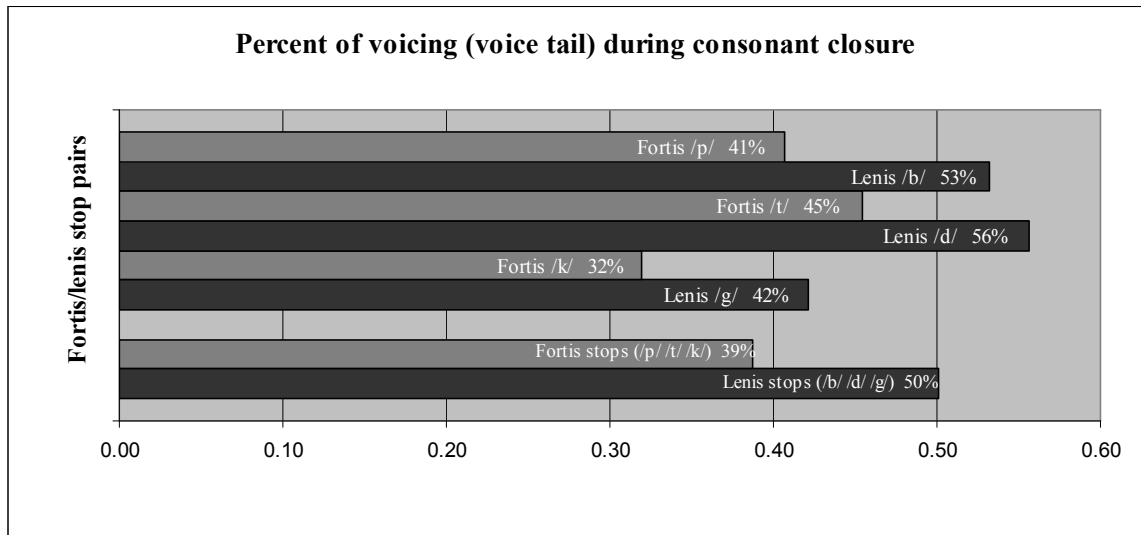


Figure 12. Percentage of consonant duration with voice tail

#### 4.4.4 Discussion and conclusion

In the environment provided by the given frame, word-final fortis/lenis consonants are always intervocalic. Notably, voicing from the preceding vowel may stop before fortis consonants, and /p/, /t/ and /k/ have positive VOT, but voicing from the preceding vowel usually continues into lenis /b/, /d/ and /g/, which fluctuate from completely voiced to voiceless aspirated. This voice tail contrast is a consistent characteristic of fortis/lenis. While both /t/ and /d/ may have similarly long voice tail and long, positive VOT, they maintain a distinction in that /d/ consistently allows longer voice tail in relation to the duration of the consonant closure; thus for lenis stops, more of the total consonant has

voice pulses.<sup>66</sup> The impressionistic voicing contrast of fortis/lenis segments, therefore, is mostly due to voicing from the preceding vowel in relation to the consonant duration. The results of the voice tail study show two patterns. Actual duration of voice tail is longer on fortis stops. However, considering the relationship between voice tail and the total duration of the consonant, fortis stops have a smaller percent of voice tail than lenis stops.

#### 4.5 Intensity

As discussed in section 1.2.1, another way the fortis/lenis contrast in Zapotec languages is often described is in terms of differences in articulatory force, meaning that fortis consonants are produced more strongly than lenis. This study tests the hypothesis that intensity measurements of fortis and lenis sonorants (/n/ and /n:/, /l/ and /l:/) will show a contrastive difference in acoustic force, evidence which would point to greater articulatory force.

The term ‘articulatory force’ implies greater muscle tension of the articulators (e.g. glottal, tongue, lips) applied to produce fortis, or strong, consonants. A direct test of this hypothesis would be to measure actual muscle movement and tension during the production of contrasting consonants, but that is beyond the scope of this experiment.

Perhaps independently, a second use of the term ‘force’ refers to greater airflow through the oral passage caused by greater pulmonic effort, resulting in greater build-up of pressure during fortis stop closure and greater intensity measurements at the release of the consonant. A direct test of this pulmonic pressure would require a capture of the air released noting the displacement of water (cm<sup>3</sup>).

---

<sup>66</sup> As an exception, the typically voiceless word-medial /t/ in *itijf* ‘will.measure’ XM2.124a, allows the voice tail to continue during closure up to the burst. However, there is a break in voicing that starts at the burst and continues for 14.5ms until the onset of the vowel.

Direct testing of the articulatory and pulmonic effort of a sound presents instrumental challenges. However, indirect correlates of this effort, amplitude and intensity, can be measured quite easily. Segment amplitude (wave magnitude or loudness) and intensity (the root mean square (RMS) of the wave amplitude or acoustic force) point to greater pulmonic factors. Intensity is a derivative of the amplitude and the pressure level of a sound or acoustic wave in a pulmonic sense, and henceforth will be referred to simply as intensity. Greater acoustic force, indicated by intensity measurements, serves as an indirect means for identifying an increase in consonantal pressure, and could be an indirect indicator of greater articulatory tension. For this reason, this experiment seeks to determine if there is any significant difference in the intensity, or sound pressure, of fortis/lenis sonorants.<sup>67</sup>

#### *4.5.1 Words used – intensity of sonorants*

The scope of the experiment is narrowed to word-final sonorants in the stressed position of a frame. Sonorants were chosen because there is no contrast in voicing. As such, the intensity study is controlled for voicing. For sonorants, voicing does not contribute to the fortis/lenis contrast, since all sonorants in SFOZ are voiced. Obstruents were avoided in order to control for voicing that naturally correlates with amplitude differences. Having already established that fortis sonorants are significantly longer than their lenis counterparts, this exploratory experiment aims to discover if greater intensity for fortis sonorants also contributes to the distinction.

As an initial test of intensity differences, I started with a pilot study of the fortis and lenis laterals /l:/ and /l/ and nasals /n:/ and /n/ listed in Table 27. Note that two of the

---

<sup>67</sup> A spectral tilt analysis is another option for future analysis of the fortis/lenis intensity contrast.



contrastive pairs do not belong to the same grammatical category, and have different tones.

Table 27. Fortis/lenis sonorants analyzed for intensity

	l	l:	n	n:
/a/	gǎl	gàl:	mbán	mbán:
	‘POT.born’	‘twenty’	‘STAT.alive’	‘STAT.quick’
/i/	pʃíl	pʃíl:	dzìn	wdzín:
	‘sugar cane’	‘spark’	‘honey’	‘COMPL.arrived’

#### 4.5.2 Procedures - intensity

Intensity measurements are taken from data recordings of six SFOZ speakers. The first study includes five repetitions each, for a total of thirty tokens. The second study includes two tokens of each word, for a total of twelve repetitions of each target segment. In spite of descriptions to the contrary (Hopkins 1995), the expected result of this experiment is that intensity will not be a contrastive correlate of fortis/lenis sonorant contrast; fortis /n:/ and /l:/ are expected to have intensity equal to their lenis counterparts, because I do not perceive them to be either louder or more intense. To test this hypothesis, intensity readings are taken from .wav files opened in Praat, in three ways: the average intensity across the duration of the sonorant, the minimum point of intensity (extrapolated by Praat, the most extreme contrast from the amplitude peak of the surrounding vowels), and midpoint intensity (approximated).

I noted the mean intensity measured by Praat (in dB) over the complete duration of the sonorant for each repetition of the token. Duration of the sonorants is determined following the same procedures for segment boundaries described in 4.1, from which point I ran a Praat script to identify the point of minimum intensity of the target segment.<sup>68</sup>

---

<sup>68</sup> The minimum point of intensity, instead of the peak, was chosen as the greatest point of contrast

Also, I noted the nearest approximation of the midpoint intensity for each repetition. Then both a *t*-test and an ANOVA were run on the mean values for significance.

#### 4.5.3 Results of sonorant intensity

The study including all the words in Table 27 show both fortis /n:/ and /l:/ to be slightly more intense than their lenis counterparts, but with mixed results. Given a total of 60 tokens each phoneme, the mean intensity of fortis /n:/ and lenis /n/ following both /i/ and /a/ show a significant contrast ( $t(117) = 2.09; p = .039$ ). The contrast between fortis /l:/ and lenis /l/, however, is not significant ( $t(113) = .95; p = .347$ ).

Table 28. Mean intensity results of fortis/lenis sonorants following i/a (in dB)

		<i>N</i>	<i>MN</i>	<i>StDev</i>			<i>N</i>	<i>MN</i>	<i>StDev</i>
mbán:	/n:/	60	62.7	4.7	gál:	/l:/	58	63.2	4.1
wdzín:	/n:/	60	60.8	5.1	pʃíl:	/l:/	60	62.5	3.4
mbán	/n/				gál	/l/			
dzín	/n/				pʃíl	/l/			

Questioning trends shown by the introductory study, I then analyzed a carefully controlled sample of just two sonorant minimal pairs, controlling for tone and word category. Word-final laterals (/l:/ and /l/) are observed in the noun pair *pʃíl*: ‘spark’ and *pʃil* ‘sugar cane’, respectively. Word-final nasals (/n:/ vs. /n/) are observed in the stative verb pair *mbán*: ‘quick’ and *mbán* ‘alive’. One pair represents fortis and lenis laterals following /i/, and one pair represents fortis and lenis nasals following /a/.

