Hypothesis

- Listeners are better at discriminating pitches implemented during modal phonation than pitches implemented during breathy phonation

Motivation for hypothesis

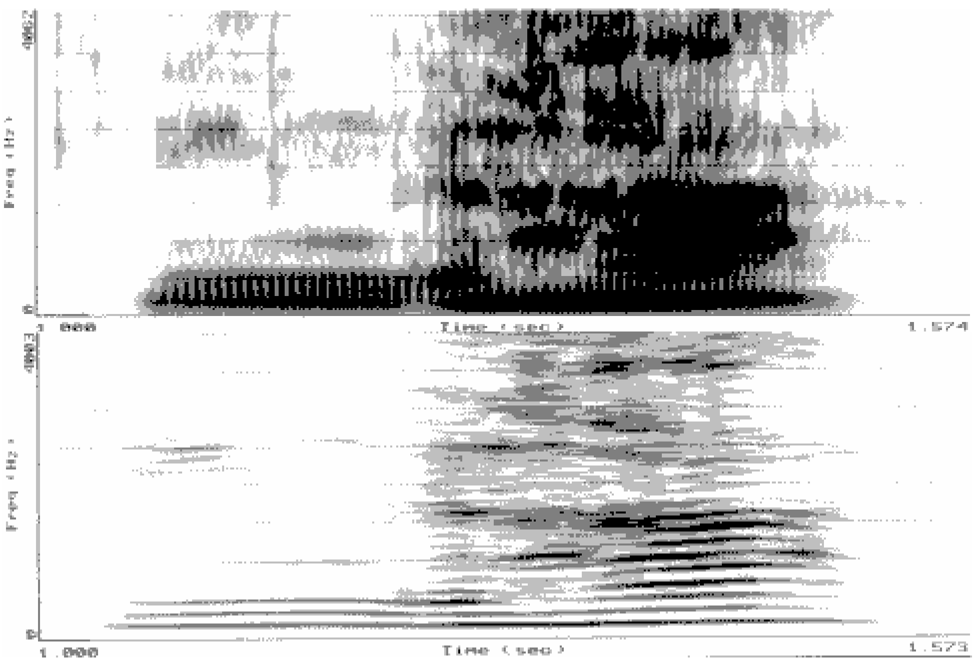
- Pitch is primarily determined by glottal pulse period and harmonic structure
- Glottal pulse rate in breathy vowels is irregular in Jalapa Mazatec (an Otomanguean language of Oaxaca, Mexico; Kirk, Ladefoged

and Ladefoged 1993); spectrum of Jalapa Mazatec breathy vowels involves significant harmonic weakening and broadband noise, (Silverman, Blankenship, Kirk, and Ladefoged 1995, Silverman, 1997, *in press*)

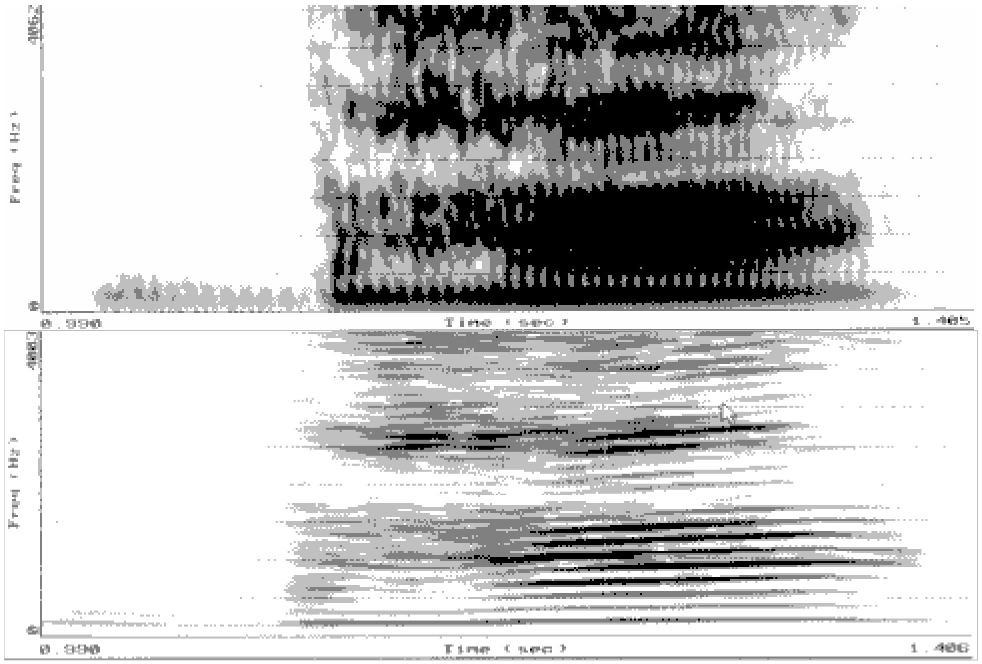
- **Pitch differences may be less reliably discriminible during breathy phonation than during modal phonation**

