Acoustics of the fortis-lenis contrast in Lachirioag Zapotec: a preliminary investigation

Iza Solá-Llonch (elsol4@ucla.edu)
Lily Xu (lilyokc@ucla.edu)

UCLA Linguistics Department
SSILA 2022 Conference

Introduction

- This study investigates the acoustic correlates of what is traditionally called the ‘fortis-lenis’ contrast in Lachirioag Zapotec
- Goals: statistical analysis of what phonetic factors are significant for the production of fortis vs. lenis consonants (à la DiCanio 2012)
  - Determine the best way of categorizing the contrast (Articulatory strength? VOT? Length?)
  - Discuss Lachirioag Zapotec in terms of larger typology of laryngeal contrasts
- This presentation summarizes preliminary results

1. Background

Language background

- Northern Zapotec language, Xhon dialect group (endonym: *dizha xhon* `xhon word/language')
- Spoken in the town of San Cristóbal Lachirioag in the Villa Alta district of Oaxaca, Mexico
- The town has a population of 1,342 as of 2021, with around 1,085 Zapotec speakers (INEGI 2021)
- There is an additional community in California with about 50 fully fluent speakers and 60-100 partially fluent ones
- The community is interested in documenting and revitalizing their language, e.g., by holding online classes and translating kids' books

Fortis/lenis in Lachirioag Zapotec

Most native consonants (except the glides [j w]) can be divided into fortis/lenis pairs

- Fortis: historically geminate
- Lenis: historically singleton

Importantly, obstruents and sonorants both participate in this contrast

		Lenis	**Fortis**
Stop	Labial	b	p, kw
	Alveolar	d	t
	Velar	g	k
Affricate	Palatoalveolar	dj	ch
Fricative	Alveolar	z	s
	Palatoalveolar	zh	sh
	Postalveolar	xh	x
Nasal	Alveolar	n	nn
Lateral	Alveolar	r	l

Fortis-lenis in other (Otomanguean) languages

The f/l contrast is found throughout Zapotec and related languages. Common phonetic properties associated with each class of consonant are:

Obstruents		**Sonorants**	
Lenis	**Fortis**	**Lenis**	**Fortis**
> Variably voiced > Frequent spirantization (stops and affricates) > Shorter duration	> Always voiceless > Consistent closure (stops & affricates) > Longer duration	> Shorter duration > Nasal: assimilates to place of articulation of adjacent Cs	> Longer duration > Nasal: doesn't assimilate

Fortis/lenis in other (Otomanguean) languages

Previous works have claimed that the f/l contrast is cued primarily by:

- **Cajonos Zapotec:** force of articulation (fortis = strong) (Nellis & Hollenback 1980)
- **Yateé Zapotec:** duration and peak amplitude (Jaeger 1983)
- **Yalálag Zapotec:** VOT (for obstruents) and duration (Avelino Becerra 2001, 2004)
- **San Francisco Ozolotepec Zapotec:** duration (Leander 2008)
- **San Pablo Güilá Zapotec:** voicing (obstruents) and duration (Arellanes 2009)
- **Itunyoso Trique:** spread glottis gesture (fortis obs) and duration (DiCanio 2012)

Summary:

Previously, the fortis/lenis contrast in Zapotec (and related) languages is claimed to be characterized primarily by:

- **Sonorants:** duration
- **Obstruents:** duration, as well as spirantization and voicing of lenis obstruents

2. Methods

Data collection

- 1 speaker (30s,M)
- Recorded in person in a sound booth using Audacity
- Frame sentence:

  Baréda' gan bziagakn ___ tnia'zë. 'I saw where they wrote ___ one time.'
- Speaker was asked to first produce sentences at a regular speech rate, then at a fast rate
- 2 repetitions x 2 speech rates = 4 instances/token (disfluencies were discarded)
- Total targets: 476 (fortis: 216; lenis: 260)

Measurements

- Voicing (percentage of consonant)
- Spirantization (stops, affricates)
- Intensity (stops and affricates)
  - Relative burst amplitude = max burst amplitude - max vowel amplitude (DiCanio 2012)
- Preceding F1, F2, F3 formant trajectories (for postvocalic consonants only)
  - Divided preceding vowel into 10 intervals
  - 2 trajectories: second half of the vowel (Int. 6 - Int. 10) and last 30% (Int. 8 - Int. 10)
- Duration: preceding vowel, closure, burst, VOT