Results of this second study of sonorant intensity support my hypothesis. Analysis of two contrastive minimal pairs in Table 29, carefully controlled for tone, vocalic environment and grammatical category, shows virtually no contrast between fortis and lenis sonorants in the word-final position.

---

from the surrounding vowels (contrast being the point of phonemic variation). Furthermore, the midpoint of the intensity curve was often near the peak, so choosing the minimum provided an additional, distinct point of reference.

Table 29. Mean intensity results of fortis/lenis sonorants (in dB)

		<i>N</i>	<i>MN</i>	<i>StDev</i>			<i>N</i>	<i>MN</i>	<i>StDev</i>
mbán:	/n:/	12	62.1	5.0	pʃil:	/l:/	12	60.9	4.1
mbán	/n/	12	61.6	5.6	pʃil	/l/	12	60.9	3.6

In Table 29, observe that given twelve tokens each of consonants /l:/ and /l/, the mean intensity is identical; both fortis and lenis laterals have an intensity of 60.9 dB. Likewise, the mean intensity of fortis and lenis nasals /n:/ and /n/ differs only slightly. Also shown in Table 30, statistical *t*-tests of intensity of sonorants show no significant contrast of the mean intensity, the mean minimum intensity, or the mean midpoint intensity.

Table 30. Statistical *t*-test values for intensity of sonorants /l/, /l:/, /n/, /n:/

The mean intensity of /n/ vs. /n:/ is  $t(22) = .23$   $p$  (2 tail) = .82

The mean intensity of /l/ vs. /l:/ is  $t(22) = .05$   $p = .96$

The mean minimum intensity of /n/ vs. /n:/ is  $t(22) = .06$   $p = .95$

The mean minimum intensity of /l/ vs. /l:/ is  $t(21) = .17$   $p = .87$

The mean midpoint intensity of /n/ vs. /n:/ is  $t(22) = .33$   $p = .75$

The mean midpoint intensity of /l/ vs. /l:/ is  $t(22) = .35$   $p = .73$

Clearly, the intensity data and statistical analyses show no significant contrast for the intensity of fortis and lenis sonorants. A separate variance *t*-test is the most conservative way to examine probability, and values still do not show significant variation between the intensity of fortis versus lenis sonorants. Results shown in Table 30 all represent very high probabilities that any differences in mean intensity, mean minimum intensity, or mean midpoint intensity are accidental. For example, a statistical test of the average intensities of fortis /n:/ and lenis /n/ demonstrates a probability value of .82, or an 82% likelihood that the difference in intensity between these two phonemes is due to chance. While results of this test alone are sufficient to redirect the search for a significant acoustic correlate of the fortis consonant away from intensity, a second test serves to confirm the conclusion and provide additional information.

The Univariate Analysis of Variance (ANOVA) tests for correlations in the intensity data. Table 31 presents the correlations between nasals (/n:/, /n/) and laterals (/l:/, /l/), between measurements of the mean, minimum and midpoint intensities, and between length of fortis versus lenis sonorants.

Table 31. Univariate Analysis of Variance (ANOVA) values for sonorant intensity

Segment (nasal vs. lateral)	F (1,132) = .837	<i>p</i> = .362
Intensity (mean, minimum, midpoint)	F (2,132) = 9.216	<i>p</i> = .000
Length (fortis vs. lenis)	F (1,132) = .121	<i>p</i> = .728

The ANOVA comparing segment intensity of nasals and laterals has a *p* value of .362, or a 36% probability that intensities of nasals and laterals do not merit separate treatment within the sonorant category. This is contrary to results presented by Avelino (2001) for Yalálag Zapotec, which show opposing intensity results for nasals and laterals, with lenis nasals having greater intensity than fortis nasals, and fortis laterals having greater intensity than lenis laterals. While Yalálag Zapotec may require separate categorization of nasals and laterals, in SFOZ, fortis nasals and laterals behave the same, and lenis nasals and laterals behave the same, easily fitting into the same category of sonorant.

The ANOVA results for intensity also point out the significance of the manner in which the intensity is determined. Significantly different results will be reported if the intensity is determined by the mean, the minimum point, or the midpoint. While the manner of intensity measurements is important, it is worth mentioning that all three ways to measure the intensity still provide high probability values, over 73%, that there is no difference between fortis or lenis sonorant intensity, as shown by the *t*-tests in Table 30.

Finally, the ANOVA for length present a very high variance in the duration of fortis sonorants and lenis sonorants. A difference in intensity of a sonorant segment is not

significantly related to whether the segment is fortis or lenis ( $p = .728$ ). Comparable to the duration statistics presented in section 4.1, the conclusion is that length is the most significant acoustic factor distinguishing fortis and lenis sonorants.

#### 4.5.4 Discussion/conclusion

The conclusion drawn from the measurement of fortis/lenis sonorant intensities is that, given minimal pairs, there is no difference in acoustic force during production of fortis/lenis sonorants in a stressed, word-final position. This experimental study indicates that increased air pressure (intensity) is not a significant correlate of the fortis/lenis contrast for all sonorants in SFOZ. Rather, there is only a subtle contrast in intensity between fortis/lenis nasals, and only when tones and grammatical categories differ.

This study is limited to the intensity throughout the duration of the consonant segment, and does not take into consideration the release of the consonant into the following vowel. While acknowledging that even for sonorants there may be a contrast in the release of air pressure into the vowel, there are two reasons this transfer section is not considered here: the first is a frequent presence of a pause after the target segment which influences the release burst into the following vowel, making it difficult to consistently segment a 10-15 ms window of release. The second is the seemingly unpredictable appearance of laryngealization on the coda consonant (i.e. creaky /l/ observed in token '47. pʃil SM6ab.wav'), or at the vowel onset (e.g. a glottal or creaky onset to the following /a/). Both of these contextual factors result in a sharp decrease in intensity at the offset of the consonant and onset of the following vowel, and would provide inconsistent and unreliable results.<sup>69</sup>

---

<sup>69</sup> In future experiments, a control for these two factors would mean selection of a different frame for SFOZ, for example *kne* ' \_\_\_\_ or *ki* 'say \_\_\_\_ now.' This frame was considered but not chosen for SFOZ because the corresponding frame in SCXZ is *kne* ' \_\_\_\_ *na* or 'say \_\_\_\_ now,' and I was seeking a

In the same way that the voicing distinction between fortis and lenis stops is inadequate to describe the fortis/lenis contrast in sonorants, the intensity distinction for stops found for Yateé is not true of all SFOZ sonorants. Even if intensity were found to be significant for stops in SFOZ, intensity would not be a sufficient unitary correlate to identify the fortis/lenis consonant contrast in SFOZ. The SFOZ results compare to those found for sonorant onsets in Yalálag which show “no significant difference between fortis and lenis sonorants with respect to the average amplitude of the onset of the following vowel” (Avelino 2001:80). In Yalálag, amplitude is greater for lenis nasals, but greater for fortis laterals. In contrast, amplitude for fortis and lenis laterals show no significant contrast in SFOZ.

#### **4.6 Pilot study: VOT and consonant duration of /p/, /b/, /t/ and /d/ in SFOZ and SCXZ**

In this section I present a pilot study of VOT and consonant duration of fortis/lenis pairs /p/ and /b/ in word-initial and final positions, and /t/ and /d/ in word-initial, medial and final positions, comparing SFOZ and SCXZ. The words used for this pilot study are not controlled for grammatical category or tone (see

Table 32). A few tokens are multi-morphemic, and one is a loanword from Spanish (in parentheses). In spite of the dissimilar environments, an analysis of the perceived fortis/lenis contrast in the initial position contributes to the discussion of the fortis/lenis contrast and gives an initial glance into variation between SFOZ and SCXZ, two mutually intelligible variants of one language.

---

comparable frame for the two communities in which both frames surrounded the target word with vowels.

Table 32. Words used in pilot study of SFOZ and SCXZ

Target word	Gloss	Segment	Data #
(pa)	‘shovel’	#pa	16.
piʃ	‘may fall’	#pi	129.
bál:	‘sister of girl’	#ba	17.
bítʃ	‘cat’	#bi	4.
dʒàp	‘has’	ap#	49.
dʒab	‘swallows’	ab#	92.
dǎd	‘sir’	#da	21.
dík	‘very small’	#di	8.
tàp	‘four’	#ta	19.
tíb	‘one’	#ti	7.
dǎd	‘sir’	ad#	21.
gìd	‘skin/leather’	id#	105.
gjàt	‘tortilla’	at#	117.
gìt	‘rainbow’	it#	106.
jdib	‘may finish’	_di	125.
jtíʃ	‘may measure’	_ti	124.

