Interaction of tone and phonation in Santiago Laxopa Zapotec

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1 Introduction

The interaction between tone and phonation is primarily believed to consist of phonation being closely linked with certain tones depending on the language under discussion (Yip 2002, Wee 2019). This has lead to a growing body of literature that assumes this to be a universal fact about tonal languages (Michaud (2012), Brunelle & Kirby (2016), Hyman & Leben (2020), and Garellek & Esposito (2021) among many others). This, however, is not true for languages of the Americas. One of the linguistic areas where tone and phonation do not seem to be closely tied to one another is in Mesoamerica (Campbell, Kaufman & Smith-Stark 1986, Silverman 1997, Campbell 2017a,b). Silverman (1997) shows how tone and phonation are truly decoupled and result in a "laryngeally complex" system.

One of these languages that shows laryngeal complexity is Santiago Laxopa Zapotec, an Oto-Manguean language spoken in Oaxaca, Mexico. As will be discussed in Section 3, Santiago Laxopa Zapotec has a system of four phonation types and five tones which allows for a detailed study into how such systems are produced.

My qualifying paper will explore the interaction of tone and phonation in Santiago Laxopa Zapotec which will add to our understanding of how such laryngeally complex system are produced. This investigation will be based on data that I have collected from two native Santiago Laxopa Zapotec speakers that live in Santa Cruz, CA. Additionally, I will explore how best to represent such systems using the Laryngeal Articulator Model (Esling et al. 2019). The Laryngeal Articulator Model is a model which takes into account the full complexity of the lower vocal tract by using a series of monovalent states. The Laryngeal Articulator Model is described in more detail in Section 5.

2 Tone and Phonation

Tone, as a linguistic phenomenon, is very wide spread and is present in many of the world's languages (Yip 2002). Most of the tonal languages that have received the most attention are languages from Africa and Asia with languages of the Americas receiving some attention (Pike 1948, Silverman 1997, Campbell 2017a,b). Because of the focus on mostly African and Asian tonal languages certain assumptions are commonly held about what is possible for tonal languages.

One of the assumptions that is made is that tone and phonation are heavily dependent on each other (Andruski & Ratliff 2000, Yip 2002, Garellek et al. 2013, Brunelle & Kirby 2016, Wee 2019, Hyman & Leben 2020, Garellek & Esposito 2021). For example, Mandarin tone three, which is produced as a dipping tone in careful speech and a falling tone in rapid speech, has creakiness throughout the vowel. This creakiness is often the sole clue to differentiate it from a normal falling tone (Duanmu 2007, Kuang 2017).

Oto-Manguean languages from Mexico clearly show that the behavior between tone and phonation in Asia is not the only way in which tone and phonation can interact. In fact, Oto-Manguean languages have what Silverman (1997) calls "laryngeally complex" vowels. These laryngeally ccomplex vowels are ones where tone and phonation are entirely independent from one another. This means that any tone can co-occur with any phonation type. Some work has been done that adequately shows this such as Avelino Becerra (2004), Chávez-Peón (2010), DiCanio (2012), and Uchihara (2016). One of the more detailed of these studies is Chávez-Peón (2010) who investigates the phonetic cues to tone, stress, and phonation in San Lucas Quiaviní Zapotec (SLQZ) a Valley Zapotec variety. Chávez-Peón shows how tone and phonation are mostly independent from each other with a notable exception being the restriction of Rising tone in SLQZ which can only appear with modal phonation. The distribution of tone and phonation type is presented in Table 1.

Table 1: SLQZ tone and phonation

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

My qualifying paper will add to this lesser studied area of phonetics and phonology by investigating the interaction of tone and phonation in Santiago Laxopa Zapotec.

3 Overview of Santiago Laxopa Zapotec

Santiago Laxopa Zapotec (SLZ) is a variety of Sierra Norte Zapotec, a member of the Oto-Manguean language family, and spoken by approximately 800 to 1200 people in the municipality of Santiago Laxopa, Oaxaca, Mexico (Adler et al. 2018, Sichel & Toosarvandani 2020). Similar to other Oto-Manguean languages, SLZ exhibits Silverman's (1997) "larnygeally complex vowels". In addition to its five-vowel inventory, SLZ makes further distinctions with the addition of breathy, checked,[1] and laryngealized[2] phonations. The different phonation types are also represented in the orthography for SLZ as seen in (1)

(1) Breathy: [a̤] <*ah*>
Checked: [aˀ] <*a'*>
Laryngealized: [aˀa] <*a'a*>

There are many words that are differentiated by only by phonation in SLZ. For example, the words for *snake* and *fish* are only distinguished by the presence of breathy phonation, (2).

