An Acoustic and Electroglottographic Study of Phonation in Santa Ana del Valle Zapotec

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Background:
Phonation in Zapotec languages

- **Phonation Types**: The phonations of Zapotec languages vary across languages:
  - **Four-way contrast** between modal, breathy, creaky, and checked (a vowel followed by a glottal stop)
    - e.g. San Lucas Quiaviní Zapotec (Munro and Lopez et al. 1999)
  - **Three-way contrast** between modal, creaky, and checked
    - e.g. San Juan Guelavía Zapotec (Jones and Knudsen 1977); Cajonos Zapotec (Nellis and Hollenbach 1980)

- **Sequences of Phonations**: Some accounts describe the possibility of having up to three phonation types in one syllable.
  - e.g. Choapan Zapotec (Lyman and Lyman 1977); San Lucas Quiaviní Zapotec (Munro and Lopez et al. 1999)

- **Tonal analyses** also vary from language to language.
  - **Strong correlation between tone and phonation**
    - e.g. San Lucas Quiaviní Zapotec (Munro and Lopez et al. 1999)
  - **Tone and phonation are independent features**
    - e.g. San Juan Guelavía Zapotec (Jones and Knudsen 1977)

- Little is known about the phonetic properties of these phonations and tones.

Current Study

- Study of the phonation and tone in one Zapotec language, **Santa Ana del Valle Zapotec** (SADVZ), spoken in Santa Ana del Valle, Oaxaca, Mexico.

About SADVZ:
- The number of speakers is not known.
- Ethnologue classifies SADVZ into the San Juan Guelavía Zapotec subgroup. This subgroup includes: San Lucas Quiaviní Zapotec, San Juan Guelavía Zapotec, Tlacolula Zapotec, etc.

- The following questions will be addressed:
  - What is a good measure of phonation for SADVZ?
  - What are the phonations and tones of SADVZ? Are they consistent across speakers, words, contexts, etc.?
  - Does phonation change over the course of a syllable?
Determining a measure of phonation

• As a starting point, I propose a three-way contrast in phonation for SADVZ, because a near-minimal triplet can be found.
  
  Modal = [lat] ‘tin can’
  Breathy = [laɛt] ‘place’
  Creaky = [laːts] ‘field’

• After a measure of phonation has been selected, it will be possible to see if the proposed three-way contrast in phonation should be expanded.

Methods

• Speakers
  – Five native speakers of SADVZ (three male, two female), from 40 to 70 years of age, were recorded for this study.

• Speech Materials

Procedure

• Simultaneous electroglottograph (EGG) and audio recordings were made for each speaker using a Glottal Enterprise Two-channel EGG.

• Tokens were digitized and analyzed in AcQuirer (Scicon RD) at a sampling rate of 22050 Hz.

• Two spectral correlates were tested:
  - H1-H2 – reflects the portion of time the vocal folds are open during each glottal cycle
  - H1-A3 – reflects the speed at which the vocal folds close

Results: Spectral Measures

• The three phonations are distinguished by:
  - H1-A3 for the male speakers
  - H1-H2 for the female speakers

A Difference in Production

• H1-A3: suggests that male speakers produce phonation differences by the speed of vocal fold closure.

• H1-H2: suggests that female speakers produce phonation differences by the proportion of time the vocal folds are open.

• This hypothesis is confirmed by the EGG results.
A Difference in Production
Results: EGG

Male Speakers

- Peak closing-velocity (not CQ) distinguishes the three phonation categories for the male speakers.
  - Suggesting that the male speakers’ phonations are produced by the speed of vocal fold closure.

Female Speakers

- CQ (not Peak closing-velocity) distinguishes the three phonation categories for the female speakers.
  - Suggesting that the female speakers’ phonations are produced by the proportion of time the vocal folds are open during each glottal cycle.

Phonation in SADVZ

- It is now possible to expand this measure to a wider range of words in SADVZ to determine whether a three-way phonation contrast suffices to describe its phonations.

Methods

- Speakers and Speech Materials
  - 5 speakers produced tokens that could exhibit a more complex phonation contrast than simply breathy, modal, and creaky (based on cognates in related languages).

Results: Checked Vowels

- Vowels followed by a glottal stop (i.e. checked vowels) had similar phonation as creaky vowels (that were not followed by a glottal stop).

- The measures used in this study distinguish three phonations.
  - These correspond to the categories of:
    modal, breathy, creaky (confirmed by perception)

NEXT: Do these results generalize across other sentence contexts?
**Methods**

- **Procedure**
  - 5 Speakers produced tokens in five prosodic positions:
    - **Isolation (with focus)** = higher f0 than sentence-medial position
    - **Isolation (without focus)** = mid-range f0
    - **Initial (focused)** = higher f0 than sentence-medial position
    - **Medial** = mid-range f0
    - **Final (end of declarative)** = lower f0 than sentence-medial position
  - H1-A3 and H1-H2 were measured from 1024 pt FFT taken over a 30 ms window before the end of the vowel.

