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Santa Ana Del Valle Zapotec Phonation

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by

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ABSTRACT OF THE THESIS

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Accounts of the phonations of Zapotec languages describe more interesting phonations than expected. The goal of this study is to investigate the phonation and tones in Santa Ana del Valle Zapotec, experimentally.

The first part of the study defines the phonations and tones of SADVZ. Speakers produced words that could exhibit a more complex phonation contrast than simply breathy, modal and creaky. H1-F3 was the measure of phonation for the male speakers; H1-H2, for female. Results showed that SADVZ's three-way contrast of modal, breathy and creaky vowels is distinguished acoustically in the directions expected. No change in phonation within a syllable was found. Each of the phonations is associated with one or two tonal patterns.

The second part of the study examines the effects of f0 and position on phonation. First, it was determined that f0 influenced phonation (not position-in-utterance). Speakers produced words with each phonation in four prosodic positions: in isolation (high f0), sentence initially (high f0), sentence medially (mid f0), and sentence finally (lower f0). In medial position, a contrast between breathy, modal and creaky voice was found. In

sentence-final position, when tokens had lower f0, the contrast between modal, breathy and creaky voice was preserved, but with the modal and breathy words both breathier. In both isolation and sentence-initial position, when tokens had higher f0, the contrast between phonations was reduced to modal versus creaky. The effect of f0 is so strong that the phonemic three-way contrast in phonations is not preserved when the f0 is high.

1 Introduction

The Zapotec language family provides an interesting case for the study of contrastive phonation.[1] The various Zapotec languages have been described as having complex phonation contrasts that vary from language to language. Accounts of Zapotec languages describe more interesting phonations than are typically expected, such as the possibility of a four-way phonation contrast and the possibility of complex phonation contours within a single syllable. In addition, many accounts report phonations that are coupled with a wide array of tone. However, little is known about the phonetic properties of these phonation and tones. This study investigates the phonation and tones in Santa Ana del Valle Zapotec, experimentally, in the hopes that this approach will shed light on the complex phonation and tones of these languages.

Santa Ana del Valle Zapotec (hereafter SADVZ) is an OtoManguean language spoken in Santa Ana del Valle, Oaxaca, Mexico. The Ethnologue (Grimes, 1990) classifies SADVZ into the San Juan Guelavía Zapotec subgroup. (The Ethnologue classifies the numerous Zapotec languages into 58 different sub-groupings based on a variety of complex criteria.) The San Juan Guelavía subgroup contains the numerous and diverse languages spoken in the Valley of Oaxaca such as San Juan Guelavía (for which the subgroup is named), San Lucas Quiaviní, Tlacolula, Jalieza , Mitla and Teotitlán del Valle Zapotec. There are approximately 28,000 speakers (1990 census) for the entire San Juan Guelavía Zapotec subgroup; it is not known what portion of this is composed of SADVZ speakers (Grimes, 1990).

[1] Abbreviations: perf = perfective, hab = habitual, irr = irrealis.

The Ethnologue considers San Juan Guelavía Zapotec to be the 'lingua franca' of the group, even though it is quite different from the other Zapotec languages spoken in the Valley. (The languages within the San Juan Guelavia subgroup have various levels of mutual intelligibility (59-100%).) For example, San Juan Guelavía Zapotec does not contain breathy vowels (Jones and Knudson, 1997) while many of the other languages in the subgroup do (e.g. San Lucas Quiaviní Zapotec (Munro and Lopez et al., 1999), Mitla Zapotec (Stubblefield and Stubblefield, 1991).

Perhaps the best studied languages in this subgroup are San Juan Guelavía Zapotec (Jones and Knudson, 1997) and San Lucas Quiaviní Zapotec (Munro and Lopez et al. , 1999). While both of these languages have a practical orthography, this orthography is not used for SADVZ, which remains unwritten.

There has been no previous research on SADVZ, except for an unpublished wordlist produced by G. Aaron Broadwell (1991). The data and description here come from fieldwork conducted at UCLA by Argelia Andrade, Olivia Martínez, Pamela Munro and myself. The analysis presented here and any errors are my own.

1.1 Phonemic Inventory

SADVZ has 30 consonants and 6 vowels, which are presented in the sections below.

1.1.1 Consonants

The consonant inventory of SADVZ is shown in Table 1. The Zapotec languages have been described as having a fortis/lenis contrast for both the obstruents and sonorants, rather than a difference in voicing (Jaeger, 1983; Avelino, 2001). The fortis/lenis distinction is characterized by greater duration and increased energy for the

fortis consonants compared to the lenis ones. In the chart below, the symbol to the left of each pair is fortis and the right, lenis. (I have represented the fortis/lenis obstruents with the symbols for voiceless and voiced consonants, respectively, since this is their typical representation in Zapotec languages. The fortis/lenis sonorants are represented by their length contrast.) Consonants in parenthesis only appear in loan words, which are generally from Spanish.

