Investigating the timing of tone and phonation in Santiago Laxopa Zapotec.

Mykel Loren Brinkerhoff

Contents

1 Introduction

- Most work on the interaction of tone and phonation has been based on descriptions of southeast and far east Asian languages.
- This lead to strong claims on the interaction between tone and phonation (Masica 1976, Thurgood 2002, Yip 2002, Enfield 2005, Michaud 2012, Brunelle & Kirby 2016).
- Main claim from these authors is that tone and phonation are codependent. This is often referred to as a register system.
  - Meaning that we only observe certain tones with certain phonations.
  - Mandarin Tone 3 is always associated with creaky voice (Duanmu 2007).
- This claim has also been made in the reverse that certain phonation types are associated with specific tonal patterns.

  - Breathy voice stereotypically appears with high pitch and creaky voice sterotypically appears with low pitch (Esling et al. 2019).
    * TODO: Look for earlier references to these claims.
  - This is often born out with research into register systems.
  - Also found in pathological voice quality (Klatt & Klatt 1990, Titze 2000, Esling et al. 2019).

- Research into Mesoamerican languages, however, shows that these claims are too strong or exaggerated (Suárez 1983, Campbell, Kaufman & Smith-Stark 1986, Silverman 1997, DiCanio 2008, Esposito 2010, Campbell 2017a,b).

- Most languages of the Oto-Manguean language family exhibits independent tone and phonation.
  - Tone and phonation freely co-occur or exhibit a much freer distribution than what is found in register languages.
  - San Lucas Quiaviní Zapotec is one such example.

Table 1: SLQZ tone and phonation

	High	Low	Falling	Rising
Modal	✓	✓	✓	✓
Breathy	X	✓	✓	X
Creaky	✓	✓	✓	X
Interrupted	✓	✓	✓	X

- This paper adds to this debate by:
  - Providing another description of a language that uses tone and phonation
  - Evaluates the claims of Silverman (1997)

2 Silverman 1997

3 Santiago Laxopa Zapotec

Santiago Laxopa Zapotec (SLZ; Dilla'xhonh Laxup) is a Northern Zapotec language spoken by approximately 1000 people in the municipality of Santiago Laxopa, Ixtlán District in the Sierra Norte of Oaxaca, Mexico (Adler & Morimoto 2016, Adler et al. 2018, Foley, Kalivoda & Toosarvandani 2018, Foley & Toosarvandani 2020). As is common among Zapotecan languages, SLZ distinguishes between lenis and fortis consonants (e.g., Nellis & Hollenbach 1980, Jaeger 1983, Uchihara & Pérez Báez 2016) and has a fairly standard five-vowel inventory. These contrasts and inventories can be seen in Table 2 and Table 3.

Table 2: Consonant inventory for Santiago Laxopa Zapotec

		bilabial	alveolar	retroflex	alveo-palatal	palatal	velar	labio-velar	uvular
nasal	lenis		n						
	fortis	mː	nː						
stop	lenis	b	d				g	gʷ	
	fortis	p	t				k	kʷ	
fricative	lenis		z	ʐ~ɽ	ʒ	ç			ʁ~χ
	fortis		s	ʂ	ʃ				
affricate	lenis		d͡z						
	fortis		t͡s		t͡ʃ				
lateral	lenis		l~ɾ						
	fortis		lː						
trill			r						
approximate						j		w	

Table 3: Vowels inventory in Santiago Laxopa Zapotec.

	front	central	back
high	i		u
mid	e		o
low		a	

In addition to the contrasts in both consonants and vowels, SLZ additionally has a phonation and tonal contrast. I will first talk about the phonation contrasts in Section 3.1 followed by the tonal contrasts in Section 3.2.

3.1 Phonation in SLZ

SLZ, in addition to the five vowel qualities, has four contrastive phonation types which are: modal, breathy, checked, and laryngealized. These contrasts are exemplified in the minimal quadruple in (1).

(1) Four-way minimal phonation contrast

a. *ya* [ja^{L}] 'bell'

b. *yah* [ja̤^{L}] 'metal/rifle'

c. *ya'* [ja^{ʔL}] 'pound'

d. *ya'a* [ja^{ʔ}a^{L}] 'market'

- SLZ has four different contrastive phonation types on the vowels.

