Pitch discrimination during breathy versus modal phonation

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HYPOTHESIS

(1) Listeners are better at discriminating pitches implemented during modal phonation than pitches implemented during breathy phonation

MOTIVATION FOR HYPOTHESIS

(2) Pitch is probably determined by **glottal pulse period** and **harmonic structure** (e.g. the spectrotemporal model of Moore 1989).

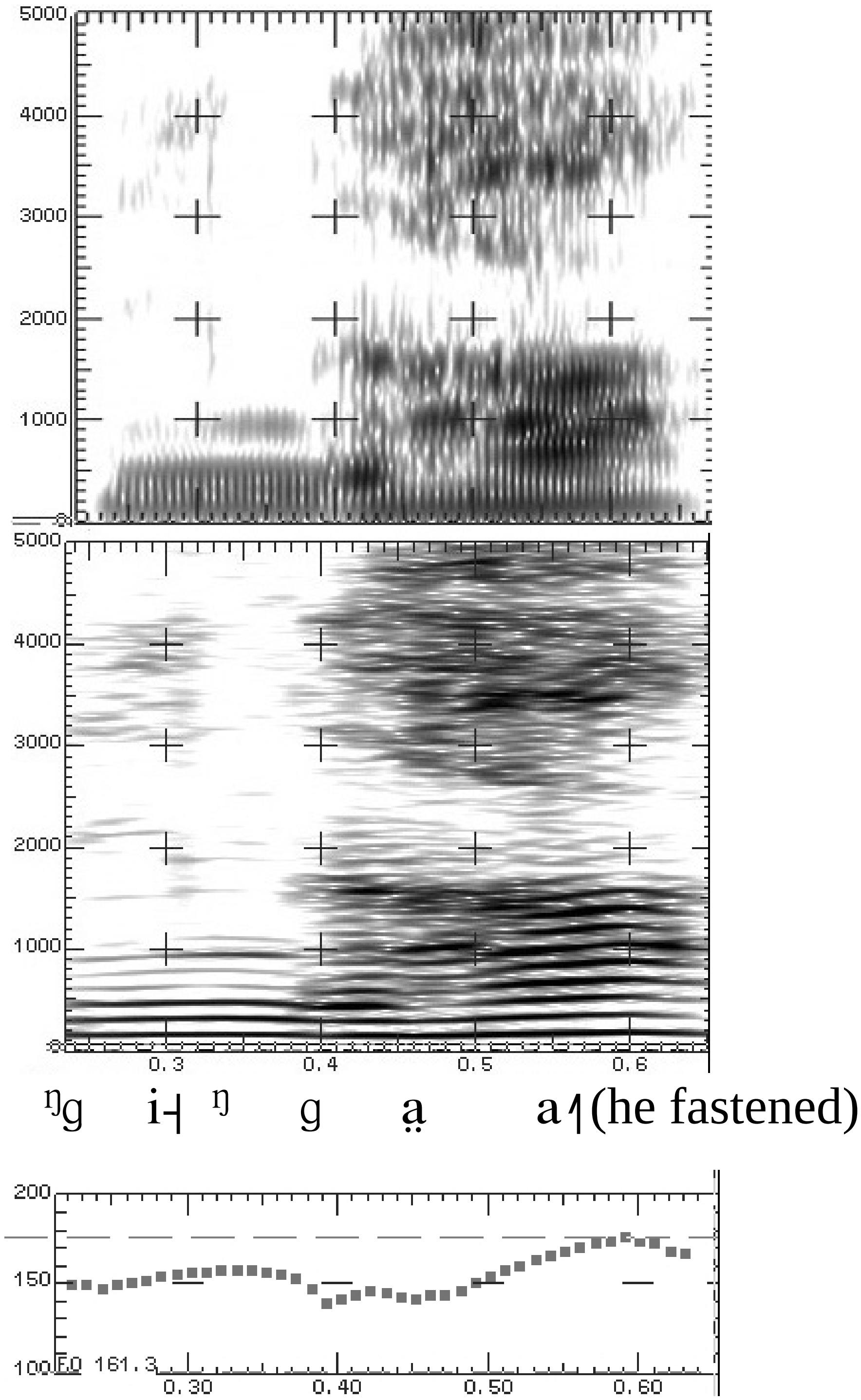
(3) Glottal pulse period in breathy vowels is **irregular** in Jalapa Mazatec (an Otomanguean language of Oaxaca, Mexico; Kirk, Ladefoged and Ladefoged 1993); spectrum of Jalapa Mazatec breathy vowels involves a **lower signal-to-noise ratio** (Silverman, Blankenship, Kirk, and Ladefoged 1995, Silverman, 1995, 1998)