Table 1:Consonants of SADVZ

	Labial	Dental	palatal-alv.	retroflex	palatal	velar	glottal
Stop	(p) b	t d				k g	ʔ
fricative	(f)	s z	ʃ ʒ	ʂ ʐ			
affricate			tʃ dʒ				
nasals	mː m	nː n				ŋː ŋ	
laterals		lː l					
approximants					j	(w)	
Trill		rː r					
Tap		ɾː ɾ					

I have analyzed the glottal stop as a phoneme, even though the distribution is somewhat defective since it only occurs after a vowel. Analyses of other Zapotec languages include the glottal stop as a vocalic feature and vowels that bear this feature are referred to as a "checked vowel" (Munro and Lopez et al., 1999; Jones and Knudson, 1977; Nellis and Hollenbach, 1980). The possibility of checked phonation will be considered in this study.

In addition, SADVZ stops are optionally released word finally and the lenis stops appear to be in free variation with fricatives. The bilabial stop [b] freely alternates with [β], the velar stop [g] alternates with [h], and the alveolar stop [d] alternates with [ð].

1.1.2 Vowels

SADVZ has six vowels qualities /a,e,i,o,u,ɨ/ which are presented in Table 2. The vowel /ɨ/ is rare.

Table 2: **Vowels of SADVZ**

	Front	Mid	Back
high	I	ɨ	u
mid	E		o
low			a

1.2 Phonation and Tone

No research has been done on the phonation and tones of SADVZ. It is expected that this language shares some of the features of phonation and tone found in other Zapotec languages. Section 2.1 will be an overview of phonation and tone in Zapotec languages.

1.3 Syntax

While a full description of the syntax of SADVZ is out of the scope of this project, it is necessary to mention some basic syntactic constructions that are relevant to this study.

1.3.1 Basic Word Order

SADVZ, like most Zapotec languages, is a VSO language. This can be seen in the following example where the verb 'see' [guṇ̣] is followed by the subject 'Elena' [elen] and object 'cow' [bag] :

1. gu- ṇ̣ elen bag
   perf -see Elena cow
   "Elena saw a cow."

1.3.2 Focus

SADVZ also allows SVO and OVS word order, in which case the preverbal material has a focused reading. Since Zapotec does not mark subject or object, the preverbal material is ambiguous. For example in 2, 'Elena' [elen] is focused and can be interpreted as either the subject or the object.

2. elen gu- nạ̈ bag
   Elena perf-see cow
   "ELENA saw a cow./The cow saw ELENA."

1.3.3 Negation

In a negative, [teka] "no" is in sentence initial position, followed by the normal VSO word order.

3. teka gu - dau elen lim
   No perf-eat Elena limes
   "Elena didn't eat limes."

1.3.3.1 Negative Yes/No Questions

Negative yes/no questions are identical to negative statements and only distinguished by a change in intonation. Thus, the sentence [teka gudau elen lim] can mean "Elena didn't eat limes" or "Didn't Elena eat limes?" depending on the intonation.

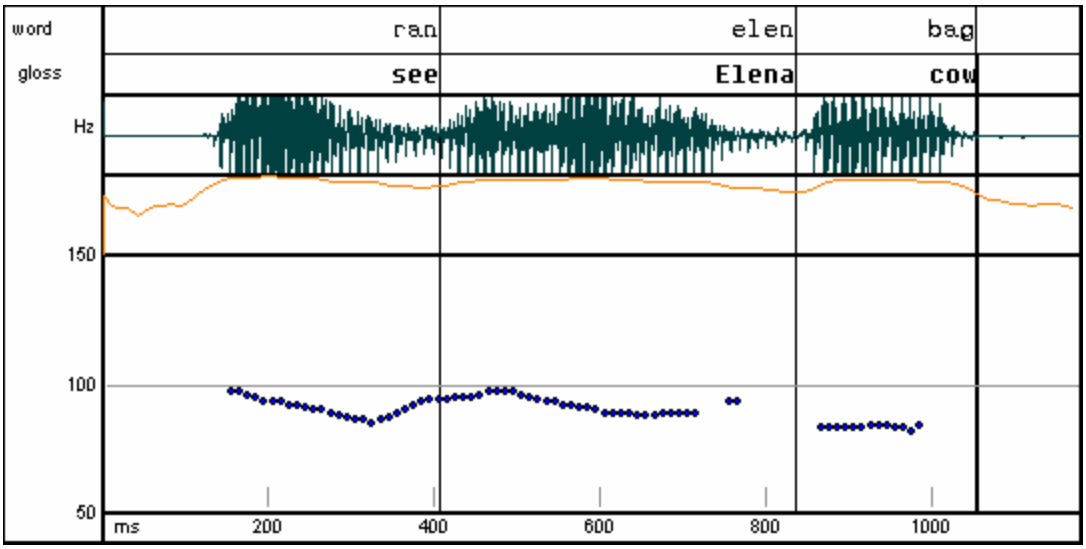
1.4 Some Basics of SADVZ Intonation

In this section, I will discuss the basic intonational contours associated with declaratives, focus, wh-questions and negative yes-no questions. Each sentence (except Figure 3) contains the target word 'cow' [bág], which has modal phonation and a high level tone. Each sentence was produced by the same speaker. The intonation of these sentence types is relevant for the experiment discussed in section 8.