  1. Modal: [a] <*a*>

2. Breathy: [a̤] <*ah*>
3. Checked: [aˀ] <*a'*>
4. Laryngealized: [aˀa] <*a'a*>

- Even though all of these contrastive phonation involve varying degrees of laryngealization, different configurations of the larynx, I choice to use the term laryngealized to refer to one of the phonation contrasts following the arguments from Avelino (2010).
  - Laryngealized vowels do not have one consistent production across speakers.
  - One consultant used only creaky voice and the other consultant used a rearticulated phonation or a creaky phonation for L toned words.

3.2 Tone in SLZ

- SLZ has five surface tones as represented in Table 4.

Table 4: SLZ tones

High	a^{1}	*xha*	[ʐ̺a^{1}]	'clothing.POSS'
Mid	a^{2}	*lhill*	[ɾiʒ^{2}]	'house.POSS'
Low	a^{3}	*yu'*	[juˀ^{3}]	'earth'
Rising	a^{21}	*yu'u*	[juˀu^{21}]	'quicklime (Sp. cal)'
Falling	a^{13}	*yu'u*	[juˀu^{13}]	'house'

- Following discussion from Brinkerhoff, Duff & Wax Cavallaro (2022) these tones are limited in their appearance.
- It is true that all five patterns can surface on a syllable but there is a restriction in what tonal patterns are allowed to surface on words that are larger than bimoraic.
- The patterns that we observe on bimoraic nominals are:
  - HL
  - MH
  - LL
- This has the appearance of being a prototypical "word tone" language following Pike's (1948) categorization.
- However, recent work from Shih & Inkelas (2019) and McPherson (In press) has argued that the "word tone" description is epiphenomenal and can be derived via surface constraints on tone.
- What is important to take away from this is that there are still five distinct tonal patterns that are productive in the speakers.

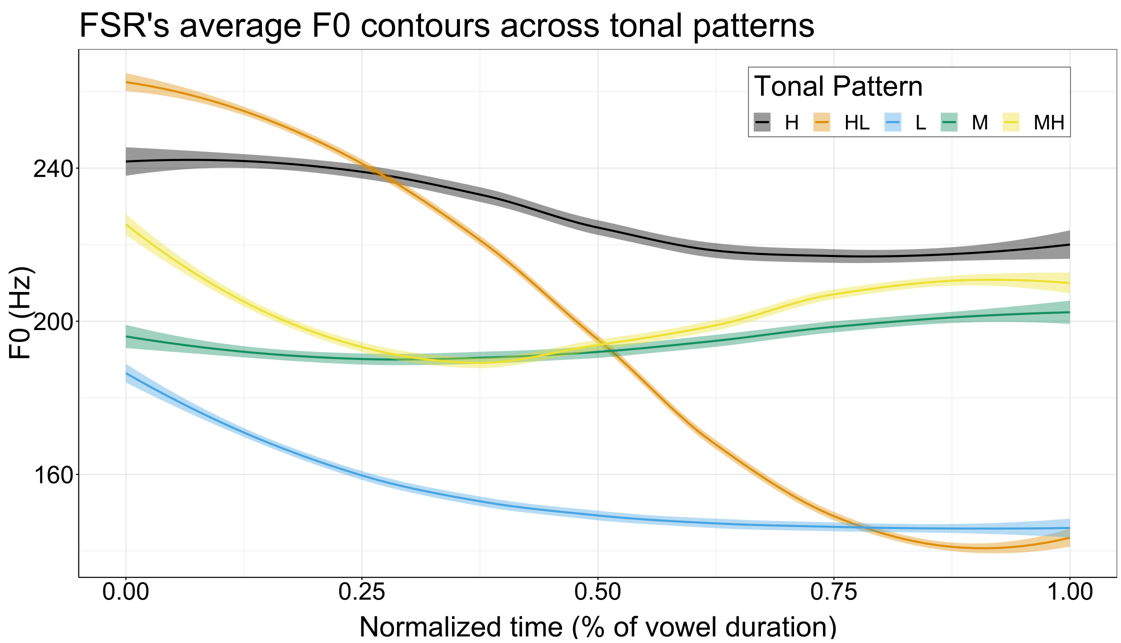

Figure 1: Tonal contrasts for FSR averaged and time normalized.