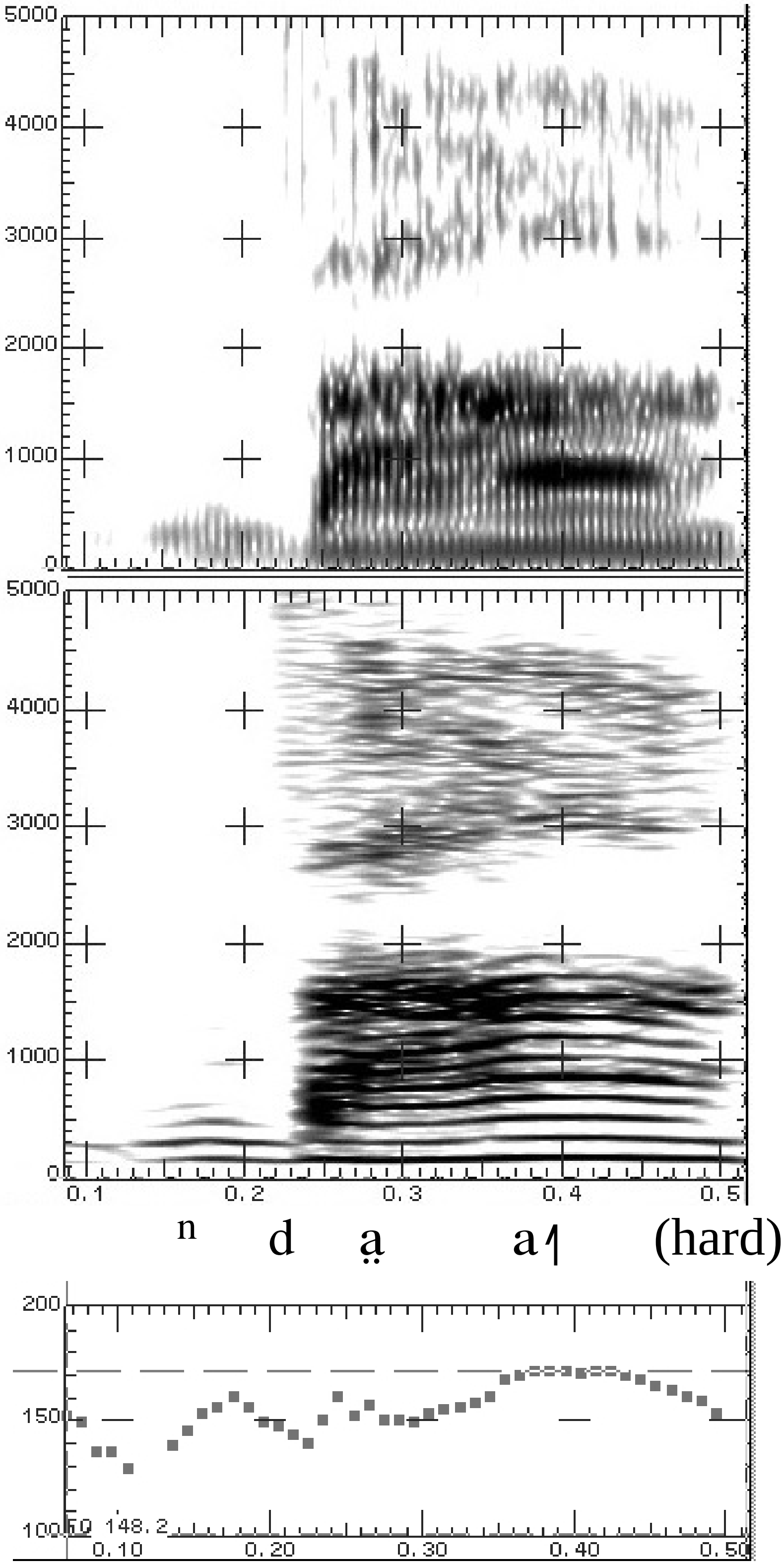
(4) Certain linguistic typological facts (to be discussed later)