1.4.1 Basic Declaratives

In basic declaratives, the end of the sentence has an overall low f0 and there is no sentence final fall of the f0, regardless of lexical f0. In Figure 1, the sentence ends with a low level f0.

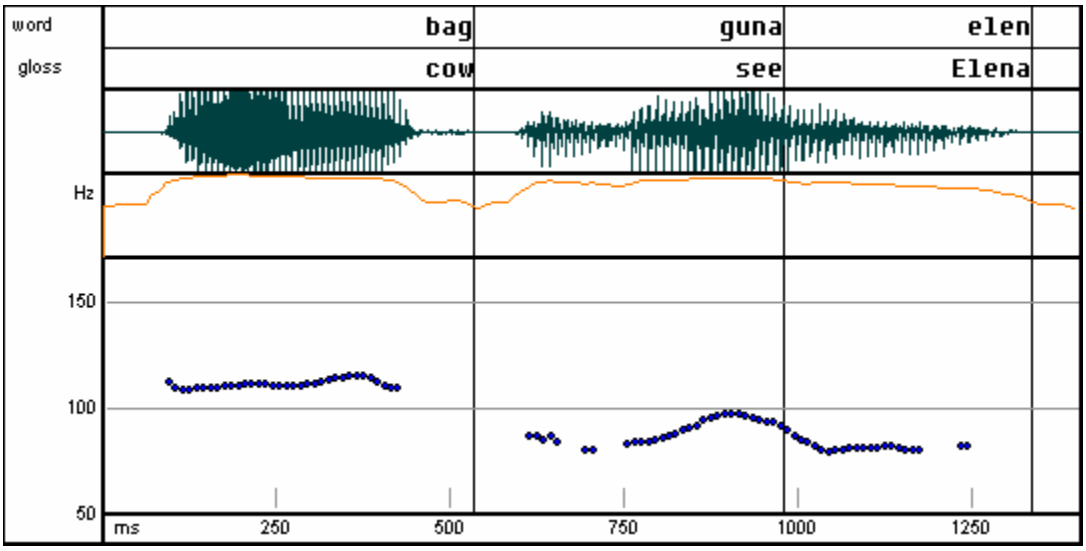
Figure 1: Pitchtrack of [ɾan elen bág] "Elena sees a cow."



1.4.2 Focus

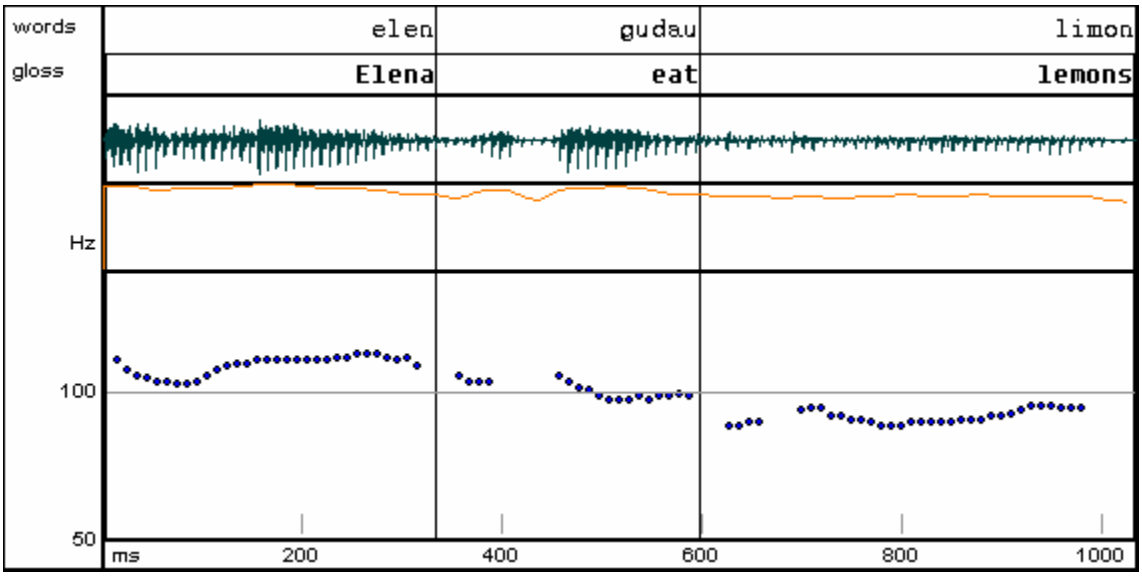
When a word is focused, it has an overall higher f0 and a greater duration than when it is uttered in a non-focus context. Compare the f0 of the word 'cow' [bág] in focused position in Figure 2, to sentence final position in Figure 1. The focused production has an overall higher, but still level, f0. There is no fall of the f0 on the focus item. The focus item is, by itself, a single intonational phrase.