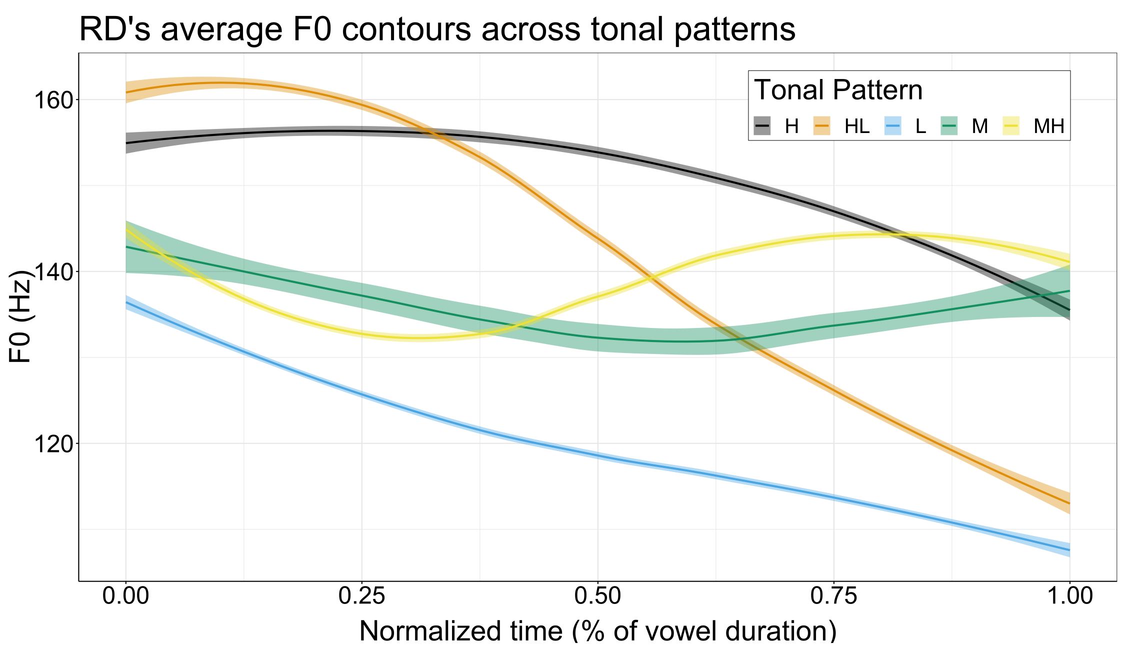

Figure 2: Tonal contrasts for RD averaged and time normalized.

4 Interaction of Tone and Phonation

- Discuss what observations have been found in other languages.
- Table 5 shows the observed patterns between tone and phonation in SLZ.
- The striking observations that we find is that there are some gaps in where breathy is allowed to occur. This is also true for the checked phonation.

Table 5: Distribution of tone and voice quality in SLZ on a syllable

	Modal	**Breathy**	**Checked**	**Laryngealized**
H	✓	–	✓	✓
M	✓	✓	✓	✓
L	✓	✓	✓	✓
HL	✓	✓	✓	✓
MH	✓	✓	–	✓

4.1 Acoustic Measurements

- Spectral measurements have been found to be very useful measure of phonation in a wide number of different languages [ADD REFERENCES FROM ESPOSITO].
- Most of these have been focused on H1-H2, however, relationships with H1 compared to higher harmonics have also been found to be useful.
- Most previous studies have not used corrected or normalized measure but have been focused on a single vowel /a/ because it minimizes the effects of the F1.
  - Using corrected values is a way to mitigate the effects of the formants on the vowels.
- Describe how acoustic measurements are taken using Garellek (2019) as a basis for how the measurements are taken.
  - maybe use SoE as well?
  - Additionally, describe the patterns that we expect to see.
- Following Esposito (2010), I use H1-H2 and H1-A3.
- Additionally, CPP is a useful measurement for modal versus a modal phonation (Garellek & Esposito 2021).
- Figure out what which charts are useful. Might be useful to follow Esposito (2010) in taking measurements from a certain portion of the vowels.

- Might be useful to validate h1-h2 and h1-a3 measurements as useful diagnostics.
- What do the measurements show me?
  - FSR shows a timing difference between checked and rearticulated in h1-h2.
  - RD shows the differences we expect to see in h1-a3 but not

