

# LARYNGEALIZED VOWELS IN TWO ZAPOTEC LANGUAGES

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## ABSTRACT

Zapotec languages contrast three types of laryngealized vowels: (1) ‘checked’, a vowel followed by a glottal stop, (2) creaky (3) ‘rearticulated’, a sequence of vowels with an intervening glottal stop [VʔV]. The current study examines these vowel types in Santa Ana del Valle Zapotec and Santiago Matatlán Zapotec. Given that creaky, checked, and rearticulated vowels are all characterized by creak, how are these vowel types distinguished? Acoustic and electroglottographic measures were made for each vowel type. Results were similar across languages. There was variation in the production of the rearticulated and checked vowels. Both vowel types were sometimes produced as [V̤], a creaky vowel without either the echo vowel or glottal stop. Phonemically creaky vowels had earlier onsets of creak than checked or rearticulated vowels, suggesting that listeners may be attuned to the timing differences in phonation in order to perceive the differences between these vowel types.

**Keywords:** phonation, Zapotec, laryngealization, voice quality

## 1. INTRODUCTION

Accounts of Zapotec languages describe a complex laryngeal system that contrasts up to three vowel types: (1) ‘checked’, defined as a vowel followed by a glottal stop [Vʔ], (2) creaky [V̤], and (3) ‘rearticulated’, described as a sequence of two vowels (often with the same quality) with an intervening glottal stop [VʔV]. San Lucas Quiavini Zapotec [6] is an example of languages that contrasts these three vowel types.

Previous research on the acoustic properties of laryngealization in Zapotec has focused on the Villa Alta subgroup of Zapotec languages spoken in the Villa Alta region of Oaxaca, Mexico. In Yalálag Zapotec [1], which contrasts modal and rearticulated vowels, the pronunciation of the rearticulated vowels was found to be quite complex with a great deal of free variation. Even

within a speaker, four possible productions of this vowel type were found: [VʔV], [V̤V̤], [V̤:V̤], [V̤V̤]. And, in a study on phonation type in San Miguel Cajonos Zapotec, a related Villa Alta language, which contrasts modal, breathy, creaky, checked, and pressed vowels, [8] showed that pressed vowels (which correspond to rearticulated vowels in other Zapotec languages but without a fully-articulated glottal stop) constituted their own phonation category, distinct from creaky. The checked vowels, on the other hand, were found to be a sequence of a modal vowel followed by a glottal stop (though they were frequently produced with creak) [8]. This suggests a four-way phonation contrast for San Miguel Cajonos Zapotec: modal, breathy, creaky, and pressed.

The current study examines creaky, checked, and rearticulated vowels in two varieties of **Valley Zapotec** languages: Santa Ana del Valle Zapotec (SADVZ) and Santiago Matatlán Zapotec (SMZ). The Valley Zapotec languages are spoken in the Valley of Oaxaca and, to some extent, are linguistically different from the Villa Alta Zapotec languages. SADVZ and SMZ include creaky, checked, and rearticulated vowels, in addition to breathy and modal ones. Both are tonal languages, but the tone is largely predictable from the phonation type. In both languages, breathy phonation is produced with a small fall in f<sub>0</sub>, while creaky, checked, and rearticulated vowels are produced with a larger fall in f<sub>0</sub>. In SMZ, the modal vowels have a high level f<sub>0</sub>, while in SADVZ they can be either high or high-rising (see Esposito [3] for more information on the tone and phonation of SADVZ.)

The three vowels, checked, creaky, and rearticulated, are structurally different when produced in their full form [Vʔ], [V̤], [VʔV]. However, due to free variation in production, there is potential for homophony. Accounts report pronunciations similar to (1) a creaky vowel without an intervening glottal stop or (2) a checked vowel because the second vowel in the rearticulated sequence optionally deletes. Thus, rearticulated vowels are potentially homophonous with either creaky or checked vowels. How are these homophonous forms distinct? The current

study uses both acoustic and electroglottographic measurements to answer this question.

## 2. METHODS

### 2.1. Speakers

Three male speakers of SADVZ and four male speakers of SMZ were recorded for this study. All were native speakers of Spanish in addition to Zapotec. Speakers ranged from 30-50 years of age. All were from Oaxaca, Mexico, but now reside in Los Angeles, California. All speakers reported that they speak Zapotec daily. The influence from other languages, such as Spanish and English, is not known.

### 2.2. Speech Materials

Monosyllabic words were recorded per vowel type (checked, creaky, and rearticulated) for a total of 30 words in each language. Words were repeated three times by each speaker (SADVZ: 3 speakers X 30 words X 3x = 270 tokens; SMZ 4 speakers X 30 words X 3x = 360 tokens). Rearticulated vowels occur only in open syllables. Creaky and checked vowels may occur in either open or closed syllables; both syllable types were included in the wordlist.

### 2.3. Procedure

Simultaneous audio and electroglottographic recordings were made using a Glottal Enterprises two-channel electroglottograph (EGG). Acoustic and EGG measurements were made automatically using VoiceSauce ([9]) and EGGWorks ([7]), respectively.