Figure 2: [bág guna elen] "Elena saw a COW./ A COW saw Elena."



An additional example, with [elen] 'Elena' focused, is presented in Figure 3. Again, there is no final fall of the f0 on the focused item.

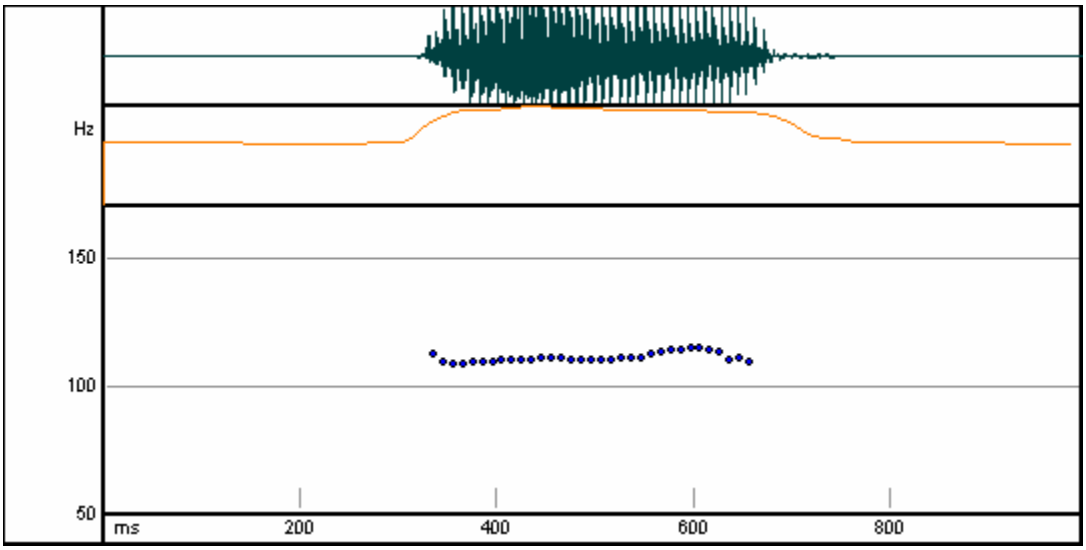
Figure 3: [elén gudau limoni] "ELENA eats lemons."



1.4.3 Isolation

Words uttered in isolation display the same f0 contour as words that are focused. When a word in uttered in isolation. the f0 is still level, but overall higher than when produced in sentence final position in the declarative (Figure 1). (A direct comparison cannot be made between a word in isolation and a non-focused word in sentence initial position. Verbs are the only element that can be in non-focused sentence initial position. But, verbs are difficult to elicit in isolation.)

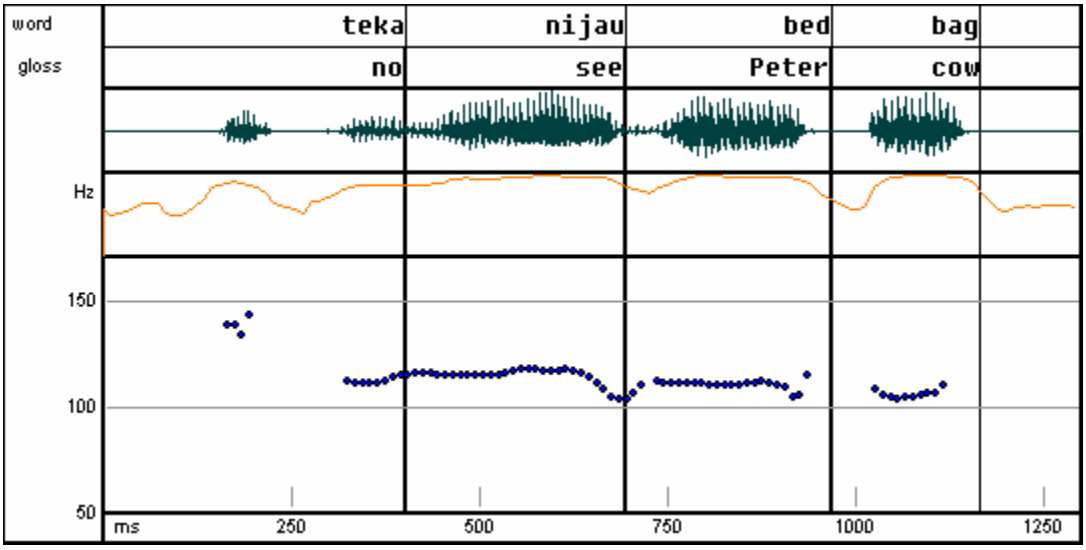
Figure 4: [bág] 'cow'



1.4.4 Negative Yes/No Questions

Negative yes/no questions have a higher pitch range than declaratives. In Figure 5, 'cow' [bág] is higher (but still level) than when produced in sentence final position in a basic declarative (Figure 1).

Figure 5: [teka nijau bed bág] "Didn't Peter see the cow?"