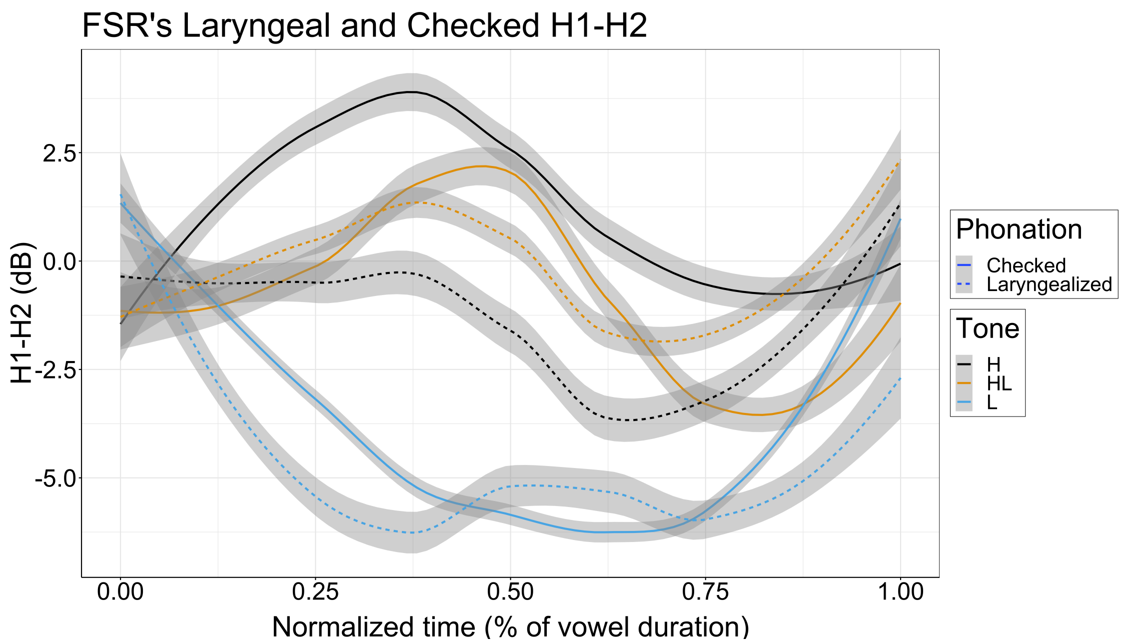

Figure 3: FSR's H1-h2 values for checked and laryngealized.

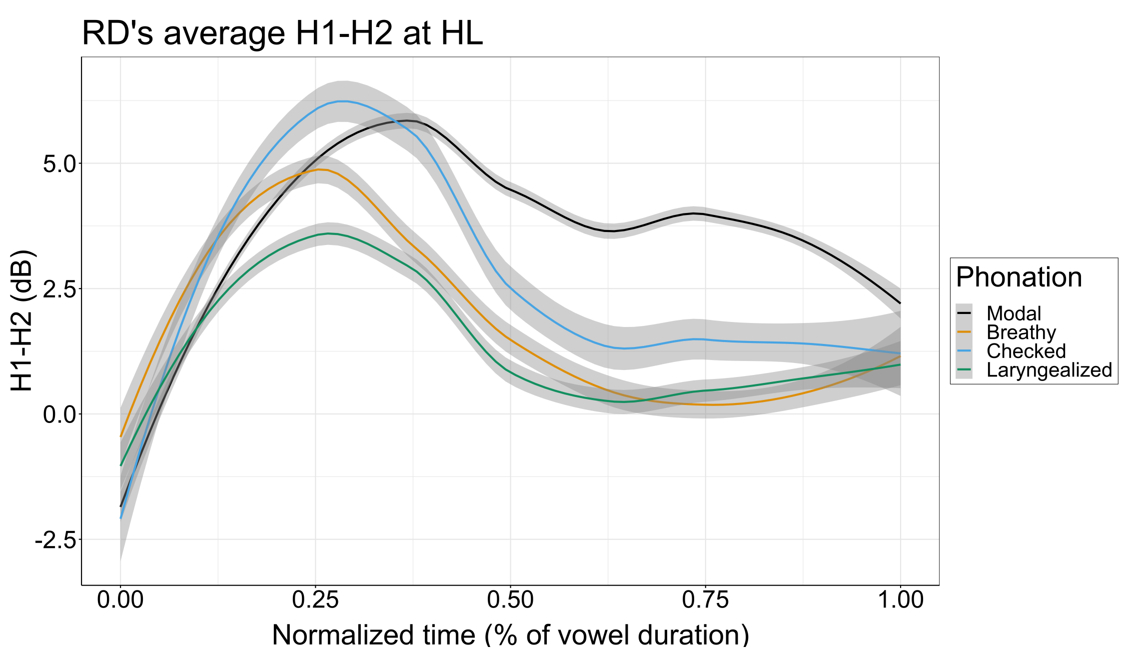

Figure 4: RD's H1-H2 values in HL toned syllables.

5 Challenges to theories

- How does this support or detract from Silverman's (1997) claims?
  - Do we see the gestural timing that Silverman (1997) claims to exist?
- Issues with breathy not present with H.