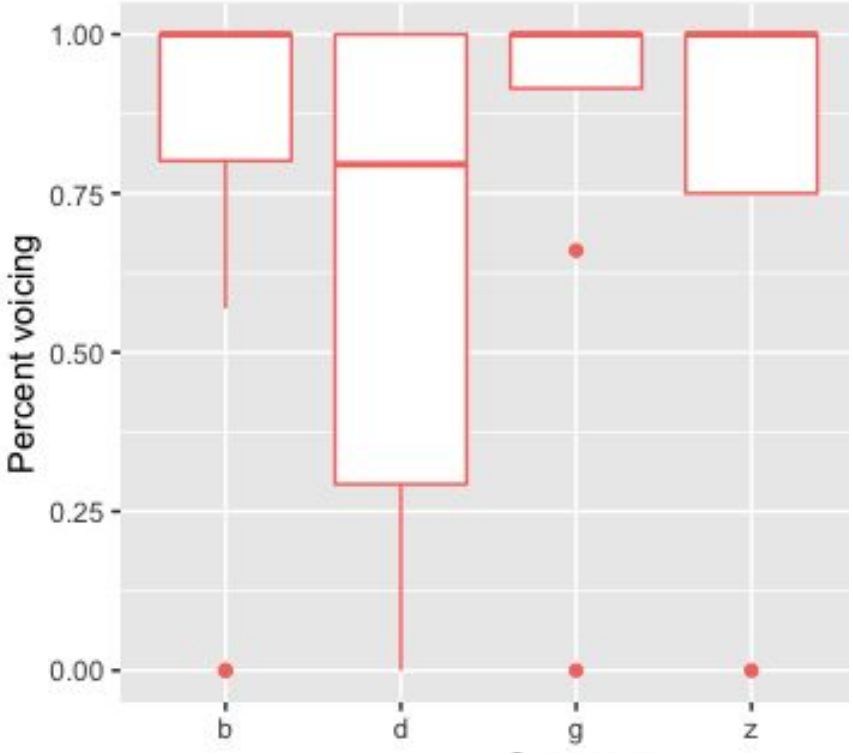
Modelling

- Linear mixed effects models were run for the duration and intensity measurements
- Baseline: Speech rate, place of articulation, and manner as fixed effects
- Compared with model including fortis/lenis as a factor
    - If significant, interactions with other factors are also investigated
- Random effect of item

3. Results

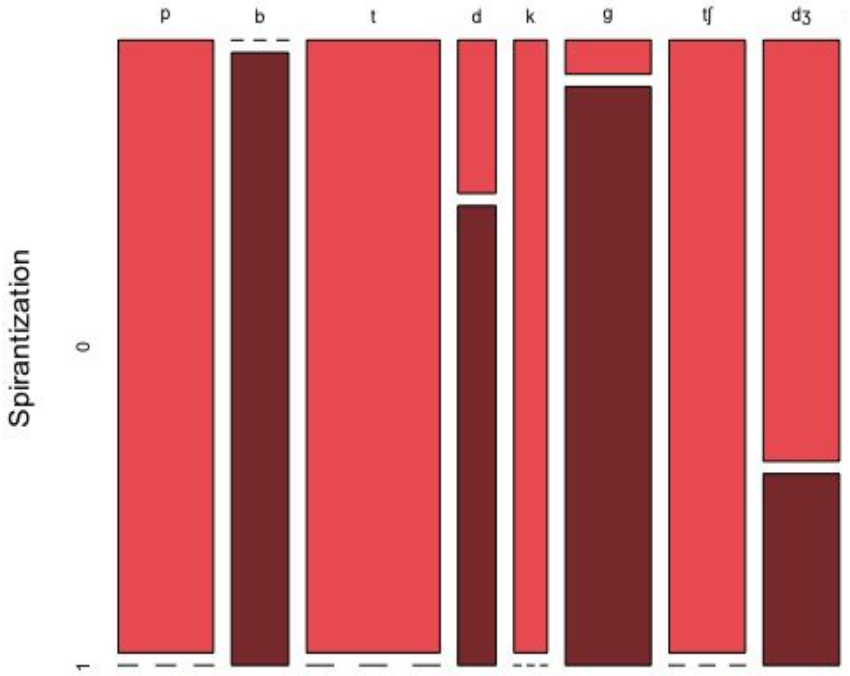
Voicing

- Lenis obstruents variably undergo voicing (fortis stops are always voiceless)
- Average % voicing: 73%