For SMZ, the amplitude of the first harmonic minus the amplitude of the second harmonic ( $H1^*-H2^*$ ) and closed quotient (CQ), the closed phase of the glottal cycle divided by the sum of the closed phase and the open phase (as measured from the EGG signal) were measured. Pilot research conducted showed that  $H1^*-H2^*$  and CQ were the best measures of phonation in this language, in that they distinguish phonation in the expected directions. For SADVZ, the amplitude of the first harmonic minus the amplitude of highest harmonic near the third formant ( $H1^*-A3^*$ ) and Derivative-EGG Closure Peak Amplitude (DECPA), the positive peak value from the derivative of the EGG signal (dEGG)—which reflects the speed of the

vocal folds during the closing phase—were measured. These measures were selected based on [3], which showed that measures of vocal fold closure speed worked best for male speakers of SADVZ. Both spectral measures ( $H1^*-H2^*$  and  $H1^*-A3^*$ ) were corrected for surrounding formant frequencies and bandwidths using the method described in [5]. Corrections, which were done automatically in VoiceSauce [9], are marked with an asterisk after the harmonic (e.g.  $H1^*$ ). Duration and  $f_0$  were also measured for both languages.

Measurements were made automatically over nine time points by averaging the value (for a given measure) of that part. To determine the properties of the laryngealized vowels, points 1, 5, and 9 (essentially, the beginning, middle, and end of the vowel) were examined.

## 3. RESULTS

The three vowel types, when produced in their full form ( $[Vʔ]$ ,  $[\underline{V}]$ , and  $[VʔV]$ ) are structurally distinct. But, what happens in cases where the variation in production leads to homophony?

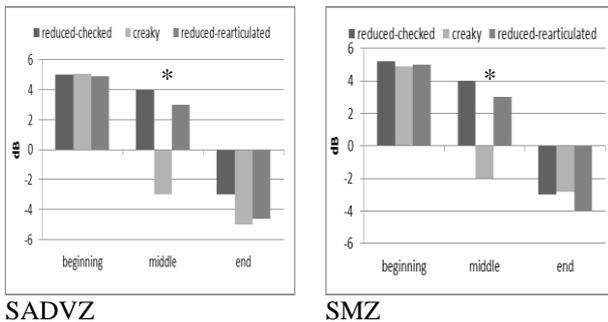
As an initial step, tokens were examined for the type of variation previously reported. Across both languages, about half of the productions of rearticulated vowels were produced as  $[VʔV]$ ; the second vowel was, at times, voiceless. The remaining productions were produced as a creaky vowel  $[\underline{V}]$ , without an echo vowel or glottal stop. These will be referred to as “reduced-rearticulated” below. Interestingly, the checked vowels also demonstrated variation; about a third of the time, they were produced without a glottal stop, but with creak  $[\underline{V}]$ ; these will be referred to as “reduced-checked”. Due to the variation in the production of checked and rearticulated vowels, all three vowel types manifested as  $[\underline{V}]$ . How are these three types of creaky vowels different? Only these potential homophonous forms will be the subject of the investigation.

Separate repeated measures ANOVAs for each language (at each of the three time points) and post-hoc pair-wise comparisons were used to determine if there was a significant ( $p \leq .001$ ) difference between the reduced-checked, creaky, and reduced-rearticulated.

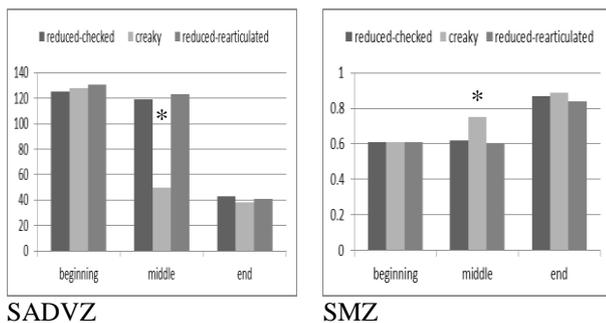
### 3.1. Voice measurements

The results of the acoustic and EGG measures for the three manifestations of [V], reduced-checked, creaky, and reduced-rearticulated, in SADVZ and SMZ are presented in Figures 1 and 2.

**Figure 1:** Graph of the average H1\*-A3\* (left) and H1\*-H2\*(right) (dB) for three types of SADVZ (left) and SMZ (right) laryngealized vowels: reduced-checked, creaky, and reduced-rearticulated vowels at three time points. An asterisk indicates that there is a significant difference between creaky vowels and the two other vowel types at this timepoint.



**Figure 2:** Graph of the average DECPA (left) and CQ (right) (uncalibrated units) for three types of SADVZ (left) and SMZ (right) laryngealized vowels: reduced-checked/, creaky, and reduced-rearticulated vowels at three time points. An asterisk indicates that there is a significant difference between creaky vowels and the two other vowel types at this time point.