The labial phonemes /p/ and /b/ analyzed in word-initial position occur before the vowels /i/ and /a/. The word-final labials are analyzed only after the vowel /a/. Target words including /p/, /b/, /t/, and /d/ were pronounced by six speakers of SFOZ and four speakers of SCXZ. For this exploratory study, I followed the same procedures for segmentation as described in previous sections. Mean values generally include two repetitions per token from each speaker, except for a few tokens where a pause preempted analysis. Duration and VOT correlates are measured in milliseconds.

#### 4.6.1 Initial consonant duration

SFOZ tends more towards voicelessness in both fortis/lenis categories, while the voicing contrast is more dependable in SCXZ. There is no apparent difference between SFOZ and SCXZ in regards to the duration of consonants. In both communities the duration contrast is generally the same; for both labial and alveolar stops, the fortis consonants are longer than lenis consonants.

Table 33. Mean consonant duration of /p/, /b/ and /t/, /d/ in SFOZ and SCXZ (in ms)

	Initial	#p			#b			#t			#d		
		N	MN	<i>StDev</i>	N	MN	<i>StDev</i>	N	MN	<i>StDev</i>	N	MN	<i>StDev</i>
/i/	SFOZ	12	131.8	15.7	12	89.8	23.1	11	124.3	23.5	10	115.0	34.1
	SCXZ	7	136.2	22.5	8	71.1	21.8	4	138.7	36.6	4	85.6	37.6
/a/	SFOZ	12	125.8	23.8	12	99.1	27.2	12	134.7	26.2	12	70.2	29.1
	SCXZ	7	139.7	16.4	8	83.7	30.3	4	118.5	18.2	4	81.7	16.4

	Final	p#			b#			t#			d#		
		/i/	SFOZ						12	168.0	23.4	12	105.6
	SCXZ						4	136.7	37.6	4	81.6	22.8	
/a/	SFOZ	12	128.4	25.6	12	97.0	42.0	12	126.8	30.0	9	95.2	42.8
	SCXZ	7	120.3	27.7	8	105.2	25.6	4	118.5	57.5	4	113.7	77.4

	Medial				_t_			_d_				
		/i/	SFOZ						12	121.3	17.8	12
	SCXZ						4	112.2	15.4	4	60.5	8.4

Data in Table 33 confirm that for SCXZ, as for SFOZ, a fortis consonant is longer than a lenis consonant in all three positions: word-initial (#p), word-final (#t), and word-medial (\_d\_). In the word-initial position, the voiceless labial /p/ is almost twice as long as its counterpart /b/. While the duration contrast holds true in the word-final position, it is not nearly as marked in this position.



While the mean values reflect the duration contrast, the standard deviation is high. Again, this is due primarily to the variation in the rate of speech between individual speakers. As shown in Table 33, the mean of all six SFOZ speakers pronouncing word-final lenis /d/ before /a/ is 70.2 ms, with a standard deviation of 29.1. If Speaker four's tokens are excluded, the mean is 59.1 ms and the standard deviation is reduced to 14.4, less than half the standard deviation including Speaker four. Both the mean and the standard deviations are considerably lower without Speaker four. When considering the mean consonant duration of an individual speaker, the standard deviation is also much lower. The mean duration of [d#] spoken by SCXZ Speaker one is 50.6 ms, with a standard deviation of 5.4. As evidenced here, future research will benefit from a control set for the rate of speech of individual speakers. The fact that there is still a contrast in fortis/lenis consonant duration, even given the considerable variation in the rate of speech, makes the contrast even more convincing. This pilot study, therefore, indicates that the duration correlation with fortis/lenis consonant contrast is strong and complete in both language communities and in all word positions.

#### *4.6.2 Initial VOT*

Voicing of word-final consonants has been shown to correlate with voice tail more than VOT. This pilot study investigates VOT in word-initial and word-medial positions as well, comparing VOT and voicing in both SFOZ and SCXZ. In Table 34, the tokens include positive VOT values of two repetitions of each word spoken by six speakers of SFOZ and two speakers of SCXZ. The column, 'N', is the number of tokens; 'MN' represents the mean of positive VOT tokens only (in ms), followed by the standard deviation. The column headed '-VOT', or negative VOT, is the percentage of tokens with a completely voiced consonant. Consider the word-initial lenis /b/ preceding the vowel /i/

as spoken in SFOZ: the mean of tokens with a positive VOT is 9.3 ms, with a standard deviation of 5.2, and fifty-eight percent of these tokens are completely voiced.

Table 34. Mean +VOT and % of -VOT of /p/, /b/, /t/, and /d/ in SFOZ and SCXZ

		N	MN	<i>StDev</i>	-VOT	N	MN	<i>StDev</i>	-VOT
Initial		#p				#b			
/i/	SFOZ	12	24.8	6.2	0%	12	9.3	5.2	58%
	SCXZ	8	11.6	4.2	0%	8	--	--	100%
/a/	SFOZ	12	17.6	5.2	0%	12	12.8	1.5	75%
	SCXZ	6	14.2	7.0	0%	8	--	--	100%
Initial		#t				#d			
/i/	SFOZ	12	34.4	11.8	0%	12	17.9	8.5	33%
	SCXZ	4	22.9	4.6	0%	4	--	--	100%
/a/	SFOZ	12	22.0	7.1	0%	12	17.1	12.8	33%
	SCXZ	3	13.7	2.8	0%	4	0	0	75%
Final		p#				b#			
/a/	SFOZ	12	42.6	24.3	8%	12	27.6	21.0	50%
	SCXZ	6	29.8	24.9	0%	8	30.9	19.1	38%
Final		t#				d#			
/i/	SFOZ	10	32.8	11.8	0%	12	32.8	14.2	30%
	SCXZ	3	27.4	10.5	0%	4	62.1	1.6	50%
/a/	SFOZ	12	26.6	9.3	0%	9	27.1	11.5	11%
	SCXZ	4	10.4	12.1	0%	4	32.3	11.5	50%
Medial		_t_				_d_			
/i/	SFOZ	12	28.3	8.9	0%	12	34.9	3.8	67%
	SCXZ	4	28.7	5.7	50%	4	--	--	100%

Generally speaking, SCXZ lenis consonants show more voicing than SFOZ lenis consonants. In both communities, fortis consonants in each word position have positive

VOT, and lenis consonants /b/ and /d/ are more often voiced. There is a trend, however, of less voicing in the word-final position; lenis consonants may have a positive VOT that is equal to the corresponding fortis VOT (i.e. VOT for it# and id# are both 32.8 ms for SFOZ). Also, word-medial lenis /d/ has a positive VOT longer than the VOT of fortis /t/ for SFOZ (34.9 ms compared to 28.3 ms respectively).

Initial /p/ and /b/ show a consistent VOT contrast. Likewise, the initial /t/ and /d/ contrast in SCXZ is voiced lenis and voiceless fortis. VOT of the fortis consonant /p/ is positive in both initial and final positions, adjacent to /i/ and /a/.<sup>70</sup> Obscuring the contrast, lenis consonants may have a positive VOT, but usually have a negative VOT, even more so in the initial position. For example, initial /b/ is completely voiced (i.e. negative VOT), with only one or two tokens where voicing does not last the complete duration of the consonant. In SFOZ, however, the initial /t/ versus /d/ contrast is not so predictable. The fortis consonant is voiceless with a positive VOT, but only about thirty-three percent of the lenis tokens have a negative (fully voiced) VOT, meaning that approximately sixty-seven percent of lenis consonants are positive, possibly being confused for a fortis in terms of voicing.

As I hypothesized, results show more voicing for lenis consonants pronounced by speakers of SCXZ than for speakers of SFOZ. In other words, voicing is a more consistent cue to the fortis/lenis contrast in SCXZ than it is in SFOZ. While VOT shows a consistent pattern for fortis consonants (a pattern that is more consistent for both fortis and lenis in SCXZ), whether or not a lenis consonant has a positive VOT is inconsistent in SFOZ. VOT, therefore, is not a primary acoustic correlate of the fortis/lenis contrast in SFOZ.

---

<sup>70</sup> There is one exceptional instance of a fully voiced /p/ in the final position ‘dʒap SM3c’.

#### 4.6.3 *Discussion and conclusion*

Due to the small sample of data, I did not run statistical tests. Its value is that it shows voice onset and duration trends for consonants perceived as categorically similar to fortis or lenis in the initial position. By considering both SFOZ and SCXZ, this pilot study shows similar patterns in duration for fortis and lenis consonants: fortis consonants are longer. Initial VOT values indicate a later onset of voicing for SFOZ than for SCXZ. There is generally more voicing of lenis consonants as pronounced by SCXZ.<sup>71</sup>

Keeping in mind the introductory nature of the pilot study, positive VOT seems to correlate with longer consonant duration. The longer the consonant, the more likely the VOT will be a positive value. For example, a long /p/ will have a positive VOT. While a shorter /b/ may have a positive VOT, it is more prone to voicing at the consonant onset. That is not to say that the length of the consonant correlates to the length of the VOT, but only whether the onset of voicing is before or after the burst.