Stimuli

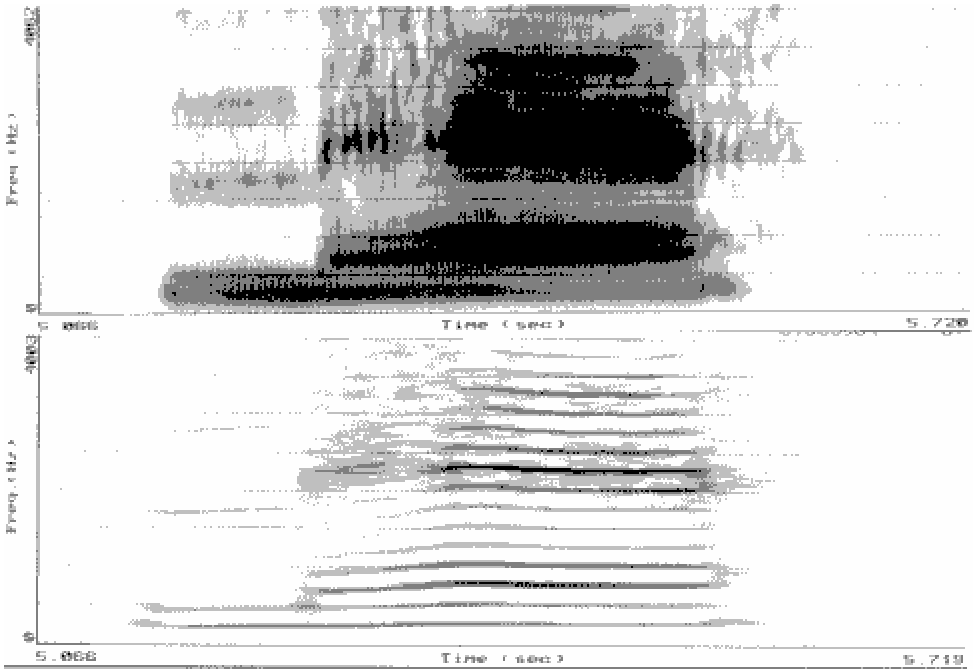
- **Digitized natural speech stimuli from Jalapa Mazatec:**



