Measuring voice quality in Zapotec

Introduction: Voice quality (VQ) refers to the manner in which phonation occurs. It is widely employed in the world's languages for both paralinguistic and phonological contrasts (see Garellek 2019 for an overview). It has long been established that VQ has acoustic correlates in the signal (Fischer-Jørgensen 1968). The most commonly used of these acoustic measures being H1-H2.

Recent research by Chai & Garellek (2022) shows that H1-H2 is less robust and is prone to error propogation. They propose using a Residual H1*, which factors out the root mean squared energy from H1*. They show that this measure is more robust and better captures the VQ distinctions in !Xõó and Mandarin Chinese than H1*-H2*.

Building on this research into residual H1*, Brinkerhoff & McGuire (2024) show that residual H1* better captures the VQ distinctions in Santiago Laxopa Zapotec. The present study validates those findinigs using generalized additive mixed models, which better account for dynamic data, such as changes in harmonic amplitude, than linear regression models (Hastie & Tibshirani 1986, Wieling 2018, Sóskuthy 2021).

Santiago Laxopa Zapotec (SLZ): SLZ is an indigenous language from Santiago Laxopa, Ixtlán, Oaxaca, Mexico and spoken by ∼1000 speakers. This variety is unique for being a Northern Core Zapotec that has developed breathy voice (B; 1b) in addition to the two types of laryngealization that characterize the rest of the Zapotecan languages, namely checked (C; 1c) and rearticulated (R; 1d) (see Ariza-García 2018 for a detailed typology of VQ in Zapotec languages). This contrast can be seen in the near minimal quadruple in (1a-d).

(1)	a.	*ya* [j̥a˦] 'temazcal'	c.	*cha'* [tʃaˀ˧] 'pot'
	b.	*yah* [j̥a̤˧] 'iron'	d.	*ya'a* [j̥aˀa˧] 'market'

SLZ additionally has three tones and two contours independent of the VQ contrast.This results in VQ and tone being orthogonal to each, which complicates acoustical analyses into SLZ.

Methodology: A word list elicitation was collected from 10 native SLZ speakers (five female) in Santiago Laxopa, Oaxaca. This word list contained 76 words across the four VQ contrasts. Each word was said in isolation and a carrier sentence three times. The vowels from the carrier sentences were segmented following Garellek (2020), and processed using VoiceSauce (Shue, Keating & Vicenik 2009). Several measures were assessed in this study: corrected H1*-H2*, Residual H1* as discussed in Chai & Garellek (2022), and corrected H1*-A3, following previous work on this variety (Adler & Morimoto 2016). Three generalized additive mixed models (GAMMs; Hastie & Tibshirani 1986) were fitted, one each for H1*-H2*, H1*-A3, and residual H1*.

Results: Figure 1 shows H1*-H2* and that each of the non-modal VQs have lower values than M and they overlap in each of the three vowel positions. Figure 2 shows that the only contrasts reliably captured by H1*-A3 are B, C, and M; R and M are nearly identical throughout the vowel. Figure 3 shows that residual H1* reliably separates B, C, and R from M, and also captures the positional distinction between R and C. The three GAMMs support the visualizations.

Conclusion: The results of this study on Santiago Laxopa Zapotec confirms the findings of Brinkerhoff & McGuire (2024) and shows that residual H1* is a reliable measures of VQ and should be considered when assessing phonation type in languages with complex phonation systems like Zapotec.

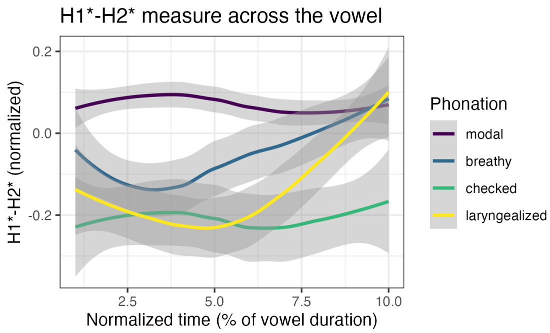

Figure 1: Smooths for H1*-H2* by phonation contrast

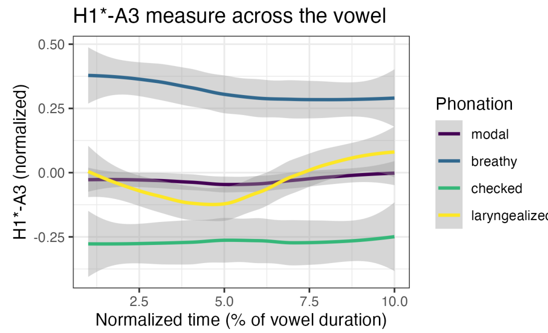

Figure 2: Smooths for H1*-A3 by phonation contrast

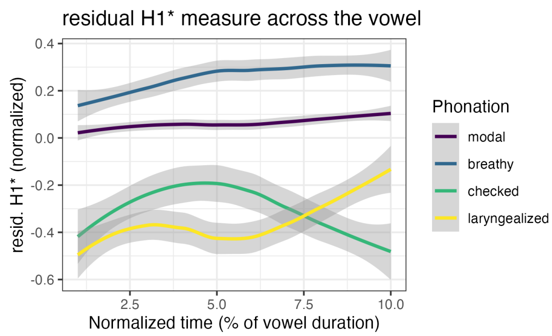

Figure 3: Smooths for residual H1* by phonation contrast

References

Adler, Jeff & 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.

Ariza-García, Andrea. 2018. Phonation types and tones in Zapotec languages: A synchronic comparison. *Acta Linguistica Petropolitana* XIV(2). 485–516.

Brinkerhoff, Mykel Loren & Grant McGuire. 2024. On residual H1* as a measure of voice quality. In Taehong Cho, Sahyang Kim, Jeff Holiday & Sang-Im Lee-Kim (eds.), *Proceedings of the 19th Conference on Laboratory Phonology*. Seoul, Korea: Hanyang Institute for Phonetics and Cognitive Sciences of Language5.

Chai, Yuan & Marc Garellek. 2022. On H1–H2 as an acoustic measure of linguistic phonation type. *The Journal of the Acoustical Society of America* 152(3). 1856–1870.

Fischer-Jørgensen, Eli. 1968. Phonetic Analysis of Breathy (Murmured) Vowels in Gujarati. *Annual Report of the Institute of Phonetics University of Copenhagen* 2. 35–85.

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. 2020. Acoustic Discriminability of the Complex Phonation System in !Xóõ. *Phonetica* 77(2). 131–160.

Hastie, Trevor & Robert Tibshirani. 1986. Generalized Additive Models. *Statistical Science* 1(3). 297–310.

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.

Sóskuthy, Márton. 2021. Evaluating generalised additive mixed modelling strategies for dynamic speech analysis. *Journal of Phonetics* 84. 101017.

Wieling, Martijn. 2018. Analyzing dynamic phonetic data using generalized additive mixed modeling: A tutorial focusing on articulatory differences between L1 and L2 speakers of English. *Journal of Phonetics* 70. 86–116.