---

<sup>71</sup> An unexpected result in the observation of the /p/ initial loan word is that it has a duration about the same length as native ‘fortis’ /p/. I would expect that if the fortis /p/ native to SFOZ is a geminate or double consonant, then the loan phoneme /p/—a single phoneme—would be shorter than the native/geminate /p/, unless the loan is nativized.

## **CHAPTER 5**

### **CONCLUSION**

This thesis has examined the fortis/lenis acoustic correlates of consonant, vowel and rime durations in the word final position, vowel quality preceding fortis/lenis consonants, VOT and voicing (voice tail) of stops, and intensity in sonorant consonants.

Of this cluster of fortis/lenis characteristics, duration of word-final segments is the most salient and reliable acoustic feature. Consonant duration is a cross-categorical acoustic correlate of the fortis/lenis consonant distinction in SFOZ. Word-final fortis consonants are statistically longer than lenis consonants, both for obstruents and sonorants. Likewise, duration of the preceding vowel is shorter before a fortis consonant and longer before a lenis consonant. The combined vowel and consonant segments result in a fortis rime that is shorter than a lenis rime. As mentioned in section 1.3.1, “In order for the terms ‘fortis/lenis’ or ‘force of articulation’ to be considered phonetically accurate terms, it must be shown that they correspond to some unitary and independently controlled phonetic parameter” (Jaeger 1983:186). This study gives evidence that – indeed – fortis/lenis in SFOZ strongly and consistently corresponds to a unitary parameter: duration. All other correlates analyzed in this study are conditioned by this singular correlate of duration. The question for future research is whether this ‘unitary parameter’ of duration is ‘independently controlled’ or in relation to ‘articulatory force’.

Another significant acoustic correlate of the fortis/lenis contrast is vowel quality, or the contrast in vowel formants (F1 and F2), preceding fortis/lenis consonants. Vowels (particularly high vowels) before fortis consonants are more central, or lax. Vowel quality is therefore conditioned by whether the following consonant is fortis or lenis. There is an obvious relationship between the contrast in vowel duration and the contrast in quality (F1 and F2). Universally, vowels in a more extreme vowel space (i.e. tense) are longer, while vowels in a more central articulatory place are shorter (i.e. lax). This vowel correlation with the fortis/lenis contrast is likely a secondary characteristic of the duration contrast involving compensatory lengthening of vowels (in a phonetic sense) before all lenis consonants.

The voicing distinction, on the other hand, is weak and unreliable, and characteristic of obstruents only. Voicing as a phonetic property is too unstable in SFOZ to be considered a distinctive feature of fortis/lenis. Fortis consonants are voiceless and have a positive VOT; but lenis consonants may also have a positive VOT, particularly in the word-final position. Any distinction in voicing is primarily from voice tail (from the preceding vowel), which permits longer voicing at the onset of word-medial and word-final lenis consonants. While voicing at the consonant onset may be a cue for lenis stops and affricates, voice tail is not contrastive in fricatives or sonorant consonants. Therefore, in agreement with Avelino (2001), this instrumental study supports the hypothesis that the phonological contrast cannot be based solely on voicing. Rather, I conclude that susceptibility of a consonant to voicing is, in part, conditioned by the consonant duration.

Impressionistically, fortis consonants seem to correlate with greater articulatory force. However, inasmuch as articulatory force directly relates to intensity, this analysis of the SFOZ sonorant intensity seems to give evidence to the contrary. The contrast is

statistically significant for fortis/lenis nasals, but not for fortis/lenis laterals. Furthermore, intensity is virtually equal for both fortis and lenis sonorants in minimal pairs. Greater intensity (i.e. amplitude) does not correlate with all fortis consonants.

This study, while limited to an acoustic phonetic analysis of fortis/lenis consonants, has phonological implications. First and foremost, the unitary correlate of duration merits two consonant categories currently identified by the terms ‘fortis’ and ‘lenis’. Further research would be useful to determine if these specific terms ‘fortis’ and ‘lenis’, which imply strength versus weakness, are acoustically accurate for a contrast that is thus far characterized only by duration in SFOZ. Acoustic analyses of other Zapotec languages would be useful to discover if the duration contrast is sufficient cross-categorically to describe fortis/lenis consonants in the Zapotec language family as a whole.

Secondly, the fact that greater intensity does not correlate with both fortis sonorants does not eliminate the possibility that articulatory force is a correlate of the fortis/lenis contrast. Duration may be an indicator of articulatory force. As understood from physics, force and time are in a ratio (force = momentum x time). If momentum (i.e. intensity) has no change, for force to be greater, time must be longer. Said another way, if [articulatory] force is increased, time [duration] is increased. Since this study did not analyze force of the articulators, but intensity or amplitude, it is left to future research to determine if articulatory force is a factor, and if so, whether duration or articulatory force (or a relationship between the two) is the ‘independently controlled’ parameter of the consonant contrast.

And finally, results of this study do not refute the geminate hypothesis. If fortis consonants were double, the distribution of fortis consonants in SFOZ is such that it would not put an undue burden on the syllable structure. Perhaps, if a fortis consonant is

a synchronic reflex of a double consonant, these ‘geminate’ consonants could be analyzed as one phonemic unit as /tʃ/ and /kw/ have been. More importantly, the significant contrast in duration of fortis and lenis consonants points to what could be an historically geminate phoneme.

Given these results and implications, there are several areas needing future research in SFOZ, other Zapotec languages, and the fortis/lenis issue in general. Within SFOZ and the Zapotec family of languages, future research should thoroughly investigate the distribution of fortis/lenis consonants and their interaction with the syllable structure, laryngeal feature, and tone, specifically as they relate to the fortis/lenis contrast.

Considering the universal tendency for languages to have more phonemic contrasts in the onset position, it is phonologically unusual that fortis/lenis consonants in SFOZ show greatest freedom of distribution word-finally. A study of onset consonants, therefore, may provide a better understanding of this pattern uncommon in the languages of the world. For example, fortis stops in the word-initial position are rare, particularly in nouns. Nellis and Hollenbach (1980) observe a relationship between length of the vowel and length of a preceding fortis consonant: Cajonos Zapotec “shortens fortis before long vowels and shortens vowels before fortis consonants” (p. 98). Future research into the duration of all segments in a word could reveal any effect of a vowel on a fortis/lenis consonant onset, perhaps explaining the apparent lack of long fortis consonants in word-initial positions in SFOZ.

The investigation of ‘articulatory force’ is called for in all Zapotec languages. It is clear that duration is not the unitary correlate for all Zapotec languages, as discussed in 1.2. It may still be, rather, that articulatory force is the unitary, independently controlled parameter that for some languages is realized as duration, and for others as intensity (or



perhaps a combination of both). Before a phonological conclusion can be made for Zapotec languages in general, additional instrumental analyses of the phonetic factors, particularly of the tension or force of articulators is necessary.

This thesis provides an acoustic phonetic description of the fortis/lenis consonant correlates of duration, vowel quality, voicing, and intensity in SFOZ. The results contribute to the known phonetic facts, inform the discussion of the phonological categories fortis/lenis in Zapotec languages, and urge continued research for a complete understanding of the ‘fortis’ and ‘lenis’ consonant contrasts in Otomanguean languages of Mexico.

## APPENDICES

## APPENDIX A

The consent form in English, Spanish, and SFOZ (Zapotec)

(Consent form: English)

Acoustic Correlates of Fortis-Lenis in San Francisco Ozolotepec and Xanaguía Zapotec

You are invited to participate in a study being done by Investigator Anita Leander, a student at the University of North Dakota, Grand Forks. For this research project, she is under the supervision of Professor Stephen Marlett of the linguistic department at the University of North Dakota.

The intention of this research is to understand the phonology of Zapotec spoken in San Francisco Ozolotepec, Santa Catarina Xanaguía, and San Jose Ozolotepec. Digital audio recordings will be made in order to study how Zapotec consonants and vowels are pronounced. The results will provide Zapotec, education and linguistic communities with objective data for understanding Zapotec phonology.

The recording procedure is expected to take less than one hour. The recording will take place in a quiet room. Each speaker will be recorded on the computer using a microphone that rests on the head close to the mouth. The Investigator will say the word or phrase and the subject will repeat it in Zapotec. The material for recording includes Zapotec words and phrases containing the 'strong' and 'weak' consonants focused on in this study. The Investigator will model how the recording is done.