ᵑgi˧ᵑga̤͡a˩˧ **(he fastened)**



^{n}da̤͡a̤˦˥ **(hard)**

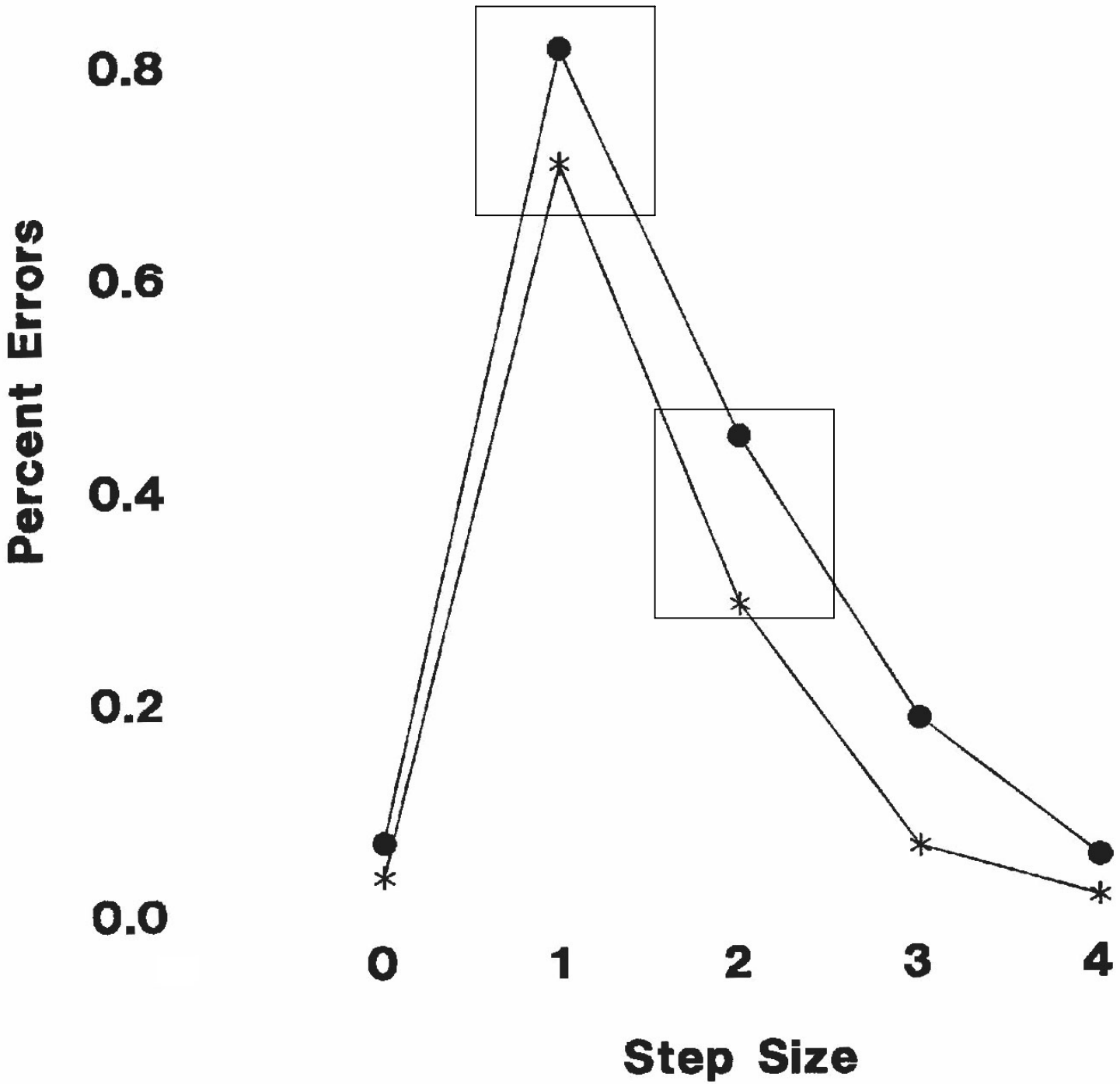


m͡m̤æ̤͡æ˦ **(he wants)**

- **Both breathy portion and modal portion extracted from each word**
- **Pitch of modal portions lowered to equal pitch of breathy portions (with SoundEdit16.2 "bender" feature)**
- **Amplitude of six spectra normalized for peak amplitude**
- **onsets and offsets ramped to avoid click artifacts**
- **Frequency of each portion increased in increments of approximately 3 Hz., resulting in six continua with five steps each.**
- **All forms converted to 200 msec in length**

- **All possible within-continuum pairs (up to one-half tone differences) produced, for a total of 366 stimulus pairs**
- **1000 trials/listener (501 “different” pairs; 499 “same” pairs), presented in blocks of 50 pairs. Inter-stimulus interval = 300 msec; inter-trial interval = 3 sec.**
- **Subjects judged for each pair whether the two stimuli were the same or different pitch.**

Results


Percent Errors
0.8
0.6
0.4
0.2
0.0
0
1
2
3
4
Step Size

Discussion

- **Most Otomanguean languages, including Jalapa Mazatec, possess vowels which are "laryngeally complex"; vowels in which contrastive phonation *and* contrastive pitch (tone) cross-classify (Silverman 1993, 1995, 1997a,b)**
- **Laryngeally complex vowels are realized in a part-modal part-nonmodal fashion**
- **Such patterns are present in Mazatec, as well in related Chinantec and Trique:**

Mazatec	hV́			ʔV́		
Chinantec	hV́	V́h		ʔV́	V́ʔ	
Trique	hV́	V́h	V́hV́	ʔV́	V́ʔ	V́ʔV́

Conclusion

- **pitch is less reliably discriminible during breathy phonation (and creaky phonation; Rosenberg 1965).**
- **Tone and non-modal phonation may be *sequenced* such that the laryngeally complex**