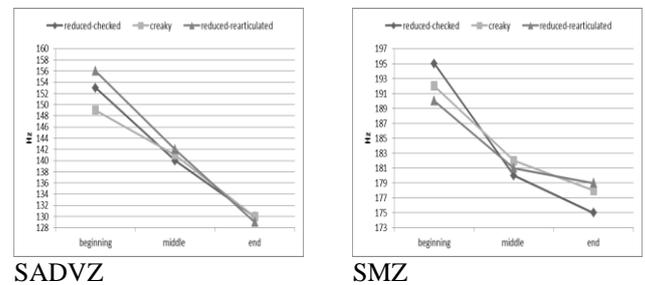
The results of the acoustic and EGG measures were similar and will be discussed simultaneously. For both languages, at the beginning of the vowel, there was no significant difference between the three vowel types. All three vowels displayed a rather modal-like phonation at the onset. However, by the middle of the vowel, there was a significant difference between the creaky vowels and the other

two vowel types. At this time point, the creaky vowels displayed much creakier phonation, than the checked and rearticulated vowels. By the end of the vowel, reduced-checked, creaky, and reduced-rearticulated were not significantly different; all three vowels types were produced with creaky voice.

### 3.2. F0

There was not a significant difference in the f0 of the three vowel types. All were characterized by a falling pitch, with roughly the same F0 value (see Figure 3).

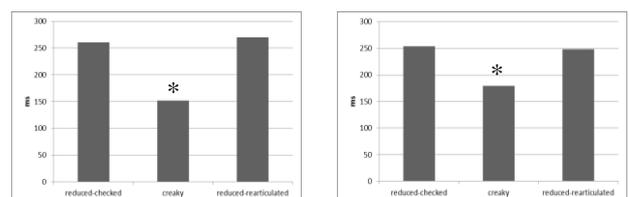
**Figure 3:** Graph of the average F0 (Hz) for reduced-checked, creaky, and reduced-rearticulated vowels at three time points in SADVZ (left) and SMZ (right).



### 3.3. Duration

The duration (ms) of all three vowel types is graphed in Figure 4. There was a significant difference in the duration between the creaky and reduced vowels. The reduced-rearticulated and reduced-checked vowels were significantly longer than phonemically creaky vowels. This may be due to a compensatory lengthening of the reduced vowels that take place after deletion of segment(s).

**Figure 4:** Graph of the average duration (ms) for three types of SADVZ (left) and SMZ (right) laryngealized vowels: reduced-checked, creaky, and reduced-rearticulated vowels. An asterisk indicates that there was a significant difference between creaky vowels and the two other vowel types.



#### 4. DISCUSSION AND CONCLUSION

The goal of the current study was to determine how checked, creaky, and rearticulated vowels might be distinguished in two Valley Zapotec languages, especially in cases of reduction that could lead to homophony. When fully-articulated, the three vowel types were structurally different [Vʔ], [VʔV], [V̤]. However, there was variation in the production of rearticulated vowels, with some productions consisting of simply a creaky vowel [V̤]. Similar variation was observed for the checked vowels, which were sometimes produced without a glottal stop, but with creak [V̤]. Thus, there are three types of [V̤]: phonemically creaky vowels, reduced-rearticulated vowels, and reduced-checked vowels. However, there is a difference in degree and timing for phonemically creaky vowels. Phonemically creaky vowels display a greater degree of creaky phonation earlier on in the vowel than the other two vowel types. Phonemically creaky vowels are also shorter in duration than the reduced-rearticulated and reduced-checked vowel types. It is not clear what distinguishes the reduced-rearticulated from reduced-checked vowels; they possess similar voice qualities, durations, and tonal patterns; it is possible that these reduced forms are the same, but that remains an area for additional research.

In both languages, minimal contrast sets exist (e.g. [baʔ] ‘testicle’, [ba̤] ‘eyeball’, [baʔa] ‘tomb’ in SADVZ). Thus, speakers must be able to distinguish between the categories when there is reduction in the pronunciation. All three are characterized by falling tones; tone can not be a perceptual cue to the difference between these vowels. The glottal stop alone does not always aid listeners either, since it appears to be optional. It is possible that listeners are sensitive to the difference in the timing of phonation and duration of these vowel types. The earlier onset of creak and shorter duration for the creaky vowel may play a role in perception.

Cross-linguistically, we see evidence for the importance of timing and magnitude in the production of phonation types [2,4], especially in cases where there are two similar but distinct manifestation of a particular phonation type within a language. For instance, Gujarati and White Hmong both possess two types of breathy voice: breathy-voiced aspirated consonants ([C<sup>h</sup>]) and breathy vowels ([V̤]). Similar to the results

presented here for Zapotec, it is the timing and magnitude of the non-modal phonation that distinguishes phonation types [4]. These results suggest that listeners may be attuned to timing differences in phonation in order to perceive the difference between similar phonation types with a language.

#### 5. REFERENCES

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