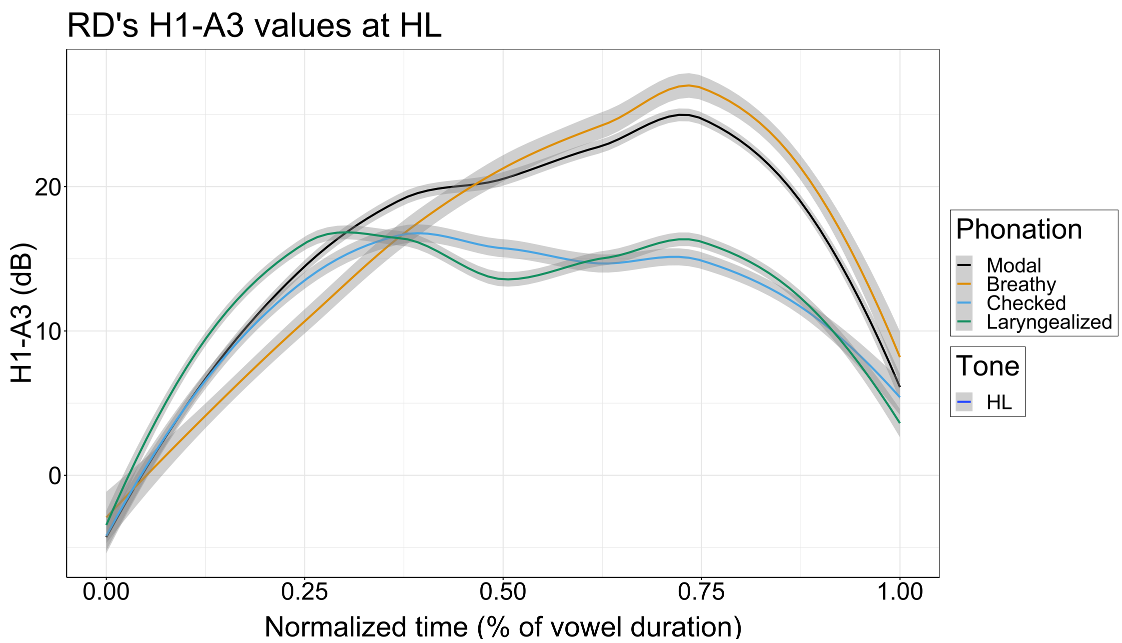

Figure 5: RD's total H1-A3 values in HL toned syllables.

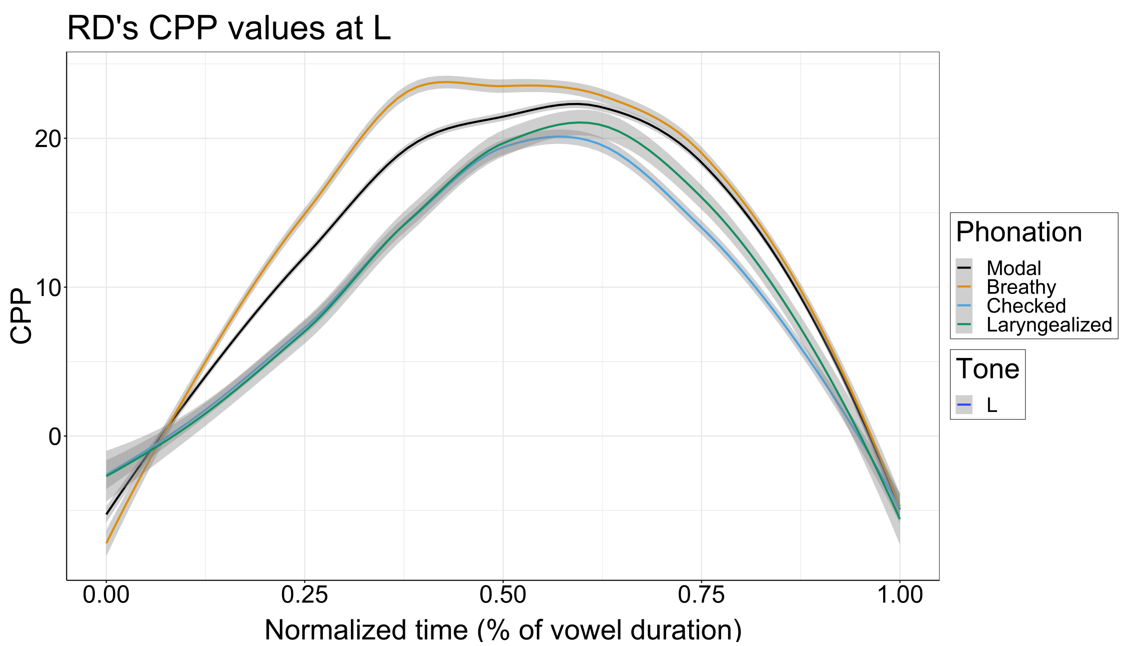

Figure 6: RD's CPP values.