(2) a. *behl* [bɛ̤lː^{13}] ‘snake’
b. *bel* [bɛlː^{13}]‘fish’

In addition to phonation, SLZ, along with all of the Oto-Manguean languages, is a tonal language (Brinkerhoff, Duff & Wax Cavallaro 2021). SLZ has three level tones of high, mid, and low, which are represented in the transcriptions with Pike's numbers, where x^1 is the highest tone and x^3 is the lowest (Pike 1948, Wee 2019). In addition to these three level tones, SLZ has two contour tones, a rising (x^{21}) and a falling tone (x^{13}). The number of tones were discovered by myself and two other researchers following the methods for tonal analysis in Pike (1948) and Snider (2018). An overview of the different tonal patterns are seen in Table 2.

Table 2: SLZ tones

High	a^{1}	*xha*	[ʐa^{1}]	‘clothing.POSS’
Mid	a^{2}	*lhill*	[ɾiʒ^{2}]	‘house.POSS’
Low	a^{3}	*yu'*	[çu^{ʔ3}]	‘earth’
Rising	a^{21}	*yu'u*	[juˀu^{21}]	‘quicklime (Sp. cal)’
Falling	a^{13}	*yu'u*	[juˀu^{13}]	‘house’

SLZ sits at an important crossroads of studying tone and phonation because it is a language that has both independent tone and phonation. This combination allows for a thorough investigation into how tone and phonation interact which is an area that is still not well understood. Additionally, SLZ allows for us to investigate the phonetic realization of phonological contrasts.

[1]There are two ways in which this vowel can be analyzed. One is the traditional way where the glottal stop is considered inseparable from the vowel. The other is to treat this as a consonant which is restricted to only reside in codas (similar to how the sound /ŋ/ is restricted to codas in English). This second approach is the one taken by Avelino Becerra (2004). I will follow the traditional way of analyzing these vowels through this paper.

[2]Previous descriptions of the the vowel system of closely related languages have used various different terms for this vowel including broken, rearticulated, interrupted, and creaky (Long & Cruz 2005, Avelino 2010, Avelino Becerra 2004, Sonnenschein 2005, Adler & Morimoto 2016). In order to avoid confusion, I will use the term laryngealized following Avelino (2010).

4 Methods and materials

In order to investigate what is occurring with SLZ tone and phonation, two SLZ speakers, who live in Santa Cruz, CA, were asked to produce approximately 200 words in SLZ in a carrier sentence three times. This allowed for a good overlap between tone and phonation type. Because data collection occurred during the COVID-19 pandemic two methods were used to elicit data. The first was using Zencastr[3], a professional podcasting website, to prevent potential exposure to each other. Once we were all vaccinated and it was deemed safe by myself and my consultants, we meet at in the backyard of the consultants and recording was done using a Zoom H4n audio recorder (44.1kh-16bit).

(3) Carrier Sentence
sh-ni=a’^{13} ____ cho^{2}ne^{2} las^{2}
CONT-speak=1SG ____ three times
‘I say ____ three times’

Once the recordings were made, the audio files were initially segmented using ELAN (Wittenburg et al. 2006) and then passed to PRAAT (Boersma & Weenink 2021) for segmenting the vowels and extracting them for analysis in VOICESAUCE (Shue, Keating & Vicenik 2009).I am currently segmenting the vowels out of the audio files in PRAAT and will shortly be analyzing the extracted vowels in VOICESAUCE.