**Summary**

- Three-way phonation contrast is clearest in:
  - **Isolation (mid-range f0)**
  - **Medial position (mid-range f0)**
  - **Final position (Lower f0)**
  - But with some changes for the female speakers. Female speakers’ modal vowels were creakier word-finally than in medial position.

However, the three-way contrast in phonation is not always well-defined.

- Minimized Contrast:
  - **Isolation, focused (high f0)**
  - **Initial position (high f0)**
  - In these two positions, breathy and creaky vowels had a much more modal phonation than when produced in sentence-medial position.

**Results**

<table>
<thead>
<tr>
<th>Male Speakers</th>
<th>Female Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Graph showing pitch" /></td>
<td><img src="image" alt="Graph showing pitch" /></td>
</tr>
</tbody>
</table>

**Is it position or fo that affects phonation in SADVZ?**

- There is evidence that it is f0 and not position-in-utterance that affects phonation.
  - **One position, two f0’s**
    - Words in isolation can be produced with either a mid-range f0 or a high f0.
    - Only when the tokens are produced with a high f0 is the three-way contrast in phonation minimized.
  - **Two positions, one f0**
    - Words in isolation (non-focused) and sentence-medial position are produced with a mid-ranged f0.
    - In both cases, there is a clear three-way contrast in phonation.

**Pitch**

- Fo was measured manually from an FFT at three time-points in the vowel (beginning, middle, and end) (using tokens elicited in sentence-medial position).
Summary: Pitch

- A strong relation between f0 and phonation was found.

<table>
<thead>
<tr>
<th>Modal</th>
<th>high, or high-rising f0 (in contrast)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breathy</td>
<td>slightly falling f0</td>
</tr>
<tr>
<td>Creaky</td>
<td>falling f0</td>
</tr>
</tbody>
</table>

Changes in Phonation within a syllable

- Procedure
  - H1-A3 (males) and H1-H2 (females) was measured at three time-points within a vowel: beginning, middle, and end (using tokens elicited in sentence-medial position).

Results: Changes in Phonation

- The frequency of occurrence of the values of H1-A3 (in dB) for the male speakers (same results in females).

Summary: Changes in Phonation

- One phonation was found per syllable, except in the case of creaky phonation.
  - Creaky phonation begins with modal phonation and concludes with creak.

Summary

- A good measure of phonation for SADVZ:
  - While H1-H2 is the most common measure of phonation, it does not always distinguish phonation types, even within a single language.

<table>
<thead>
<tr>
<th>Speakers</th>
<th>Successful measures of phonation</th>
<th>Suggested manner of phonation production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>H1-A3, Peak closing-velocity</td>
<td>the speed of vocal fold closure</td>
</tr>
<tr>
<td>Female</td>
<td>H1-H2, Closed Quotient</td>
<td>the proportion of time the vocal folds are open</td>
</tr>
</tbody>
</table>
Summary

• The phonations and ‘tones’ of SADVZ
  – Three phonations:
    • modal, breathy, and creaky
  – F0: A strong relation between f0 and phonation was found, unlike some of the other Zapotec languages, which can have several independent tones and phonations.
    • Modal – High or a High-rising f0 (with no change in phonation).
    • Breathy – Slightly falling f0
    • Creaky – Largely falling f0

Summary

• Changes in phonation over the course of a syllable
  – One phonation was found per syllable, except in the case of creaky phonation.
  – Creaky phonation begins with modal phonation and concludes with creak.

Summary

• Strong effect of f0 on phonation:
  • When the f0 is mid-ranged (sentence-medial position, isolation), there is a three-way contrast in phonation.
  • When the f0 is high (isolation (with focus), sentence-initial position), the three-way contrast in phonation is minimized.

Summary

• The results obtained show that in order to see a full range of phonation contrasts, it is important to elicit data that display a range of f0’s.
• It is possible that the effect of f0 on phonation is one of the reasons that there is disagreement as to the number of phonation categories in the Zapotec languages.
  – Breathy vowels are least apparent in precisely the position one would elicit them – isolation.

Footnotes

1. There is no significant difference in phonation between the creaky vowels and vowels followed by a glottal stop: t(43) = 1.9 p > .05.
2. There is no significant difference in phonation between the modal vowels with a high and a high-rising tone: t(58) = 3.5 p > .05.

References

Chicano Studies Research Center Publications, UCLA.