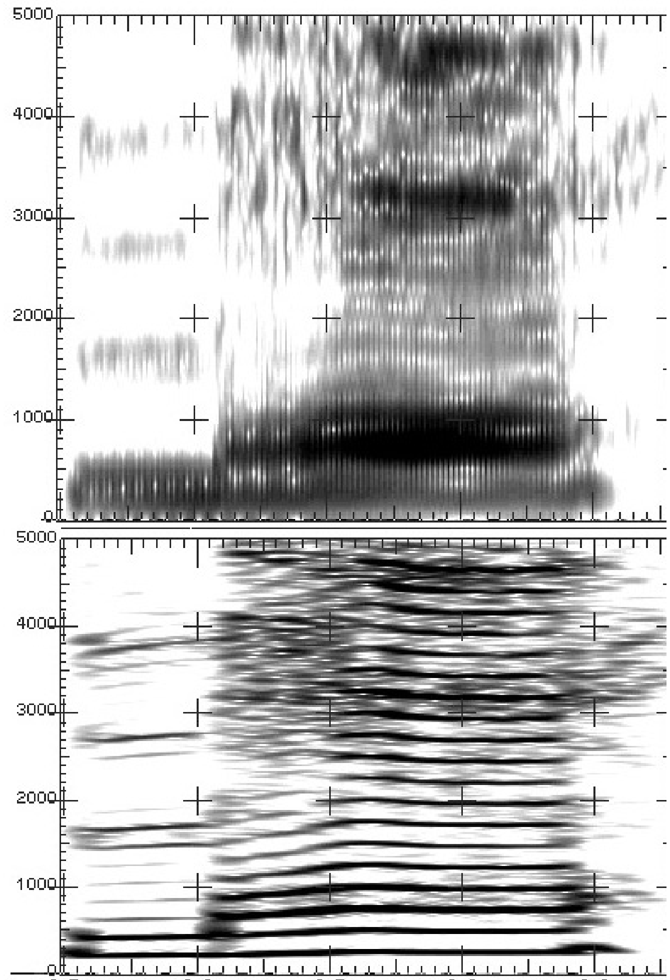
(5) Pitch differences may be less reliably discriminible during breathy phonation than during modal phonation

STIMULI

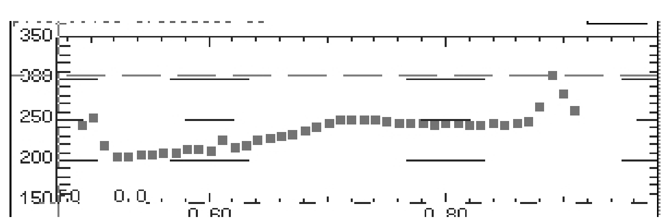
(6) Digitized natural speech from Jalapa Mazatec:




5000
4000
3000
2000
1000
0
0.1
0.2
0.3
0.4
0.5
n
d
a̤
a˥
(hard)
200
150
100
50 148.2
0.10
0.20
0.30
0.40
0.50



m m̤ æ̤ æ˥ (he wants)