1.5 Structure of SADVZ Words

The vast majority of native Zapotec words are monosyllabic, while Spanish loan words are typically polysyllabic. Native polysyllabic words can be formed by the addition of morphemes; these often create changes in phonation. For example, the irrealis aspect can trigger a change from breathy to modal phonation. In the example below, the verb "to wash" [rigï̤bi] has a breathy vowel in the habitual form (4), but a modal verb in the irrealis[2] form (5):

4. ri-gï̤bi
   hab-wash

5. k-ibi
   irr.-wash

[2] The underlying form of the irrealis of 'wash' is /g- gï̤bi/. The /g-g/ sequence is realized phonetically as [k].

To avoid any changes in phonation, the majority of words examined in this study were monosyllabic. Section 6 of this study concentrates on polysyllabic words. These words were carefully chosen to avoid morphemes that would trigger changes in phonation.

1.6 Influence of Spanish

For over 500 years, Spanish words have been borrowed into SADVZ. The borrowing process is a complicated one, and will not be fully described here. However, I will mention some aspects that are relevant to this thesis.

When a word is borrowed from Spanish into SADVZ, several changes take place. The unstressed final vowel of the Spanish word is always dropped. In each of the examples in Table 3, the final vowel of the Spanish has been dropped in the SADVZ. For example, the Spanish [ˈlata] '(tin) can' *lata* is [lát] in SADVZ.

In addition, any other unstressed vowel or syllable may be dropped (though the factors which determine whether an unstressed syllable will be deleted or will remain have yet to be determined). For example, [gaˈbino] 'Gabino' *Gabino,* is borrowed into SADVZ as [bín], losing both the final vowel [o] and the unstressed syllable [ga]. But, [baˈɾato] 'cheap' *barato*, also a three syllable word, only loses the final vowel in the SADVZ [baɾăt].

Spanish vowels are always borrowed with modal phonation. Modal phonation, on both native and borrowed words, can have either a high or a high rising tone. Thus, borrowed words exhibit a tonal contrast not in the original language. Examples of borrowed words that display this tonal contrast are presented in Table 3. At this time, the

factor(s) that determine whether a loanword will be borrowed with a high or a high rising tone is not known. Cross-linguistically, a usual conditioning factor for a high versus rising tonal distinction is the voicing of the initial consonant; this does not seem to be the case for SADVZ . For example, [ˈ falda] *falda* 'skirt' is borrowed with a high rising tone [fǎld] but [ˈfab] *faba* 'brand of detergent (Fab)' is borrowed with a high tone [fáb]. Nonetheless, since minimal pairs distinguishing the high and high rising tones have not been found, it is possible that tone is predictable in borrowed words. Further research is necessary to fully understand the borrowing process.

Table 3: Spanish Loan Words

Spanish	SADVZ
[ˈlata] *lata* '(tin) can'	[lát]
[ˈpato] *pato* 'duck'	[bǎd]
[baˈɾato] *barato 'cheap'*	[baɾǎt]
[ˈfab] *faba* 'brand of detergent (Fab)'	[fáb]
[gaˈbino] *Gabino* 'Gabino'	[bín]
[ˈfalda] *falda* 'skirt'	[fǎld]

In general, most of the words with modal phonation recorded for this study are loans from Spanish. In fact, it was difficult to find native words with modal phonation, though many neighboring languages do have native words with modal vowels and modal vowels are believed to have existed in Proto-Zapotec (Swadesh, 1947).

2 Phonation

The goal of this study is to understand phonation and tones, and the complex relation between the two, in a Zapotec language. But, before discussing the results

obtained for SADVZ, I will review the descriptions of phonation and tone in other Zapotec languages and then present the phonetic literature on phonation, in general.

2.1 Overview of Phonation and Tone in Zapotec Languages

There are numerous and diverse accounts of the phonation types and tones in Zapotec languages. Here, I briefly summarize some of the analyses of Zapotec phonation and tones.

Cajonos Zapotec (Nellis and Hollenbach, 1980) includes four vowels /i,o,e,a/ which can occur with one of three phonations: modal, checked, and laryngealized. Checked vowels, which only occur in open syllables, are articulated as a vowel followed by a glottal stop. Laryngealized vowels are defined as "a rapid sequence of two vowels with an intervening glottal stop" (Nellis and Hollenbach, 1980: 99) that is analyzed as a single-vowel segment. There is also a four-way tonal distinction between high, low and mid tones, and a "downglide from high to low tone" (Nellis and Hollenbach, 1980: 99). The tonal distribution is quite complex and determined by a number of factors such as the number of syllables in a word, if the vowel is followed by a lenis or fortis consonant, and the phonation of the vowel. For example, in "... monosyllabic roots with open syllables, simple vowels closed by either a fortis or lenis consonant, or checked vowels, there is a contrast only among the high...low...and glide" (Nellis and Hollenbach, 1980: 101). In monosyllabic roots "with laryngealized vowels, there is a four way contrast: both morae may have high tone, both low tone, the first high tone and the second mid, or the first high and the second low" (Nellis and Hollenbach, 1980: 101). In native disyllabic roots,

the tonal pattern is “high-high, low-high, and low-low” (Nellis and Hollenbach, 1980: 101).