- Additionally there is this question about why we are seeing laryngealized vowels in H tone
  - Could Esling et al.'s (2019) model of interactions be used to explain what we are seeing?

6 Esposito 2010

- Esposito investigates variation in Santa Ana del Valle Zapotec for variation due to gender, F0 and prosodic position.
- Results were inconclusive as to whether or not gender was creakier or breathier though the acoustic measurements (H1-H2 and H1-A3) suggest that there is a difference in PRODUCTION.
- Strong effects of F0 were observed
- The phonation contrasts were present in all positions but were not always well-defined.
- There has been a wide number of studies that have observed phonation differences based on gender, F0, and position. For example females are often described as being breathier than males (though this was not true all the time) and prosodic position produced different phonations. Additionally, all of these cases involve allophonic or suprasegmental phonation (i.e., non-phonemic)
- Very little work has investigated languages with phonemic phonation contrasts
- Jalapa Mazatec and San Lucas Quiaviní Zapotec are some of the few that have seen some study.
- In those studies females were breathier than the male speaker.
- SADVZ is an ideal language to study the variation in phonation because it has relatively free word order and the contrastive phonation that exists.
- Spectral measurements have been found to be very useful measure of phonation in a wide number of different languages.
- Most of these have been focused on H1-H2, however, relationships with H1 compared to higher harmonics have also been found to be useful.
- Most previous studies have not used corrected or normalized measure but have been focused on a single vowel /a/ because it minimizes the effects of the F1
- Esposito focuses on H1-H2 (open quotient) and H1-A3 (speed of vocal fold closure) based on a pilot study she ran in 2003.
- Vowel measurements were made by splitting the vowel into four equal parts and h1-h2 and h1-h3 measurements were made in the last quarter of each vowel.
- H1-A3 and H1*-A3* were effective in distinguishing the different phonation types in males. The difference between corrected and uncorrected were not significant.
- H1-H2 was effective for females speakers.

- The fact that h1-h2 was effective for females and h1-a3 for males suggests that they are using different laryngeal settings. Female speakers are making more use of open-quotient whereas male speakers are using the speed of vocal fold closure to distinguish the different phonation types.
- When looking at whether or not there is an effect for prosodic position it was observed that F0 had more of an effect than position.
- What was found was that all three contrasts were maintained but differed in how clearly they are produced.

7 DiCanio 2012

- DiCanio is concerned with exploring the effects that tone and glottal consonants have on each other.
- Much of the earlier work on coarticulation claimed that the processes of the interaction of tone and phonation/glottal consonants revealed something universal or a set of constraints that applied to all languages.
- More recent work actually argues against this notion specifically that there aren't language-wide or universality but instead is based on language-specific patterns.
- One of these areas has to do with the phasing or co-articulation discussion.
- One area that has received substantially less discussion is on the realm of tone and phonation type contrasts.
- This study serves two main purposes: (i) expand the emperical basis for the analysis of tone-segment coarticulation and (ii) test how changes in relative timing of glottal consonants affect F0 on adjacent vowels.
- One main question I have is that these contrasts that DiCanio is describing seem to be almost more akin to phonation contrasts instead of segmental changes. However, he does seem to have a good amount of information from his dissertation which suggests that these are segmental instead of qualities of the vowel (DiCanio 2008).
- There is some discussion about Silverman (1997) where glottal consonants are abruptly phased relative to the vowels.
- According to Silverman there needs to be abrupt phasing so listeners can distinguish the tone and the glottal contrast.
- Trique does a wonderful job to at allowing us to test this claim that there is abrupt phasing. Specifically this paper investigates whether the amount of coarticulatory overlap between glottals and vowels effect the F0 perturbation.

- Trique has prominence and is reflected by a large distribution of contrasts in the final-syllables of words. But these contrasts are neutralized in non-final syllables. Phonetically realized by increased duration
- Spectral tilt was used to measure the magnitude of glottal tension or spreading. H1-H2 is a useful diagnostic for differentiating breathy, modal, and tense/creaky phonation. Additionally, H1-A3 is useful for breathy vs. non-breathy.
- Results were z-transformed and then a linear mixed effects model was run with speaker as random.
- Breathy phonation is described as higher h1-h2 values and lower H1-H2 values with lower F0. Lower F0 is associated with breathy voice.