Spirantization

- Defined as the absence of closure in the production of a stop or affricate consonant
- Lenis stops and affricates are spirantized 74% of the time in medial/final positions

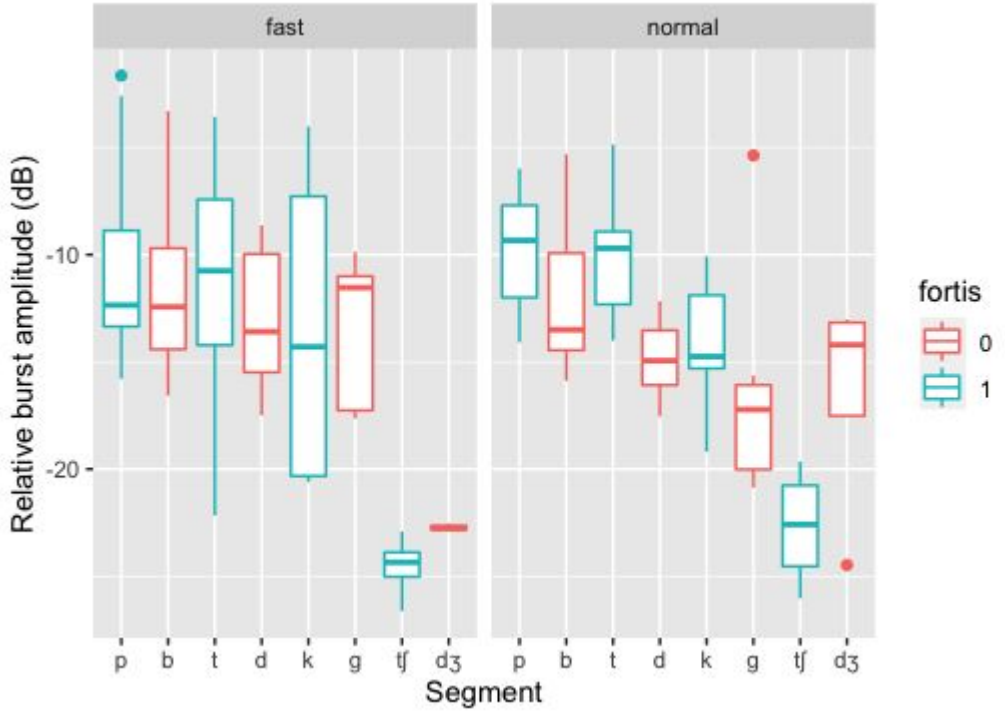


Force of articulation

- Greater force of articulation is associated with:
  - Larger relative burst amplitude
  - Faster formant trajectory
- Relative burst amplitude was found to be not significant
- Formant trajectory was found to be significant for the Int. 8 - Int. 10 trajectory for F1, but not significant elsewhere