5 Laryngeal Articulator Model

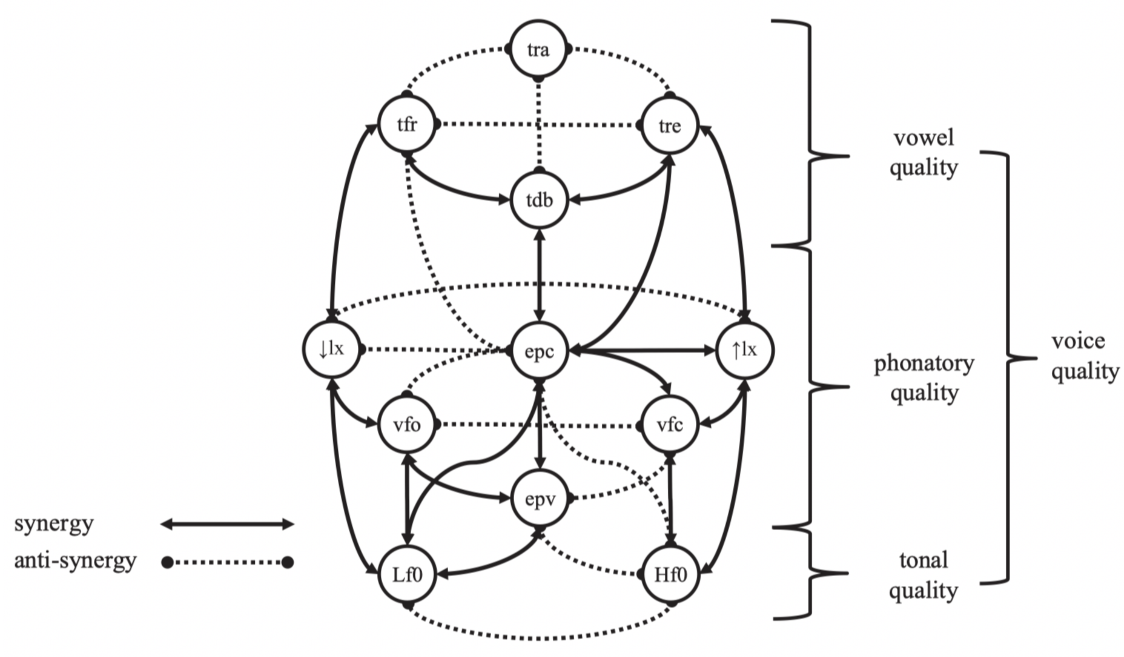
One way that the interaction between phonation and tone could be understood is with Esling et al.’s (2019) Laryngeal Articulator Model. The Laryngeal Articulator Model takes as a basic assumption that laryngeal articulations are more complex than what most phonological feature systems represent. For example the feature system in Hayes (2009) assumes that only three features ([± voice], [± constricted glottis], and [± spread glottis]) are able to capture the full range of laryngeal complexity. This, however, is a gross simplification of the articulation in the larynx. For breathy voice because the larynx is open, the airflow is less turbulent and less impeded allowing for more linear airflow through the pharyngeal space (Esling et al. 2019: p. 56). Creaky voice on the other hand is produced with thick, short vocal folds. Additionally, a loose aspect is required which is thyroarytenoid muscles from the borders of the arytenoids to the front of the epilaryngeal tube Esling et al. (2019: p. 63). However, the ventricular folds can couple with the vocal folds during creaky phonation. This coupling has four effects: (i) it increases the overall

[3] https://zencastr.com/

effective vibrating mass, lowering frequency; (ii) it adds damping, making vibration more likely to cease; (iii) it adds increased degrees of freedom to the system, encouraging irregular vibration; and, most importantly, (iv) it perturbs the transmission of the mucosal wave by preventing its traversal across the surface of the vocal folds, causing the wave energy to be reflected back towards the midline earlier than what would occur for modal phonation (Esling et al. 2019: p. 63).

Based on these complexities in the lower vocal tract that accompany laryngeal and pharyngeal, Esling et al. propose their Laryngeal Articulator Model which attempts to capture the ‘articulatory’ realization of the larynx following Ohala (2005, 2011). In accounting for the physiological states that the lower vocal tract is in during speech production, Esling et al. propose the addition of a network of synergistic and anti-synergistic physiological relations that are represented in the Figure 1.

Figure 1: Network of synergistic and anti-synergistic physiological relations among vocal tract states



Using these networks, one can more accurately describe what is occurring in the larynx during phonation. I plan on using these networks to describe and account for the the interaction between tone and phonation in SLZ.

6 Conclusion

This paper has laid out our current understanding of the interaction of tone and phonation and what is possible. Additionally, our current understanding of the tone and phonation in SLZ was

Table 3: Physiological states of the lower vocal tract

States	Physiological description
vfo	vocal folds open (abducted)
vfc	vocal folds closed (adducted/prephonation)
epc	epilaryngeal constriction
epv	epilaryngeal vibration
tfr	tongue fronting
tre	tongue retraction
tra	tongue raising
tdb	tongue double bunching
↑lx	raised larynx
↓lx	lowered larynx
Hf0	increased vocal fold tension, less vibrating mass (high f0)
Lf0	decreased vocal fold tension, more vibrating mass (lower f0)

described. I also provided a description of the methods that I am employing to investigate this interaction. One potential way of explaining the complex interactions of tone and phonation could potentially be found in the Laryngeal Articulator Model was also introduced.