(7) Both breathy portion and modal portion extracted from each word

(8) Pitch of modal portions lowered to equal pitch of breathy portions (with SoundEdit16.2 "bender" feature)

(9) Amplitude of six spectra normalized for peak amplitude

(10) Onsets and offsets ramped to avoid click artifacts

(11) Frequency of each portion increased in increments of approximately 3 Hz up to one whole tone, resulting in six continua with nine steps each

(12) All forms converted to 200 msec in length

(13) All possible within-continuum pairs produced, up to one-half tone difference (61 pairs per continuum, for a total of 366 stimulus pairs)

(14)

	0	.125	.25	.375	.5	.625	.75	.875	1 tone
0									
.125									
.25									
.375									
.5									
.625									
.75									
.875									
1 tone									

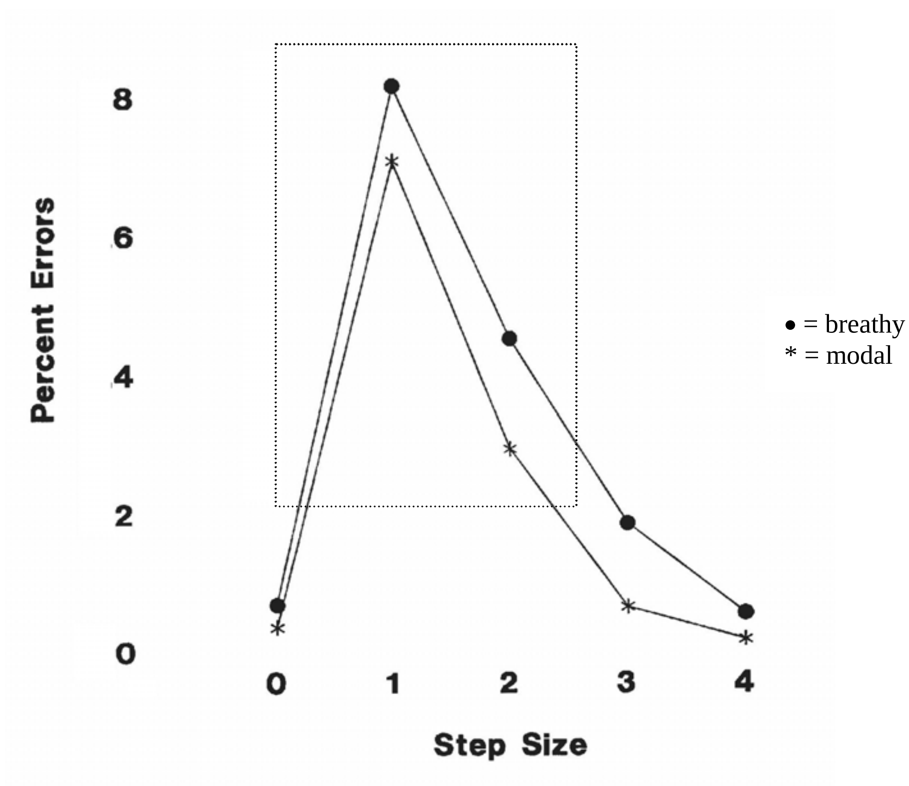
SUBJECTS/PROCEDURE

(15) 10 non-Jalapa Mazatec-speaking UCLA graduate students

(16) 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.

(17) In a sound booth, subjects judged for each pair whether the two stimuli were the same or different in pitch.

RESULTS
(18)



(19) Subjects performed more accurately on modal vowel pairs than on breathy vowel pairs ($p<.05$). No significant learning took place.

(20) Moreover, at the 3- and 6-Hz intervals, performances was significantly worse than performance at the 9- and 12-Hz intervals ($p<.05$) (see "□" in 18).