Possible risks of participating are no greater than those in an average conversation. The computer is able to replay your voice like a music cassette, therefore, a possible risk of participating is that someone will overhear the recording and recognize your voice. To avoid this, the recordings will not be played in the hearing of other Zapotec speakers. The recordings will be kept anonymous, unless the speaker would like to be acknowledged for their participation. There is no risk of physical harm.

The research results may benefit Zapotec people who read and write their own language, bilingual school teachers, and people who study about languages. As a result of this study, Zapotec may be easier to read, write and teach to Zapotec-speaking students. Society will have a better understanding and increased appreciation for your unique language. The Investigator will not receive any financial benefits from this study.

If you choose to participate, there is no cost to you. For your participation you will receive one 2006 calendar in Zapotec or story of equal value, one Zapotec picture dictionary, and one Zapotec alphabet leaflet. In addition, you will receive a bottle of soda or juice, a total value of approximately 30 Mexican pesos. If you wish, you may receive a

summary of the investigation results in Spanish which will be completed within one year.

Any information from this study that can be identified with you will remain confidential and will be disclosed only with your permission, if granted below. All data and consent forms will be kept in separate locked cabinets for a minimum of three years after the completion of this study. After three years, the consent forms will be destroyed. The digital recordings of the language data will be preserved for future Zapotec generations and, with permission, will be put on the internet where others may listen to the data. The Investigator will write the results of the research in a paper that will be presented to the University of North Dakota. Neither the names of subjects nor the audio recordings will be included in the document presented to the university, unless otherwise indicated by the participant.

Participation is voluntary, and your decision whether or not to participate will not change your future relationship with the Investigator. If you decide to participate, you may leave the study at any time without penalty.

If you have questions about the research, you may contact the Investigator, Anita Leander, by phone at 951-513-5785 or by e-mail at [Anita\\_Leander@sil.org](mailto:Anita_Leander@sil.org) (English, Spanish or Zapotec) or Professor Stephen Marlett by e-mail, [Steve\\_Marlett@sil.org](mailto:Steve_Marlett@sil.org) (English or Spanish). If you have any other questions or concerns, please call the Research Development and Compliance office at 001-701-777-4279 (English). You will receive a copy of this consent form for future reference.

Indicate your consent by marking one box below:

- I give permission for my recording to be used for this research. Only the Investigator, her professors, and people who audit the IRB will have access to my recording.
- I give permission for my recording to be used for this research. My recording may also be made available to the public on internet, where Zapotecs, linguists and others may hear it.

Indicate your preference to (not) share your name by marking one box below:

- Please acknowledge my participation by including my name. My complete name is: \_\_\_\_\_.
- Please do not acknowledge my participation. Do not include my name.

All of my questions have been answered and I am encouraged to ask any questions that I may have concerning this study in the future.

\_\_\_\_\_  
Participant's Signature

\_\_\_\_\_  
Date

(Consent form: Spanish)

## DOCUMENTO DE PERMISO

### Características de los consonantes fuertes y débiles en el zapoteco De San Francisco Ozolotepec y Santa Catarina Xanaguía

Se le invita a participar en un estudio hecho por la Investigadora Srta. Anita Leander, una estudiante de la Universidad de Dakota del Norte, en Grand Forks. Para este proyecto, ella está bajo la supervisión del Profesor Stephen Marlett del departamento de lingüística en la Universidad de Dakota del Norte.

La propuesta de esta investigación es entender la fonología del zapoteco hablado en San Francisco Ozolotepec, Santa Catarina Xanaguía, y San José Ozolotepec. Se harán grabaciones digitales para estudiar cómo se pronuncian las consonantes y vocales del zapoteco. Los resultados proveerán a las comunidades zapotecas, educativas, y lingüísticas datos objetivos para entender mejor la fonología del zapoteco.

El procedimiento de la grabación debe ser de menos de una hora. Se harán las grabaciones en un cuarto silencioso. Se grabará la voz de cada hablante en la computadora con un micrófono que se pone en la cabeza cerca de la boca. La investigadora dirá la palabra o frase y el participante la repetirá en zapoteco. Los datos se grabarán se incluyen palabras y frases del zapoteco que contienen las consonantes “fuertes” y “débiles” que son el enfoque de este estudio. La investigadora mostrará como se hará la grabación.

No hay mayor riesgo en este estudio que el de una conversación cotidiana. La computadora es capaz de emitir la voz como un casete de música, así que un posible riesgo al participar es que alguien más oír y reconocerá su voz. Para evitar esto, las grabaciones no se podrán en presencia de otros hablantes del zapoteco. Las grabaciones se quedarán anónimas, a menos que el hablante quiera ser reconocido por su participación. No hay riesgo de daños físicos.

Los resultados del estudio beneficiarán a los zapotecos que leen y escriben en su propio idioma, a maestros bilingües, y a lingüistas. Como resultado de este estudio, puede ser que el zapoteco sea más fácil de leer, escribir y enseñar a estudiantes zapotecos. La sociedad en general tendrá mayor entendimiento y aprecio de su idioma. La investigadora no recibirá ningún beneficio financiero por haber hecho ésta investigación.

Si decide participar, no hay ningún costo para usted. Por su participación recibirá un calendario de 2006 escrito en zapoteco o un cuento del mismo valor, un Pequeño Diccionario Ilustrado, y un folleto del alfabeto zapoteco. También recibirá un refresco o jugo, un valor total de 30 pesos mexicanos. Si quiere, puede recibir un resumen de la investigación en español, el cual se hará dentro de un año.

Cualquier dato de este estudio en que se pueda identificar a usted se mantendrá confidencial y solamente se dará a conocer con su permiso, especificado mas adelante. Todos los datos y documentos de permiso se quedarán en un archivero asegurado por un mínimo de tres años después de concluir este estudio. Al cumplir este tiempo los documentos de permiso se destruirán. Las grabaciones digitales serán archivadas para

generaciones futuras de zapotecos y, con su permiso, se pondrán al Internet donde otros pondrán escuchar a los datos. La investigadora escribirá los resultados de la investigación en un trabajo que se presentará a la Universidad de Dakota del Norte. Ni los nombres de los participantes ni las grabaciones se incluirán en el trabajo presentado a la universidad, a menos que usted lo permita.

Su participación es voluntaria, y una decisión de no participar no cambiará su relación con la investigadora. Si decide participar, se puede salir del estudio en cualquier momento sin consecuencias negativas.

Si tiene preguntas sobre la investigación, puede comunicarse con la investigadora, Anita Leander, al teléfono (951) 513-5785 o por correo electrónico [Anita\\_Leander@sil.org](mailto:Anita_Leander@sil.org) (Inglés, español o zapoteco) o al Profesor Stephen Marlett por correo electrónico, [Steve\\_Marlett@sil.org](mailto:Steve_Marlett@sil.org) (Inglés o español). Si tiene otras preguntas o dudas, favor de llamar a la oficina de *Research Development and Compliance* por teléfono 001-701-777-4279 (Inglés). Usted recibirá una copia de este documento.

Indique su preferencia con una X en uno de los siguientes cuadros:

- Doy permiso para que se use mi grabación en ésta investigación. Solamente la investigadora, sus profesores, y las personas encargados de asuntos de estudios (IRB) podrán tener acceso a mi grabación.
- Doy permiso para que se use mi grabación en ésta investigación. También doy permiso para que se publique mi grabación donde zapotecos, lingüistas y otros la puedan oír.

Indique su preferencia con una X en uno de los siguientes cuadros:

- Por favor de a conocer mi participación yendo mi nombre. Mi nombre completo es: \_\_\_\_\_.
- Por favor NO de a conocer mi nombre. No incluya mi nombre.

Todas mis preguntas han sido contestadas y entiendo que puedo hacer mas preguntas sobre este estudio en el futuro.

\_\_\_\_\_  
Firma del participante

\_\_\_\_\_  
Fecha

(Consent form – SFOZ (in the local orthography))

### GITS PERMIS

Tib use'd di'tsë, xku'n nak letr ndip ña letr nlas.

Anita Leander, chu'nna inbitar lo tib use'd Universidad Dakota del Norte. Lë' minn nak mextr lë Profesor Esteben Marlett. Gu'n xla'nnu isedta xku'n inema tib di'dz ditsë, gu'n xne minn San Fransisk, gu'n xne minn Sant Lin, gu'n xne minn San José. Gak graba par ikën used xkun inema, o xku'n ilabma ichësa di'dz ditsë. Or idib skwel lë'na ine gu'n usedn lotá.

Tib or nak or gak grabar, tib lenn yu di'l dzé nak par gak grabar. Ñana gak grabar tsi minn lenn komputadora kon tib mikrofono ikë gyal chow minn. Lë' minn gu'n grabar ine tib di'dz o ine tib di'dz nol y lë' minn gedz ineu di'tsë sigit. Lë' ichë gu'n gak grabar lë' gu'n igwiy ichë di'dz gu'n dzëts ndip y gu'n dzëts tsëw. Gunnu nak use'd. Lë' minn chunn grabar ine' gan xkun chak grabar.