Choapan Zapotec (Lyman and Lyman, 1977) includes six vowels /i,e,ɛ,u,o,a/ and three phonations: laryngealized, checked, modal (“unchecked”). A laryngealized vowel is a sequence of two vowels, which do not have to be of the same quality, with an intervening glottal stop; and a checked vowel is a vowel followed by a glottal stop. A typical Choapan syllable can have up to three phonation types over one vowel “segment”. The tones of Choapan Zapotec include: a high tone (which is slightly rising), a low tone (which is perceptually longer in duration than the other tones) and a mid tone. It is not clear if there is any relationship between tone and phonation in this language.

San Juan Guelavía (Jones and Knudsen, 1977) includes six vowels /i,e, ɨ, a, u, o/ each of which can occur with one of three phonations: modal, laryngealized or checked. Modal and checked vowels contrast phonemically. Laryngealized and checked vowels occur in complementary distribution; laryngealized vowels occur preceding lenis consonants or glides and checked vowels occur elsewhere. In addition, there are three level phonemic tones: low, mid, and high, which can occur on any of the three phonations.

San Lucas Quiaviní Zapotec (SLQZ) (Munro and Lopez et al., 1999) includes six vowels /a,e,i,o,u, ɨ/ which can occur with four phonations: modal, breathy, checked and creaky. A checked vowel is defined as a vowel followed by a glottal stop; creaky vowels co-occur in syllables with checked vowels. An SLQZ syllable can have up to three different phonations. “The fullest SLQZ syllable template is CCGVVVCG, where C represents a true consonant, G a glide and V is a vowel” (Munro and Lopez et al.,

1999:3). Most often, "only the final syllable of a non-compound uninflected native word … is as elaborated as this template" (Munro and Lopez et al., 1999:3). Within the syllable the VVV sequence, referred to as the vowel complex, "may contain up to three individual vowels, each with its own phonation" (Munro and Lopez et al., 1999:3). SLQZ is also a tonal language, but the tones are dependent on the number and type of phonations found in a word. A characterization of the tonal system of SLQZ is as follows: "plain vowels (especially two plain vowels together) have high tone, creaky vowels have low tone ... and final phrasal breathy vowels have an extra-low tone. The tone of checked and other breathy vowels is derived from the vowel complex environment in which they occur" (Munro and Lopez et al., 1999:3).

In sum, the phonations of Zapotec languages are complex and vary across languages. Some studies describe either a four-way contrast between modal, creaky, breathy and glottalized ("checked") vowels (e.g. San Lucas Quiaviní Zapotec) or a three-way contrast between modal, laryngealized or checked vowels (e.g. Cajonos Zapotec; Choapan Zapotec; San Juan Guelavía). For many analyses, it is not clear to what extent the checked vowel is thought to be a distinct phonation. It is possible that the checked vowel is a combination of a modal vowel followed by a glottal stop, but this is not explicit. On the same note, some analyses use the term laryngealized, but it is not clear if the term laryngealized is used to refer to creaky phonation or the presence of a glottal stop.

Tonal analyses also vary from language to language. Languages such as San Lucas Quiaviní Zapotec (Munro and Lopez et al., 1999) describe a strong correlation between

tone and phonation, while in languages such as San Juan Guelavía (Jones and Knudsen, 1977) there is no link between tone and phonation type.

In addition, some accounts describe the possibility of having up to three phonation types in one syllable (San Lucas Quiaviní Zapotec (Munro and Lopez et al., 1999) and Choapan Zapotec (Lyman and Lyman, 1977)).

Based on the accounts of other Zapotec languages, it is possible that SADVZ could have up to four phonations, which may or may not be correlated with tone, and could have changes in phonation within a single syllable.

2.2 Overview of Phonation across Languages

In this section, I will present an overview of phonation across languages, to see how Zapotec phonation fits in cross-linguistically. I will begin by discussing how the different phonations are characterized in the phonetic literature, limiting the discussion to languages that use phonation types contrastively, and then discuss properties commonly associated with non-modal phonation, such as an increase duration and localization of non-modal phonation.

There are three main types of phonations that occur cross-linguistically: modal, breathy, and creaky voice. Modal voice is the neutral phonation to which other phonations are compared. Modal phonation is characterized by vocal folds with normal adductive and longitudinal tension. During modal phonation, the vocal folds are open during approximately half of the glottal cycle and closed for the other half, which results in regularly spaced glottal pulses.

Breathy phonation is characterized by vocal folds that vibrate, but without much contact. For breathy voice, there is minimal adductive tension and little longitudinal tension in the vocal folds. Breathy voice is contrasted with modal voice on vowels in languages such as Gujarati and Tamang (as reviewed by Gordon and Ladefoged, 2002).