(21) Thus, not only was subject performance significantly worse overall on breathy token pairs, but also, subjects performed increasingly worse as the pitch interval between tokens fell to approx. 6 Hz and below.

DISCUSSION

(22) The results of this study may be seen as complementing those of Rosenberg (1965), who found that when a pulse train varies, or jitters, by more than 10%, an otherwise just-noticeable pitch difference within the 300-1000 Hz range is rendered indiscriminible. Thus whether jittered (an acoustic correlate of vocalic ‘creak’) or reduced in signal-to noise ratio (an acoustic correlate of vocalic breathiness), pitch perception during non-modal phonation suffers.

(23) These findings may be viewed as consistent with certain typological linguistic facts: Tone and breathy phonation are very rarely implemented simultaneously (Silverman 1995, 1998).

(24) Some languages are tonal.
-**Mandarin** tones (D.S.):

high	t^han˥	greedy
mid-rising	t^han˧˥	deep
low (-rising)	t^han˨˩˦	perturbed
high-falling	t^han˥˩	spy

(25) Some languages have contrastive breathiness.
-**Gujarati** breathy vowels (Patel and Mody 1961, Fischer-Jørgensen 1970, Taylor 1985):

tʃi̤r	mo̤r	dṳd
bi̤	do̤ɽ	pe̤lo
se̤dʒ	ko̤ɽ	ta̤ro
me̤k	ko̤	wa̤li
ba̤r	po̤r	kə̤ɽi

(26) Some tonal languages possess non-modal phonation contrasts on vowels. While a full array of tonal patterns is found on *modally* phonated vowels, *non*-modally phonated vowels *never* contrast for tone.
-**White Hmong** “tones” Hmong (Lyman 1974, Smalley 1976, M.K. Huffman 1987, Ratliff 1992):

High	tau˥	pumpkin
Rising	tau˧˥	to dam up (water)
Low	tau˨	axe
Mid (normal)	tau˧	to be able
Falling (normal)	tau˥˧	sp. of grass
Creaky “tone”	tau˧˩	bean
Breathy “tone”	tau˥˧	to follow

(27) Some languages (e.g. Otomanguean languages such as Jalapa Mazatec) possess vowels in which tone and non-modal phonation fully cross-classify. As pitch (<tone) is more reliably distinguished during modal phonation, a portion of the vowel is given to plain voicing, where tone contrasts are presumably more salient. The remaining portion of the vowel, however, is breathy (or creaky).

-**Jalapa Mazatec**:

m͡m̤͜æ̤͡æː˦	wants
n͡n̤͜a̤͡a˦	my tongue
ɲ͡ɲ̤͜a̤͡a˧	nine
ʝ̤͡ʝ̤͜æ̤͡æ˩	boil
w͡w̤͜o̤͡o˧	hungry

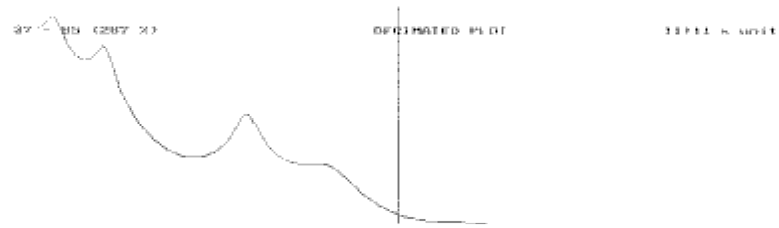
(28) Of course, experimental data cannot be generalized directly to natural linguistic data. However, the results of the present study suggest that tonal and phonation contrasts have the distributions they do for good reason.

(29) More specifically, although it is only in an experimental setting, as opposed to a natural linguistic setting, that listeners may be called upon to determine just- and near-just-noticeable differences in pitch, it should not be surprising that languages might evolve to avoid less-good contrasts in favor of better ones.