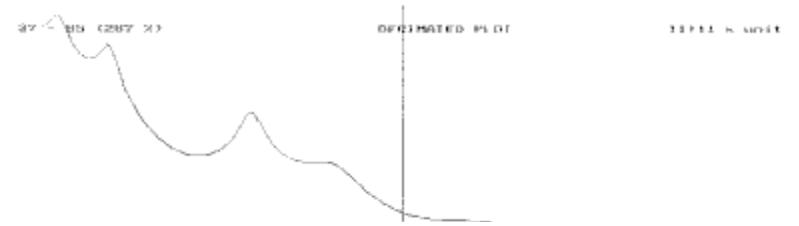
vowel is realized in a part modal/part non-modal fashion

- In this way, both tone and phonation contrasts may be saliently cued to the listener

A note on the SoundEdit16.2 "bender" feature

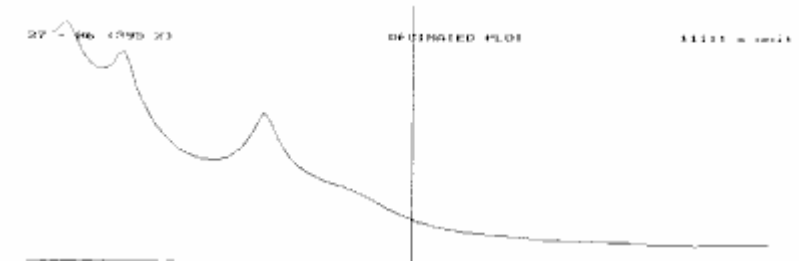
The SE16.2 "bender" slows down or speeds up the playback of a sound. The playback sample rate is manipulated and the sound is resampled to the original (and constant) sample rate. The spectra are equally shifted in frequency and thus the ratios of the component frequencies are preserved. Given the spectral shift involved, some slope distortion may be added to the modifed signal: a shift up in formants for sped-up playback, and a shift

down for slowed-down playback. But given the very minor signal adjustments employed in this study (roughly 3 Hz. per step), spectral shifts are exceedingly minor, increasing, of course, as more steps are made.

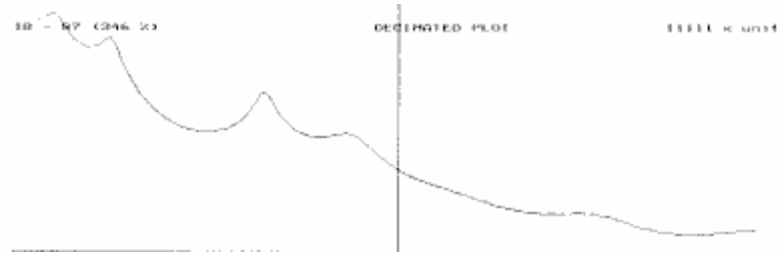


step 1

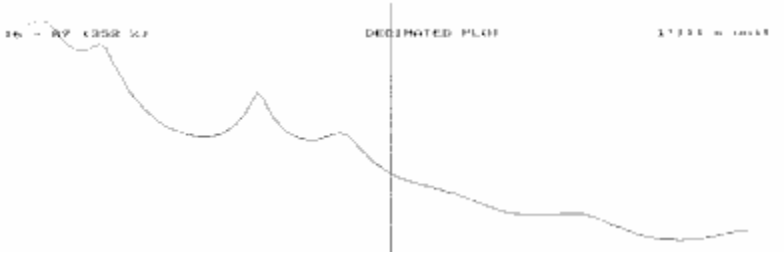
step 2



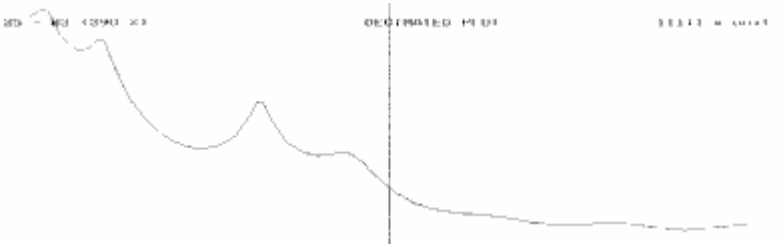
step 3



step 6



step 7



step 8

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This research was supported by NIH Training Grant T32 DC 00008. Thanks to Norma Antoñanzas-Barroso, Bruce Gerrett, and Jody Kreiman for their support at every stage of this study.