Creaky voice is distinguished from breathy and modal voice by little longitudinal tension and high adductive tension in the vocal folds. During creaky voice, the vocal folds are opened just enough to allow for voicing, which often results in irregularly spaced glottal pulses. Creaky voice is contrasted with modal voice on vowels in Sedang and Southern Nambiquara. In addition, certain languages use a voice quality that is similar to creaky voice, but does not fall precisely under the category of creaky. Examples of this are Bruu, which has a contrast involving stiff and slack vocal folds and !Xóõ, which uses a strident voice quality to distinguish vowels (as reviewed by Gordon and Ladefoged, 2002).

Some languages, such as Jalapa Mazatec and Chong, have a three way contrast in phonation between modal, breathy and creaky vowels (Blankenship, 1997). In the phonetic literature, no languages have been described as contrasting four phonation types or as having a sequence of contrastive non-modal phonations within a syllable. (Laver (1980) presents a more elaborate set of phonetic phonations, but only breathy, modal and creaky phonations are known to contrast.)

2.2.1 Localization of Non-Modal Phonation

Non-modal phonation on vowels is often confined to a portion of the vowel, especially in languages with contrastive phonation and contrastive tone. This is the case

for Jalapa Mazatec, a language with both contrastive tone and phonation. In this language, creaky and breathy voice are localized to the first portion of the vowel (Silverman, 1997; Blankenship, 1997). "The second portion of the vowel usually possesses severely weakened breathiness or creakiness, verging on modal phonation" (Silverman, 1997: 238). Silverman (1997) suggests that the localization of non-modal phonation is linked to the use of tone. Since non-modal phonation influences the saliency of the fundamental frequency, it would be difficult for creaky or breathy vowels to carry a full range of tonal contrasts. But, by limiting creaky or breathy voice to the beginning of the vowel, a portion of the vowel remains modal, and is thus able to support a full range of tonal contrasts (Silverman, 1997).

2.2.2 Duration of Vowels with Non-Modal Phonation

In some languages, non-modal phonation is associated with an increase in duration. This is true of Jalapa Mazatec, where creaky and breathy vowels are longer than modal vowels (Silverman et al. 1995). However, this is not true of all languages that have contrastive phonation. In San Lucas Quiaviní Zapotec, a language that also contrasts creaky and breathy vowels, there is not a significant duration difference between modal and non-modal phonation (Gordon and Ladefoged, 2002).

In summary, the Zapotec languages presented in section 2.1 are typologically unusual when compared cross-linguistically. For example, the four-way contrast in phonation (e.g. San Lucas Quiaviní Zapotec (Munro and Lopez et al., 1999) is typologically rare (since most languages have a maximum of three phonations). Another unusual feature is the sequence of phonations within a syllable that is described for some

Zapotec languages (e.g. Cajonos Zapotec (Nellis and Hollenbach, 1980) and San Lucas Quiaviní Zapotec (Munro and Lopez et al., 1999)). In the next section, I will review some of the common measurements of non-nodal phonation that can assist with identifying and defining the phonations of SADVZ.

3 Measuring Non-Modal Phonation

There are numerous acoustic and auditory properties that can be useful measures of non-modal phonation. In this section, I will briefly discuss some of the major methods for measuring non-modal phonation from an audio signal. (Measures based on the glottal source will not be discussed here.)

3.1 Periodicity

Creaky phonation is generally characterized by aperiodic glottal pulses. The aperiodicity of creaky vowels can be quantified by jitter, "the variation in duration of successive fundamental frequency cycles" (Gordon and Ladefoged, 2002:15). Jitter values are greater for creaky vowels than for modal or breathy vowels, where the glottal pulses are more regularly spaced.

Another measure of aperiodicity is cepstral peak prominence. A cepstrum is an "inverse spectrum generated by taking the FFT ... of the log magnitude values of a power spectrum" (Blankenship, 1997:8). For modal phonation, which is a periodic signal, the spectrum has well-defined harmonics and therefore a higher (in amplitude) cepstral peak. Non-modal phonation has less distinct harmonics and therefore a lower cepstral peak. (Blankenship, 1997).

3.2 Acoustic Intensity

In some languages, breathy and creaky voice are associated with a decrease in acoustic intensity compared to modal voice. This is true of breathy vowels in Gujarati and Chong, and of creaky vowels in Chong and Hupa (as reviewed by Gordon and Ladefoged, 2002).

3.3 Spectral Noise

Breathy voice can be characterized by an increase in spectral noise, particularly at higher frequencies. This noise is due to the continuous leakage of air through the glottis that occurs during breathy phonation. Languages that express breathiness through noise include Newar, Jalapa Mazatec and San Lucas Quiaviní Zapotec (as reviewed by Gordon and Ladefoged, 2002).

3.4 Spectral Tilt

One of the major ways to measure phonation is spectral tilt. Spectral tilt "is the degree to which intensity drops off as frequency increases" (Gordon and Ladefoged, 2002:15). Subtracting the amplitude of a higher frequency harmonic from the amplitude of the fundamental frequency (also called the first harmonic) yield a largely positive value for breathy vowels, a smaller positive value for modal vowels, and a negative value for creaky vowels. Spectral tilt has been a reliable measure of phonation in numerous languages such as Jalapa Mazatec, Gujarati, Kedang and Hmong (as reviewed by Gordon and Ladefoged, 2002).