Bët gu'n ndzep gënd lo used che'n, lë' komputadora nak xiknak tib kaset di, ke yu minn gonu y gon tsi minn ichësa gun uyak grabar gakda gon minn ditsë. Ichësa gu'n uyak grabar di'ltsa xlan minn ikë lë minn o ikëda lë minn bët gilndze'p gënd.

Lë' minn che'n ise'd izau ilabu lo mextr skwel y lë' minn nak lingüista (chiknak Lina ichop Anita). Or knu dzekn ichësa di'dz che'n lëma sak ngandachi. Xku'n tsau y xku'n ikëu y xku'n ised minn ichë minn ditsë. Lë' minn kë use'd che'n ne tip demi xkañada.

Di'ltsa xlan ikëla use'd che'n ni tib kixda minn ika'l. Di'ldza lë'l ikë use'd che'n nonda ti kalendario igad minn lo'l gu'n kë di'tsë o gu'n kë kwent, gana tib diccionario win, y tib gits gu'n kë alfabeto di'dzë, y gad minn tib nìs nex, iza gu'n che'n gak non 30 pës. Di'ltsa xlan minn tib copia (gu'n chën use'd) per axta tib yiz lë'u gak di'dz-xtil.

Ichësa gu'n chen gakda gon kwalkier minnu. Ichësa gu'n chen gya'n tib lger por tson yiz. Or gak tson yiz lë' gits che'n izëb. Lë' gu'n uyak grabar yutsëw'ga, y di'ltsa xla'n minn tsutsëwl lënn internet par gon stib minnu. Lë' minn kë use'd chen iza'u lo tib gits par ilu lo skwel, di'ltsa xlan minn tsada lë minn lo gits gu'n ilu lo skwel, zaku.

Di'lsta xla'n'l gu'nla yud, bolunta. Di'ldza xlandl gunnla yud, ilë'dna. Di'ldza xla'n'l inabdi'dzl tib gu'n o ba gu'n cho'ntl, kwne' lo Anita, lë' numr telefono ne'g, 951-513-5785 ada kza' tib kart lo mextr Esteban (lo komputadora – [Steve.Marlett@sil.org](mailto:Steve.Marlett@sil.org)), ada lo skwel 001-701-777-4279 (nonda di'dz ingles xne' minn). Gits che'n gyan lo'l.

Kwza' tib 'X' lënn kwadr che'n:

- Inedzn di'dz par gondá gu'n uyak grabar (Anita na xmextr na minn skwel).
- Inedzn di'dz par icha' tib gits gu'n uyak grabar di'dzë, ña dzak tsu gu'n uyak grabar lo internet.

Kwza' tib 'X' lënn kwadr che'n:

- Dzak tsa lënn lo gits che'n. Lënn xnú xyà \_\_\_\_\_.
- Gakda iza'ta lënn.

Ne'g xne' zak inab di'dz china, gan be gu'n inab di'dzn.

\_\_\_\_\_  
Firm chënl

\_\_\_\_\_  
dze më'

## APPENDIX B

Recorded data in alphabetical order

SFOZ	SCXZ	English	Spanish	Token
bál:	bal:	sister	<i>hermana</i>	17.
bědz	bedz	bean tamales	<i>tamales de frijol</i>	46.
bèts	bets	crack	<i>grieta</i>	112.
bæn: (L)	bæn:	mud	<i>lodo, mojado</i>	67.
bítʃ	bítʃ	cat	<i>gato (michi)</i>	4.
blak	blag	leaf	<i>hoja del árbol</i>	78.
blak~g	bla	How many, much?	<i>¿cuánto?</i>	80.
bʒóz~pʃos	bʒoz	dad, father	<i>papá</i>	131.
dād	dad	mister	<i>señor</i>	21.
dām:	mgu	owl	<i>buo</i>	66.
dæn	dæn	field	<i>campo, loma</i>	113.
dík~t <sup>h</sup> ɪk	dik	very small	<i>muy pequeño</i>	8.
dubaʔan		rope	<i>mecapal</i>	128.
dupaʔan	dapaʔan	my dad	<i>mi papá</i>	11.
dzìn	dzin	honey	<i>miel</i>	71.
dzit	dzit	bone	<i>hueso</i>	97.
dzab	ʒgab	swallows	<i>traga</i>	92.
dzàp	dzap	has	<i>tiene</i>	49.
dzas	dzas	chews	<i>mastica</i>	74.
dzaz̄	dzaz	bathed	<i>causó a bañar</i>	100.
dʒen	dʒen	blood	<i>sangre</i>	20.
dʒep	dʒap	says	<i>dice</i>	85.
dʒídʒ	ʒidz	smiles	<i>sonrie</i>	13.
dʒòb	dʒòb	tortilla basket	<i>tenate</i>	48.
dʒut	tʃut	make tortillas	<i>hacer tortillas</i>	53.
<b>gádʒ</b>	gadz	seven	<i>siete</i>	58.
gâl:	gâl:	twenty	<i>veinte</i>	104.
gāl	gal	will be born	<i>va a nacer</i>	107.
gan:	gan:	will see	<i>a ver</i>	2.
gäts	gatso	break	<i>quebra</i>	59.
gedz	gedz	town, city	<i>pueblo, ciudad</i>	110.
gib	gíb	vein	<i>vena</i>	103.
gìd	gìd	leather	<i>cuero, piel</i>	105.
gìk	gik	head	<i>cabeza</i>	41.
gís	ges	pot	<i>olla</i>	98.



gìt	gít	rainbow	<i>arcoiris</i>	86.
gìt		squash	<i>calabaza</i>	106.
gìts	gits	paper	<i>hoja de papél</i>	79.
giʒ~giʃ	giʃ	large bag (for harvest)	<i>bolsa, costal</i>	23.
giʒ	giʃ	herb	<i>planta, hierba</i>	44.
gjan	gjan	deep plate	<i>plato hondo</i>	76.
gjan:	gjan:	will burn	<i>va a arder</i>	18.
gjàt	gjat	tortilla	<i>tortilla</i>	117.
gôn	gon	cleans/prepares	<i>limpieza</i>	69.
gon:	gon:	be careful	<i>cuidado</i>	72.
got	got	lay down	<i>acuéstate</i>	94.
gots	gotso	mix it	<i>mezcla</i>	60.
gun:	gun:	going to do, make <sup>11</sup>	<i>va a hacer</i>	3.
guts	guts	tell	<i>diga</i>	95.
jdib	jdib	will end	<i>va a terminar</i>	125.
jtij	jtij	to measure	<i>pesar, medir</i>	124.
kib	kib	will sew	<i>va a coser</i>	99.
(kwátʃ)	(kwatʃ)	twin	<i>gemelo (cuate)</i>	61.
ládʒ	lædz	clothing	<i>ropa</i>	122.
lædz (L)	lædz	full/good corn	<i>está llena la mazorca</i>	87.
læts	læts	flat	<i>plano, parejo</i>	108.
lídʒ	lidz	home	<i>casa de alguien</i>	55.
ljæw (LH)	ljej	key	<i>llave</i>	15.
màl:	mal:	fish	<i>pescado</i>	63.
mbán	mban	alive	<i>vivo</i>	51.
mbán:	mban:	quick	<i>rápido</i>	56.
medʒ	medʒ	turkey	<i>guajolote</i>	83.
mæt (L)	mæt	skunk	<i>zorrillo</i>	75.
mgídʒ	mgidz	sick person	<i>enfermo</i>	77.
midz	midz	seed	<i>semilla</i>	82.
min:	men:	people/person	<i>gente</i>	81.
mín:dzâb	min:dzâb	devil	<i>diablo</i>	35.
mín:ntsàʔp	ntsàʔp	lazy person	<i>persona floja</i>	68.
mjas	mjas	fox	<i>zorro</i>	36.
nàl:	nal	cold	<i>frío</i>	84.
náp	nap	later	<i>más tarde</i>	96.
nàs	nas	day before yesterday	<i>anteayer</i>	38.
næd (H)	næd	doesn't want to	<i>no quiere</i>	70.
næn (LH)		to appear	<i>aparecer</i>	121.
ngud	ngud	round	<i>redondo, peludo</i>	93.
ngúp	ngup	armadillo	<i>armadillo</i>	24.
<i>ngut</i>		sweet corn tamale	<i>tamale de elote</i>	93b.
nìp	nip	cane liquor	<i>tepache</i>	39.
nìs	nis	water	<i>agua</i>	42.