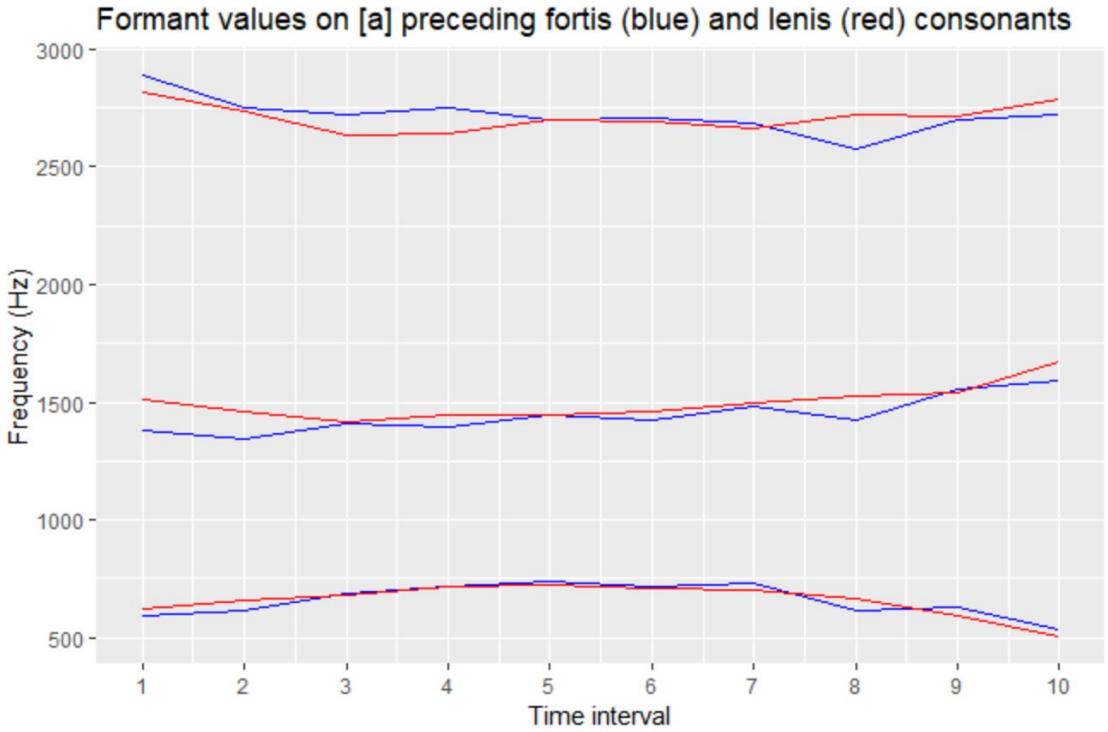
Intensity

- Relative burst amplitude of fortis and lenis stops/affricates does not differ significantly *(p = 0.47)*
- Speech rate does not interact with fortis/lenis sig. (*p = 0.71*)
- Fortis affricates have weaker amplitude compared to lenis ones (sig. Interaction with fortis/lenis, *p = 0.02*)



Formant trajectory

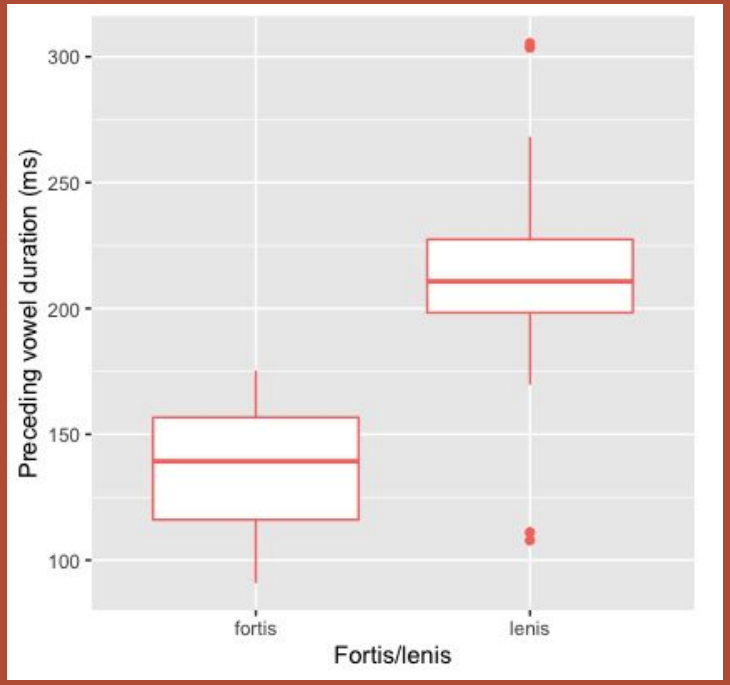
- Only tokens with preceding low vowel [a] were used (fortis: 26; lenis: 62)
- Significant difference (p = 0.0242) between fortis/lenis consonants in the trajectory of F1 in the last 30% of the vowel (Int. 8 - Int. 10)
- Likely due to the small data sample