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.

Andruski, Jean E. & Martha Ratliff. 2000. Phonation types in production of phonological tone: the case of Green Mong. *Journal of the International Phonetic Association* 30(1-2). 37–61. https://doi.org/10.1017/S0025100300006654.

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.

Avelino Becerra, Heriberto. 2004. *Topics in Yalálag Zapotec, with particular reference to its phonetic structures*. Los Angeles, CA: University of California, Los Angeles dissertation. 315 pp.

Boersma, Paul & David Weenink. 2021. *Praat: Doing Phonetics by Computer [Computer Program].* http://www.praat.org/ (3 December, 2021).

Brinkerhoff, Mykel L., John Duff & Maya C. Wax Cavallaro. 2021. Downstep in Santiago Laxopa Zapotec and the prosodic typology of VSO languages. In *Manchester Phonology Meeting*. Manchester, England.

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.

Chávez-Peón, Mario E. 2010. *The interaction of metrical structure, tone, and phonation types in Quiaviní Zapotec*. University of British Columbia dissertation. https://doi.org/10.14288/1.0071253.

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.

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.

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.

Garellek, Marc, Patricia Keating, Christina M. Esposito & Jody Kreiman. 2013. Voice quality and tone identification in White Hmong. *The Journal of the Acoustical Society of America* 133(2). 1078–1089. https://doi.org/10.1121/1.4773259.

Hayes, Bruce. 2009. *Introductory phonology* (Blackwell Textbooks in Linguistics 23). Malden, MA ; Oxford: Wiley-Blackwell. 323 pp.

Hyman, Larry M. & William R. Leben. 2020. Tone Systems. In Carlos Gussenhoven & Aoju Chen (eds.), *The Oxford Handbook of Language Prosody*, 44–65. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198832232.013.6.

Kuang, Jianjing. 2017. Covariation between voice quality and pitch: Revisiting the case of Mandarin creaky voice. *The Journal of the Acoustical Society of America* 142(3). 1693–1706. https://doi.org/10.1121/1.5003649.

Long, Rebecca & Sofronio Cruz. 2005. *Diccionario zapoteco de San Bartolomé Zoogocho, Oaxaca.* 2nd edition (Serie de vocabularios y diccionarios indígenas "Mariano Silva y Aceves" no. 38). Coyoacán, D.F. [Mexico]: Instituto Lingüístico de Verano. 531 pp.

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

Ohala, John J. 2005. Phonetic Explanations for Sound Patterns: Implications for Grammars of Competence. *UC Berkeley Phonology Lab Annual Reports* 1. https://doi.org/10.5070/P75M77T155.

Ohala, John J. 2011. Accommodation to the Aerodynamic Voicing Constraint and its Phonological Relevance. In *ICPhS XVII*. Hong Kong: International Phonetic Association.

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.

Shue, Yen-Liang, Patricia Keating & Chad Vicenik. 2009. VOICESAUCE: A program for voice analysis. *The Journal of the Acoustical Society of America* 126(4). 2221. https://doi.org/10.1121/1.3248865.

Sichel, Ivy & Maziar Toosarvandani. 2020. Pronouns and Attraction in Sierra Zapotec. In Andrew Hedding & Morwenna Hoeks (eds.), *Syntax and semantics at Santa Cruz, Volume IV* (Syntax & Semantics at Santa Cruz (SASC) 4). Santa Cruz, CA: Linguistics Research Center.

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

Snider, Keith L. 2018. *Tone analysis for field linguists.* Dallas: SIL International Publications. 183 pp.

Sonnenschein, Aaron H. 2005. *A descriptive grammar of San Bartolomé Zoogocho Zapotec.* Munich: Lincom Europa.

Uchihara, Hiroto. 2016. Tone and registrogenesis in Quiaviní Zapotec. *Diachronica* 33(2). 220–254. https://doi.org/10.1075/dia.33.2.03uch.

Wee, Lian-Hee. 2019. *Phonological Tone.* 1st edn. Cambridge University Press. https://doi.org/10.1017/9781316410912.

Wittenburg, Peter, Hennie Brugman, Albert Russel, Alex Klassmann & Han Sloetjes. 2006. ELAN : a professional framework for multimodality research. In 1556–1559.

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