There are different ways to characterize spectral tilt. Primarily, the difference between the amplitudes of the first and second harmonics, which correlates with the portion of the glottal cycles in which the glottis is open (the open quotient), has been used

to distinguish between modal and breathy phonation. However, other studies have made use of the relationship between H1 and harmonics exciting higher formants, which correlates with the abruptness of the closure of the vocal folds. These measurements include: H1-F3 (Stevens and Hanson, 1995; Blankenship, 1997), H1-F1 or H1-F2 (Ladefoged, 1983) and the average of H1-H2 compared to F1 (Stevens, 1988). Other studies have used the relationship of higher formants to lower ones such as F2-F3 (Klatt and Klatt, 1990).

Because they reflect different aspects of phonation, the different measures of spectral tilt do not always distinguish phonation types, even within a single language. For example, Blankenship (1997) found that in Mpi the measurement of H1 – H2 was a more reliable measurement of phonation on vowels with high tone than with mid or low tone. This suggests that in Mpi, the phonations of high tone vowels differ in their open quotient, while the phonations of low tone vowels do not.

4 Experimental Comparison of Phonation in SADVZ

Some of the Zapotec languages discussed in section 2.1 have a three-way contrast in phonation between breathy, creaky and modal vowels. However, other accounts propose a possible fourth phonation, a "checked vowel." Analyses also differ in the number and types of phonation that can be produced on a single syllable and the possible tonal contrast on different phonations. Thus, the numerous and diverse accounts of phonation in Zapotec languages cast doubt on a simple three way contrast as an accurate description for the phonation of SADVZ.

As a starting point, however, I propose a three-way contrast in phonation for SADVZ, because a near minimal triplet (distinguished by the phonation of the vowel) can be found. In the next section, I will determine the most appropriate measure of phonation to distinguish between the modal, breathy and creaky vowels of the near minimal triplet. Once a measure of phonation has been selected to distinguish the minimal triplet, it will be possible to see if the proposed three-way contrast in phonation should be expanded to include a possible fourth "checked" phonation or any other additional phonation types. In addition, once a measure of phonation has been selected, it will be possible to determine if phonation ever changes over the course of a syllable.

4.1 Selecting a Measurement of Phonation

Spectral measurements were used to measure phonation in SADVZ. Spectral noise, periodicity, and acoustic intensity were not measured.

4.1.1 Spectral Measurements

Different spectral measures yield different results depending on the nature of the phonation. In this section, I will concentrate on selecting the most appropriate measure of phonation in SADVZ. To determine which spectral measurement would best distinguish phonations for this study, 6 measures (H1-H2, H1+H2/2-F1, H1-F1, H1-F2, H1-F3, and F2-F3) were tested on the near minimal triplet consisting of the three words shown in Table 4. The near minimal triplet was selected based on cognates in a related language, San Lucas Quiaviní Zapotec. In Table 4, the San Lucas Quiaviní data is presented in the orthography for this language; I have written the phonation that

corresponds to the San Lucas Quiaviní orthographic conventions in parenthesis next to the word. Perception confirmed that these words were cognates in SADVZ.

Each word was uttered in sentence medial position, and repeated ten times by three native speakers ranging from 40-50 years of age (two male, Speaker 1 and Speaker 2, and one female, Speaker 3). Tokens were digitized and analyzed in PCQuirer at a sampling rate of 22050 Hz. Figures 6-8 and Figure 9-11 are spectrograms, waveforms and FFTs of the sample data as pronounced by Speaker 1 and Speaker 3, respectively. Each measurement was made over a 30 ms window, 50 ms before the end of the vowel. Spectrograms were used to position the 30 ms window. In the case of creaky token, this window would naturally include the silent intervals between pitch pulses. In addition, for the female speaker's breathy tokens, the window is partially during the noise interval. Measurements were taken manually from the FFT. H1 is equal to the height of f0 in the FFT; H2 equals the height of the second harmonic; F1, the amplitude of the highest harmonic near the first formant; F2, the amplitude of the highest harmonic near the second formant; F3, the amplitude of the highest harmonic near the third formant. The measure of phonation is the difference between the two measures (H1-H2, H1+H2/2-F1, H1-F1, H1-F2, H1-F3, and F2-F3) in dB.

Table 4: Words for the measurement trials and their cognates

SADVZ	Cognate in San Lucas Quiaviní Zapotec
lat ‘(tin) can’	la’t ‘(tin) can’ (modal)
l̤a̤t ‘place’	laht ‘place’ (breathy)
l̰a̰ts ‘field’	làa’ts ‘flat area’ (creaky)

Figure 6: Waveform, spectrogram and FFT of ‘can’ [lat] produced by Speaker 1. Pitch track fails at end.