nɨʃ	nɨʃ	tastes burnt	<i>huele quemado</i>	101.
níʒ	níʒ	delicious	<i>sabroso</i>	34.
níz	niz	dry corn	<i>mazorca</i>	22.
njáǵ	njag	cold	<i>frío</i>	43.
njaʔk	njak	yesterday	<i>ayer</i>	6.
njáʒ	njaz	road	<i>camino</i>	37.
nkits	nkits	white	<i>blanco</i>	109.
nküb~kub	nkub	new	<i>nuevo</i>	27.
(pal)	(pal)	shovel	<i>pala</i>	16.
piʃ	piʃ	will fall	<i>va a caer</i>	129.
píʃ	piʃ	will put on	<i>va a poner?</i>	30.
psàn		sister, brother	<i>hermana</i>	123.
pʃil	bʒil	cane	<i>carrizo</i>	47.
pʃil:	midzgi	spark	<i>chispa</i>	9.
pʃòz	bʒoz, ŋ <sup>w</sup> laj	priest	<i>sacerdote</i>	114.
sĩ	sî	will buy	<i>va a comprar</i>	5.
sĩl		early morning	<i>temprano</i>	12.
sjà	sjá	corn	<i>elote</i>	1.
ʃík	ʃik	arm	<i>brazo, hombro</i>	64.
ʃkódz	ʃkodz	tail	<i>cola</i>	120.
ʃòʔp~ ʃòp	ʃop	six	<i>seis</i>	31.
ʃùn	ʃun	eight	<i>ocho</i>	111.
tàp	tap	four	<i>cuatro</i>	19.
tíb~b̥	tib	one, a	<i>uno, un</i>	7.
tsij	tsij	voice	<i>voz</i>	10.
tʃen	tʃen	stain, rust	<i>mancha, oxidado</i>	90.
tʃën:	tʃen:	belongs to	<i>pertenece a</i>	73.
tʃib	tʃib	goat	<i>chivo</i>	45.
tʃòp	tʃóp	two	<i>dos</i>	62.
wbán	wbăn	lived	<i>vivió</i>	102.
wbiʃ		fell	<i>se cayó</i>	130.
wdzeb	wdzeb	was afraid	<i>asustado</i>	116.
wdzín:	wdzin:	arrived	<i>llegó</i>	88.
wgaʔ	wgaʔ	caught	<i>atrapó</i>	65.
wjàs	wjas	jumped	<i>brincó</i>	118.
wjáʒ	wjaz	bathed	<i>bañó</i>	119.
wkaʔa	wkaʔ	bought	<i>compró</i>	26.
wlán:	wlan:	held	<i>abrazó</i>	54.
wlán:	wlan:	arrived	<i>llegó</i>	57.
wsap	wsap	protect from the elements	<i>proteger de la lluvia,</i>	29.
wtʃep		pushed	<i>empujó</i>	115.
wzak	wzak	happened	<i>se le pasó</i>	32.

zàkú	zako	okay	<i>se puede</i>	126.
zĩ ~ dzi	zî	always buys	<i>siempre compra</i>	28.
zid	zjat	will come	<i>ya viene</i>	127.
zín	zin	belt	<i>faja</i>	89.
zjà~zja	zia	left	<i>se fue</i>	25.
zàb	zab	clothing	<i>ropa de alguien</i>	50.
ʒgap~ʃkap	ʃkap	pat	<i>palmadita,</i>	91.
zíd	zid	in the midst of	<i>entre</i>	40.
(zìg)	(zìg)	bowl	<i>jícara</i>	14.
zìk~dzìk	zìk	like	<i>como, parecido</i>	52.
zòʔb	zob	kernels	<i>granos de maíz</i>	33.

## APPENDIX C

### Example of a creaky vowel

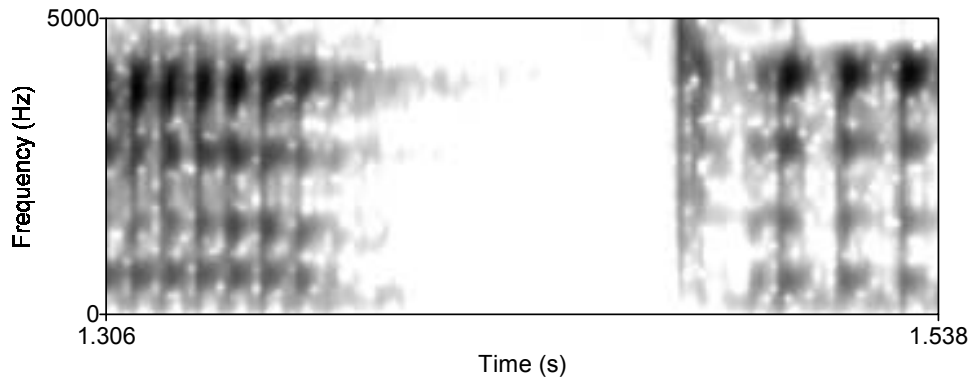


Illustration of unexpected glottal feature causing creaky /a/ following gyat 'tortilla'

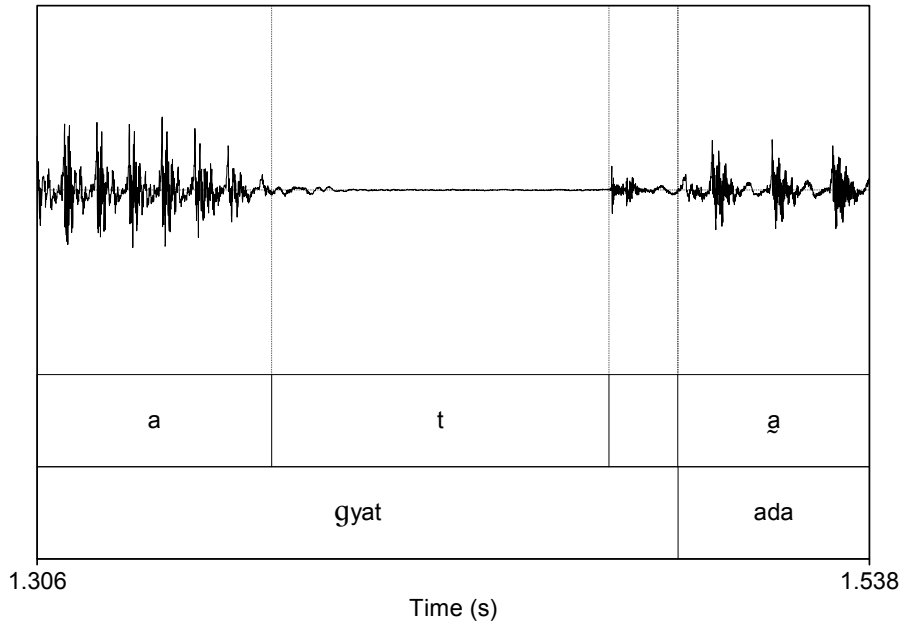


Figure 13. Spectrogram and wave file of creaky /a/ in the context of *kne? gjat* *ada inedl* as spoken by SFOZ Speaker three

## REFERENCES

- Avelino, Heriberto. 2001. The phonetic correlates of fortis-lenis in Yalálag Zapotec Consonants. University of California at Los Angeles. MA thesis.
- Beam de Azcona, Rosemary. 1998. Preliminary remarks on tone in Coatlán-Loxicha Zapotec. *Workshop on American Indigenous Languages*. Santa Barbara, CA: University of California at Santa Barbara, Department of Linguistics.
- Beam de Azcona & Mary Paster, eds. 2004. Introducing San Agustín Mixtepec Zapotec. *Conference on Otomanguan & Oaxacan Languages. Report 13: Survey of California and other Indian Languages. March 19-21, 2004*. University of California at Berkeley.
- Benton, Joseph P. 1987. Clause and sentence-level word order and discourse strategy in Chichicapan Zapotec oral narrative discourse. *SIL Mexico Workpapers* 9. 72-84.
- Benton, Joseph P. 1988. Proto-Zapotec Phonology. ms. SIL.
- Bickford, J. Albert. 1985. Fortis/Lenis Consonants in Guichicovi Mixe: A Preliminary Acoustic Study. *Work Papers of the Summer Insitutute of Linguistics* 29. 195-207. Grand Forks, ND: University of North Dakota.
- Bickmore, Lee & George Aaron Broadwell. 1998. High Tone Docking in Sierra Juarez Zapotec. *International Journal of American Linguistics* 64(1). 37-67.
- Boersma, Paul, & David Weenink. 2008. *Praat: Doing phonetics by computer* (Version 5.0.25) [Computer program]. Retrieved from <http://www.praat.org> (July 20, 2008.)
- Butler H. Inez M. 1980. *Grammatica Zapoteca: Zapoteco de Yatzachi el Bajo*. (Serie Gramáticas de lenguas indígenas de México.) México: Instituto Lingüístico de Verano (ILV).
- Butler Haworth, Inez M. 1997. *Diccionario Zapoteco de Yatzachi el Bajo, Yatzachi el Alto, Oaxaca*, 1st edn. Summer Institute of Linguistics (SIL). Tucson, AZ.
- Catford, J.C. 1977. *Fundamental Problems in Phonetics*. Bloomington: Indiana University Press.
- Dixon, R.M.W. & Alexandra Y. Aikenvald (eds.). 2000. *Changing valency: Case studies in transitivity*. Cambridge University Press.