Duration

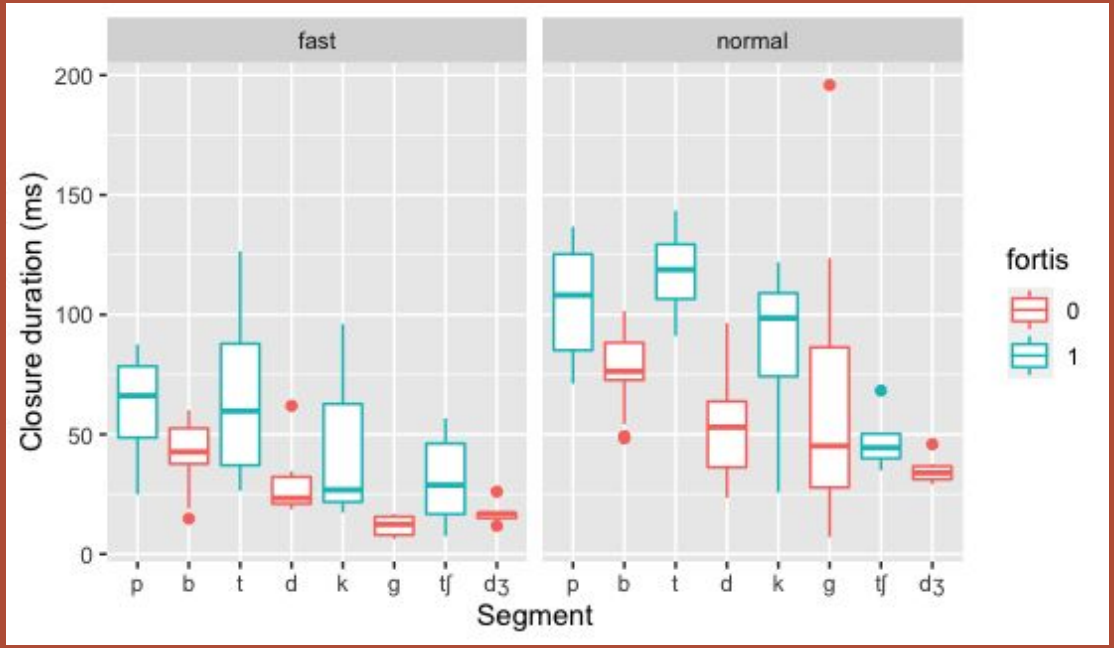
- Preceding vowel (prevocalic consonants): significant
- Stops/affricates: closure duration significant
- Continuants: overall duration significant

Duration
preceding vowel



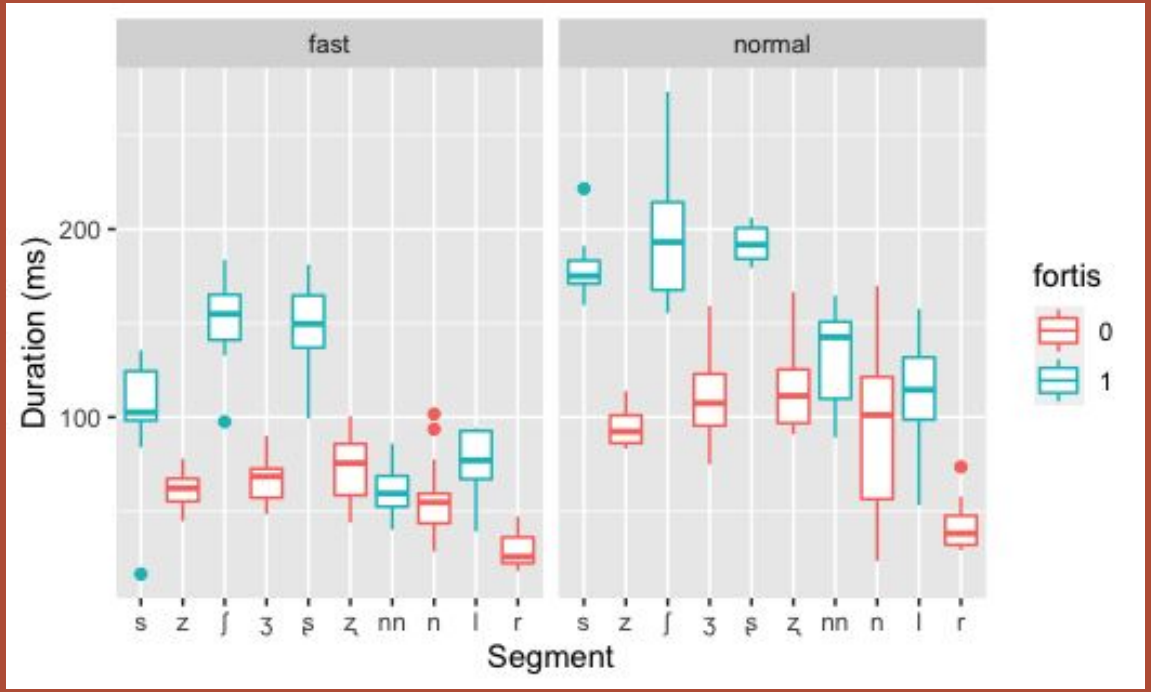
- Vowels preceding lenis consonant is significantly longer in duration than vowel preceding fortis consonants
- This is true for both regular ($p < 0.001$; see plot) and fast ($p = 0.007$) speech rates