8 Holmberg, et al. 1995

- Holmberg et al. (1995) are interested in comparing different acoustic measuring systems.
- Specifically, they were interested in seeing how aerodynamic, EGG, and spectral measures differed in capturing aspect of female voices.
- They found the following seven things:
  1. Significant differences in parameter values between /pTe/ and /a/ were related to significant differences in the sound pressure level (SPL).
  2. An "adduction quotient," measured from the glottal waveform at a 30% criterion, was sensitive enough to differentiate between waveforms reflecting abrupt versus gradual vocal fold closing movements.
  3. DC flow showed weak or nonsignificant relationships with acoustic measures.
  4. The spectral content in the third formant (F3) in comfortable loudness typically consisted of a mix of noise and harmonic energy. In loud voice, the F3 spectral content typically consisted of harmonic energy.
  5. Significant differences were found in all measures between tokens with F3 harmonic energy and tokens with F3 noise, independent of loudness condition.
  6. Strong relationships between flow- and EGG-adduction quotients suggested that these signals can be used to complement each other.
  7. The amplitude difference between spectral peaks of the first and third formant (F1 -F3) was found to add information about abruptness of airflow decrease (flow declination) that may be lost in the glottal waveform signal due to low-pass filtering.
- Even though EGG data was useful it was also extremely limited in nature.
- They found that if the larynx was to small, the neck was to fat, or there was a lot of gross laryngeal movement that the EGG data was inconclusive.
- EGG is best for determining the adduction quotient (closed time/T).

9 Conclusion

References

Adler, Jeff, Steven Foley, Jed Pizarro-Guevara, Kelsey Sasaki & Maziar Toosarvandani. 2018. The derivation of verb initiality in Santiago Laxopa Zapotec. In Jason Merchant, Line Mikkelsen, Deniz Rudin & Kelsey Sasaki (eds.), *A reasonable way to proceed: Essays in honor of Jim McCloskey*, 31–49. Santa Cruz, Berkeley, Chicago: University of California.

Adler, Jeffrey M. & Maho Morimoto. 2016. Acoustics of phonation types and tones in Santiago Laxopa Zapotec. *The Journal of the Acoustical Society of America* 140(4). 3109–3109. https://doi.org/10.1121/1.4969713.

Avelino, Heriberto. 2010. Acoustic and Electroglottographic Analyses of Nonpathological, Nonmodal Phonation. *Journal of Voice* 24(3). 270–280. https://doi.org/10.1016/j.jvoice.2008.10.002.

Brinkerhoff, Mykel Loren, John Duff & Maya Wax Cavallaro. 2022. Tonal patterns and their restrictions in Santago Laxopa Zapotec.

Brunelle, Marc & James Kirby. 2016. Tone and Phonation in Southeast Asian Languages. *Language and Linguistics Compass* 10(4). 191–207. https://doi.org/10.1111/lnc3.12182.

Campbell, Eric W. 2017a. Otomanguean historical linguistics: Exploring the subgroups. *Language and Linguistics Compass* 11(7). e12244. https://doi.org/10.1111/lnc3.12244.

Campbell, Eric W. 2017b. Otomanguean historical linguistics: Past, present, and prospects for the future. *Language and Linguistics Compass* 11(4). e12240. https://doi.org/10.1111/lnc3.12240.

Campbell, Lyle, Terrence Kaufman & Thomas Smith-Stark. 1986. Meso-America as a linguistic area. *Language* 62(3). 530–570.

DiCanio, Christian T. 2008. *The Phonetics and Phonology of San Martín Itunyoso Trique*. Berkeley, CA: University of California, Berkeley dissertation.

DiCanio, Christian T. 2012. Coarticulation between tone and glottal consonants in Itunyoso Trique. *Journal of Phonetics* 40(1). 162–176. https://doi.org/10.1016/j.wocn.2011.10.006.

Duanmu, San. 2007. *The phonology of standard Chinese*. 2nd ed (Oxford Linguistics). Oxford ; New York: Oxford University Press. 361 pp.

Enfield, Nick J. 2005. Areal linguistics and mainland Southeast Asia. *Annual Review of Anthropology* 34. 181–206.

Esling, John H., Scott R. Moisik, Allison Benner & Lise Crevier-Buchman. 2019. *Voice Quality: The Laryngeal Articulator Model*. 1st edn. (Cambridge Studies in Linguistics 162). Cambridge University Press. https://doi.org/10.1017/9781108696555.