- Fernández de Miranda, Ma. Teresa. 1995. *El Protozapoteco*. (Serie estudios de lingüística y literatura 28). Miguel J. Piper & Doris A. Bartholomew (eds). Colmex INAH (Instituto Nacional de Antropología e Historia).
- Fischer- Jørgensen, Eli. 1969. Voicing, tenseness and aspiration in stop consonants, with special reference to French and Danish. *ARIPUC* 3. 63-114.
- Gittlen, Laura & Stephen A. Marlett. 1985. Ñumí Mixtec syllable structure and morphology. *Work Papers of the Summer Insitute of Linguistics* 29. 175-94. Grand Forks, ND: University of North Dakota.
- Gordon, Raymond G., Jr. (ed.), 2005. *Ethnologue: Languages of the World*, 15th edn. Dallas, TX: SIL International. Online Version: [www.ethnologue.com](http://www.ethnologue.com)
- Heise, Jennifer Lynn. 2003. Participant Reference and Tracking in San Francisco Ozolotepec Zapotec. Dallas: Graduate Institute of Applied Linguistics. MA thesis.
- Hopkins, Mary L. 1995. Narrative peak in Xanaguía Zapotec. *SIL Mexico Workpapers* 11. 17-36.
- Hopkins, Mary L. (n.d.) 501 Verbs: Santa Catarina Xanaguía Zapotec. ms. SIL.
- INEGI (Instituto Nacional de Estadística y Geografía e Informática). 2000. *Censo*. México, D.F.: INEGI.
- Itô, Junko. 1988. Syllable theory in prosodic phonology. (Series: Outstanding dissertations in linguistics) New York: Garland.
- Jaeger, Jeri. 1983. The fortis/lenis question: evidence from Zapotec and Jawañ. *Journal of Phonetics*. . 177-189.
- Jakobson, Roman & Gunnar Fant & Morris Halle. 1951. *Preliminaries to Speech Analysis: The distinctive features and their correlates*. Cambridge, MA: MIT Press.
- Jakobson, Roman & Linda Waugh. 1979. *The Sound Shape of Language*. Bloomington, IN: Indiana University Press.
- Jones, Ted E. & Lyle M. Knudson. 1977. Guelavia Zapotec Phonology. In Merrifield, William R. ed. *Studies in Otomanguan Phonology* 54. 163-180. Mexico: Summer Institute of Linguistics & the University of Texas at Arlington.
- Kent, Raymond D. & Charles Read. 2002. *Acoustic Analysis of Speech*, 2nd edn. Canada: Singular, Thomson Learning.
- Kreikebaum, Wolfram. 1987. Fronting and related features in Santo Domingo Albarradas Zapotec. *SIL Mexico Workpapers* 9. 33-71.

- Ladefoged, Peter. 1971. *Preliminaries to Linguistic Phonetics*. Chicago: University of Chicago Press.
- Ladefoged, Peter. 2003. *Phonetic Data Analysis: An Introduction to Fieldwork and Instrumental Techniques*. Blackwell.
- Lisker, Leigh. 1957. Closure duration and the intervocalic voiced-voiceless distinction in English. *Language* 33. 215-230.
- Lofquist, Anders. 1976. A study of subglottal pressure during the production of Swedish stops. *Journal of Phonetics* 3. 175-189.
- López L., Filemón & Ronaldo Newberg Y. 1990. *La conjugación del verbo zapoteco: Zapoteco de Yalálag*. México, DF: Instituto Lingüístico de Verano, A.C.
- Lyman, Larry & Rosemary Lyman. 1977. Choapan Zapotec Phonology. In William R. Merrifield (ed.), *Studies in Otomanguean Phonology* 54. 137-161. Mexico: Summer Institute of Linguistics & the University of Texas at Arlington.
- Macaulay, Monica & Joseph C. Salmons. 1995. The Phonology of Glottalization in Mixtec. *International Journal of American Linguistics* 61. 38-61.
- Maddieson, Ian. 1977. Phonetic Universals. In William J. Hardcastle & John Lauer (eds.), *The handbook of phonetic sciences*. Blackwell.
- Malécot, André. 1970. The Lenis-Fortis Opposition: Its Physiological Parameters. *The Journal of the Acoustical Society of America* 47(6). 1588.
- Marks, Donna Louise. 1976. Zapotec verb morphology: categories and tonomechanics with special attention to Sierra Juarez Zapotec. MA thesis.
- Marlett, Stephen & Velma Pickett. 1987. The syllable structure and aspect morphology of Isthmus Zapotec. *International Journal of American Linguistics* 53. 398-422.
- Marlett, Stephen A. 1993. Zapotec Pronoun Classification. *International Journal of American Linguistics* 59. 82-101.
- Merrill, Beth. n.d. Classifications of Zapotec. ms. SIL International.
- Merrill, Elizabeth D. 2008a. Illustrations of the IPA: Tilquiapan Zapotec. *Journal of the International Phonetic Association* 38(1). 107-114.
- Merrill, Elizabeth D. 2008b. The formation of causative in Tilquiapan Zapotec. Forthcoming. SIL International.
- Nellis, Donald G. & Barbara E. Hollenbach. 1980. Fortis versus lenis in Cajones Zapotec phonology. *International Journal of American Linguistics* 46. 92-105.
- Nelson, Julia Louise. n.d. Phonology Sketch of San Francisco Ozolotepec. ms. SIL

International.

- Nelson, Julia Louise. 2004. Tone and glottalization on nominals in San Juan Mixtepec Zapotec. Arlington: University of Texas. MA thesis.
- Newberg, Ronald. 1987. Participant Accessibility in Yalálag Zapotec. *SIL Mexico Workpapers* 9. 12-25.
- Olive, Julie Nan. 1995. Speech verbs in Xanaguia Zapotec narrative. *SIL Mexico Workpapers* 11. 47-52.
- Operstein, Natalie. 2004. Spanish Loanwords and the Historical Phonology of Zaniza Zapotec. *Conference on Otomanguean and Oaxacan Languages. Report* 13. 107-116. *Survey of California and other Indian Languages. March 19-21, 2004.* University of California at Berkeley.
- Pickett, Velma. 1951. Nonphonemic Stress: A Problem in Stress Placement in Isthmus Zapotec. *Word* 7(1). 60-65.
- Pickett, Velma. 1960. The Grammatical Hierarchy of Isthmus Zapotec. Bernard Bloch (ed.), Supplement Language dissertation 56. *Language Journal of the Linguistic Society of America* 36(1). Baltimore, MD: Waverly Press.
- Pickett, Velma B. 1967. Isthmus Zapotec. In N.A. McQuown (ed.), *Handbook of Middle American Indians, Linguistics* 5. 291-310. Austin: University of Texas.
- Pike, Eunice V. & Priscilla C. Small. 1974. Downstepping terrace tone in Coatzospan Mixtec. In Ruth M. Brend (ed.), *Advances in tagmemics. North-Holland Linguistic Series*, 9. 105-134. Amsterdam: North-Holland.
- Radin, Paul. 1930. A preliminary sketch of the Zapotec language. *Language* 6. 64-95.
- Reeck, Roger. 1991. A trilingual dictionary in Zapotec, English and Spanish. Puebla, Mexico: Universidad de las Americas-Puebla. MA thesis.
- Regnier, Sue. 1993. Quiegolani Zapotec phonology. *Work Papers of the Summer Institute of Linguistics* 37. 37-63. Grand Forks, ND: University of North Dakota.
- Rendón, Juan José. 1995. *Diversificación de las lenguas zapotecas. Instituto México: Oaxaqueño de las culturas centro de investigaciones y estudios superiores de antropología social.*
- Robinson, Dow F, 1963. Field Notes on Coatlán Zapotec. *Hartford Studies in Linguistics* 7. 2-3. Hartford: Hartford Seminary Foundation.



- SIL International. 2008. *Speech Analyzer: A speech analysis tool* (Version 3.0.1) [Computer program]. Retrieved from <http://www.sil.org/computing/speechtools/> (July 20, 2008)
- Speck, Charles. 1978. The Phonology of Texmelucan Zapotec verb irregularity. University of North Dakota, Grand Forks, ND. MA Thesis.
- Smith Stark, Thomas C. 2001. *El estado actual de los estudios de las lenguas Mistecanas y Zapotecanas. III Coloquio Internacional de Lingüística Mauricio Swadesh*. Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México.
- Swadesh, Morris. 1947. The Phonemic Structure of Proto-zapotec. *International Journal of American Linguistics* 13. 220-30.
- Thiessen, Grace. 1987. Western Ixtlán Zapotec Phonology. ms. SIL.
- Ward, Michael. 1987. A focus particle in Quiquitani Zapotec. *SIL Mexico Workpapers* 9. 26-32.
- Zemlin, Willard R. 1997. *Speech and Hearing Science: Anatomy and Physiology*, 4th edn.