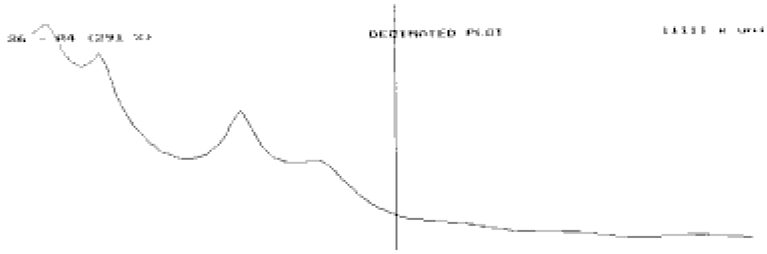
(30) That is, phonetic distinctions that are never employed in phonological systems might nonetheless constitute the ‘phylogenetic’ origin of phonetic distinctions that *are* linguistically relevant. Non-linguistic phonetic experimentation may thus serve as a jumping-off point for this potentially fruitful area of theorization.

A note on the SoundEdit16.2 "bender" feature

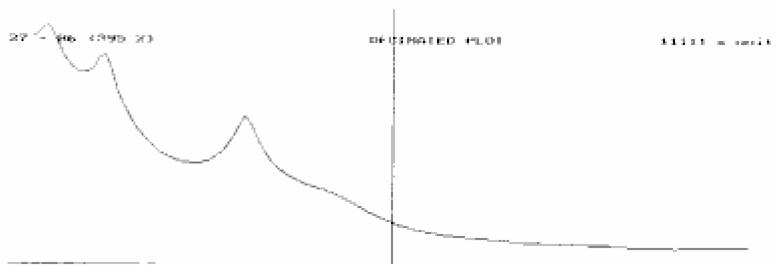
The SE16.2 "bender" slows down or speeds up the playback of a sound. The playback sample rate is manipulated and the sound is resampled to the original (and constant) sample rate. The spectra are equally shifted in frequency and thus the ratios of the component frequencies are preserved. Given the spectral 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.