Esposito, Christina M. 2010. Variation in contrastive phonation in Santa Ana Del Valle Zapotec. *Journal of the International Phonetic Association* 40(2). 181–198. https://doi.org/10.1017/S0025100310000046.

Foley, Steven, Nick Kalivoda & Maziar Toosarvandani. 2018. Forbidden clitic clusters in Zapotec. In Daniel Edmiston, Marina Ermolaeva, Emre Hakgüder, Jackie Lai, Kathryn Montemurro, Brandon Rhodes, Amara Sankhagowit & Michael Tabatowski (eds.), *Proceedings of the Fifty-third Annual Meeting of the Chicago Linguistic Society*, 87–102.

Foley, Steven & Maziar Toosarvandani. 2020. Extending the Person-Case Constraint to Gender: Agreement, Locality, and the Syntax of Pronouns. *Linguistic Inquiry*. 1–40. https://doi.org/10.1162/ling_a_00395.

Garellek, Marc. 2019. The phonetics of voice. In William F. Katz & Peter F. Assmann (eds.), *The Routledge handbook of phonetics* (Routledge Handbooks in Linguistics), 75–106. Abingdon, Oxon ; New York, NY: Routledge.

Garellek, Marc & Christina M. Esposito. 2021. Phonetics of White Hmong vowel and tonal contrasts. *Journal of the International Phonetic Association*. 1–20. https://doi.org/10.1017/S0025100321000104.

Holmberg, Eva B., Robert E. Hillman, Joseph S. Perkell, Peter C. Guiod & Susan L. Goldman. 1995. Comparisons Among Aerodynamic, Electroglottographic, and Acoustic Spectral Measures of Female Voice. *Journal of Speech, Language, and Hearing Research* 38(6). 1212–1223. https://doi.org/10.1044/jshr.3806.1212.

Jaeger, Jeri J. 1983. The fortis/lenis question: evidence from Zapotec and Jawoñ. *Journal of Phonetics* 11(2). 177–189. https://doi.org/10.1016/S0095-4470(19)30814-9.

Klatt, Dennis H. & Laura C. Klatt. 1990. Analysis, synthesis, and perception of voice quality variations among female and male talkers. *The Journal of the Acoustical Society of America* 87(2). 820–857. https://doi.org/10.1121/1.398894.

Masica, Colin P. 1976. *Defining a linguistic area: South Asia*. Chicago: The University of Chicago Press.

McPherson, Laura. In press. ”Word tone” is epiphenomenal: A case study from Poko (Skou, PNG). In Haruo Kubozono, Junko Itô & Armin Mester (eds.), *Prosody and prosodic interfaces*. Oxford: Oxford University Press.

Michaud, Alexis. 2012. The Complex Tones of East/Southeast Asian Languages: Current Challenges for Typology and Modelling. 8.

Nellis, Donald G. & Barbara E. Hollenbach. 1980. Fortis versus Lenis in Cajonos Zapotec Phonology. *International Journal of American Linguistics* 46(2). 92–105. https://doi.org/10.1086/465639.

Pike, Kenneth L. 1948. *Tone Languages: A Technique for Determining the Number and Type of Pitch Contrasts in a Language, with Studies in Tonemic Substitution and Fusion*. Ann Arbor, MI: University of Michigan Press.

Shih, Stephanie S & Sharon Inkelas. 2019. Autosegmental Aims in Surface-Optimizing Phonology. *Linguistic Inquiry* 50(1). 137–196. https://doi.org/10.1162/ling_a_00304.

Silverman, Daniel. 1997. Laryngeal complexity in Otomanguean vowels. *Phonology* 14(2). 235–261. https://doi.org/10.1017/S0952675797003412.

Suárez, Jorge. 1983. *The Mesoamerican Indian languages*. Cambridge: Cambridge University Press.

Thurgood, Graham. 2002. Vietnamese and tonogenesis: Revising the model and the analysis. *Diachronica* 19(2). 333–363. https://doi.org/10.1075/dia.19.2.04thu.

Titze, Ingo R. 2000. *Principles of voice production*. 2nd printing. Iowa City, IA: National Center for Voice and Speech. 409 pp.

Uchihara, Hiroto & Gabriela Pérez Báez. 2016. Fortis/lenis, glides and vowels in Quiaviní Zapotec. *Glossa: A Journal of General Linguistics* 1(1). 27. https://doi.org/10.5334/gjgl.13.

Yip, Moira Jean Winsland. 2002. *Tone* (Cambridge Textbooks in Linguistics). Cambridge ; New York: Cambridge University Press. 341 pp.