Duration
stops & affricates



- Fortis stops and affricates have longer closure duration than lenis ones across speech rate, position and place *(β= 32, p < 0.001)*
- Fortis/lenis does not interact with speech rate (p = 0.20) or manner of articulation (p = 0.78)

Duration
continuants



- Fortis continuants have longer overall duration than lenis ones across speech rate, position and place *(β= 44, p < 0.001)*
- The duration difference between fortis and lenis continuants is larger in normal speech compared to fast speech *(β= 24, p < 0.01)*

Summary of results:

- Voicing is a reliable correlate for obstruents (but all sonorants are voiced)
- Lenis obstruents undergo spirantization
- Intensity and formant trajectory do not seem to be reliable correlates of the fortis/lenis contrast
- Duration is generally found to be a robust cue
  - Preceding vowel duration (all consonants)
  - Closure duration (stops, affricates)
  - Overall duration (continuants)

4. Discussion

How does Lachirioag Zapotec compare to previous findings?

- Duration was found to be a robust cue for the f-l contrast (Avelino 2001, 2004; Leander 2006; DiCanio 2012)
    - Closure duration for stops and affricates, total duration for continuants
    - Lenis consonants robustly associated with a longer preceding vowel
- F-l also manifests as a voicing contrast, similar results by Avelino (2001, 2004)
- Intensity results match DiCanio (2012): no significant difference between lenis and fortis (contra Jaeger 1983)

Future directions

To do:

- More speakers, producing more data targets
- Look to get more tokens of certain consonants by looking more at different parts of speech
- Different frame sentence(s) (current one causes major issue with segmenting initial nasals)
- Interaction with F0/tone

Otomanguean fortis–lenis in the laryngeal-contrast typology

Burroni et al. (2021) examined initial geminates in three languages: Dunan (Japonic), Pattani Malay (Austronesian), Salentino (IE)

- ➢ Found multiple cues to be reliable in distinguishing initial geminates: duration, f0, intensity, spectral tilt
- ➢ Languages trade off in the importance of different cues; not equally significant in all languages - consistent with the larger literature on laryngeal contrasts
- ➢ Singleton/geminates = fortis/lenis (at least phonetically) (cf. Ladd & Schmid 2018)

Acknowledgements

Thanks to Julio Dominguez, Minerva Mendez, and the Lachirioag Zapotec community for all of their work and patience.

We are also grateful to the AIS UCLA seminar for their comments on a previous version of this talk. Also to Megha Sundara for her advice.

References

1. Arellanes, F. A. 2009. *El sistema fonológico y las propiedades fonéticas del zapoteco de San Pablo Güilá: Descripción y análisis formal.* PhD dissertation, el Colegio de México.
2. Avelino, H. 2001. *The phonetic correlates of fortis-lenis in Yalálag Zapotec consonants.* MA thesis, UCLA.
3. Avelino Becerra, H. 2004. *Topics in Yalálag Zapotec, with particular reference to its phonetic structures*. PhD dissertation, UCLA.
4. Burroni, F., R. Lau-Preechathammarachb, & S. Masponga. 2021. Unifying Initial Geminates and Fortis Stops via Laryngeal Specification. Talk given at AMP 2021.
5. DiCanio, C. 2012. The phonetics of fortis and lenis consonants in Itunyoso Trique. *IJAL* 78, 239-272.
6. INEGI, Instituto Nacional de Estadística y Geografía. 2021. *Panorama sociodemográfico de Oaxaca: Censo de Población y Vivienda 2020*. México: INEGI.
7. Jaeger, J. 1983. The fortis/lenis question: evidence from Zapotec and Jawoñ. *Journal of phonetics* 11, 177-189.
8. Ladd, D.R. and Schmid, S. 2018. Obstruent voicing effects on F0, but without voicing: Phonetic correlates of Swiss German lenis, fortis, and aspirated stops. *Journal of Phonetics* 71, 229-248.
9. Leander, A. 2008. *Acoustic correlates of fortis/lenis in San Francisco Ozolotepec Zapotec*. MA thesis, University of North Dakota.
10. Nellis, D. & B. Hollenbach. 1980. Fortis versus lenis in Cajonos Zapotec phonology. *IJAL* 46, 92-105.