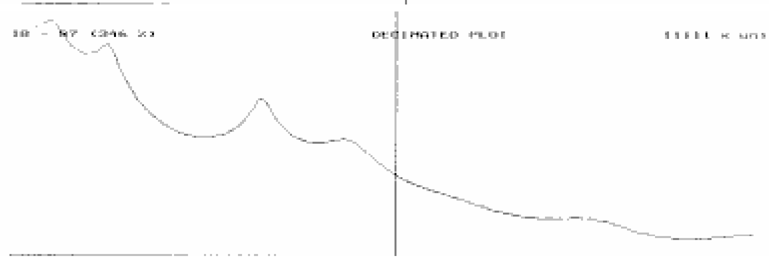
step 1



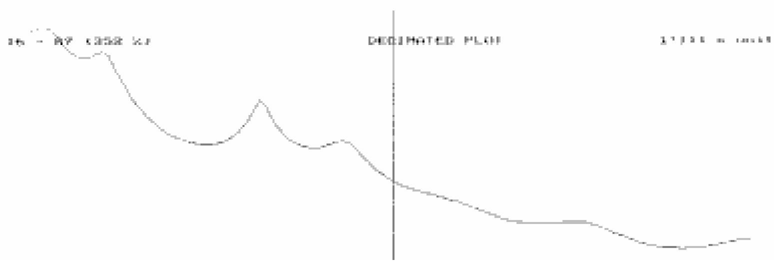
step 2



step 3

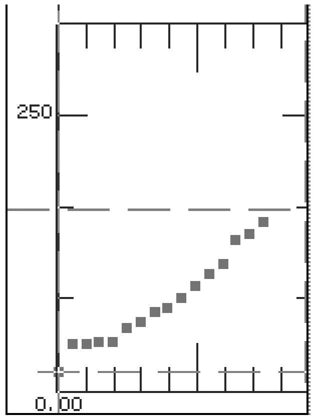


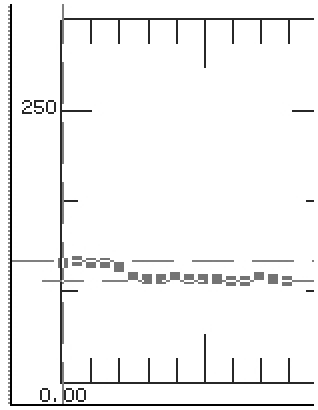
step 7



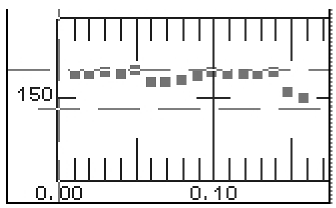
step 8

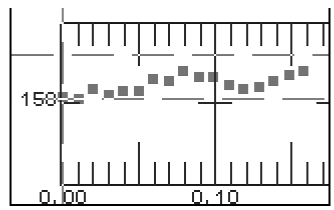
Pitch tracks of base stimuli



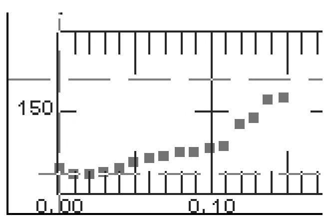


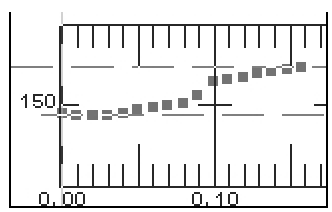
(gi˧$^{\text{ŋ}}$g) a̤ a˦ (he fastened)





(^{n}d) a̤ a˦ (hard)





(mm̤) æ̤ æ˦ (he wants)

REFERENCES

Fischer-Jørgensen, E. (1970) "Phonetic analyses of breathy (murmured) vowels in Gujarati," Indian linguistics 28:71-140.

Kirk, P.L., J. Ladefoged, and P. Ladefoged (1993) "Quantifying acoustic properties of modal, breathy, and creaky vowels in Jalapa Mazatec," in A. Mattina and T. Montler, eds., *American Indian Linguistics and Ethnography in Honor of Lawrence C. Thompson*. Occassional Papers in Linguistics 10, University of Michigan, 435-450.

Huffman, M.K. (1987) "Measures of phonation types in Hmong," Journal of the acoustical society of America 81.2:495-504.

Lyman, T. (1974) *Dictionary of Hmong Njua*. The Hague, Mouton.

Moore, B.C.J. (1989) *An introduction to the psychology of hearing*, 3rd edtion. London : Academic.

Patel, M.S. and J.J. Mody (1961) *The vowel system of Gujarati*. Faculty of education and psychology, Maharaja Sayajirao University of Baroda, Baroda.

Ratliff, M. (1992) *Meaningful tone: a study of tonal morphology in compounds, form classes, and expressive phrases in White Hmong*. Center for Southeast Asian Studies, Monograph series on Southeast Asia, Special Report 27, Northern Illinois University.

Rosenberg, A.E. (1965) "Pitch discrimination of jittered pulse trains," Journal of the Acoustical Society of America 39.5:920-928.

Silverman, D. (1995) *Phasing and recoverability*. UCLA dissertation. Published in 1997 in Outstanding Dissertations in Linguistics series. New York : Garland.

Silverman D. (1998) "Laryngeal complexity in Otomanguean vowels." Phonology 14.2.

Silverman, D., B. Blankenship, P. Kirk, and P. Ladefoged (1995) "Phonetic structures in Jalapa Mazatec," Anthropological Linguistics 37.1:70-88.

Smalley, W.A. (1976) "The problems of consonants and tone: Hmong (Meo, Miao)," in W.A Smalley, ed., Phonemes and orthography: language planning in ten minority languages in Thailand. Pacific Linguistics Series C, No. 43.

Taylor, G.P. (1985) *The student's grammar of Gujarati*. Asian Educational Services, New Delhi.

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