Glottal articulations in tense vs. lax phonation contrasts

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Goals

- Explore the glottal articulations of tense vs. lax phonation (voice quality) contrast in three Yi languages
- Understand better what glottal pulse shapes show about phonation contrasts
- Compare methods of analyzing glottal pulse shapes

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Tense vs. lax phonations

- 3 Yi languages of southwestern China with tense/lax phonation contrasts: Southern Yi, Bo, Hani
- These are tone languages where phonation type is contrastive independently of tones (f0)

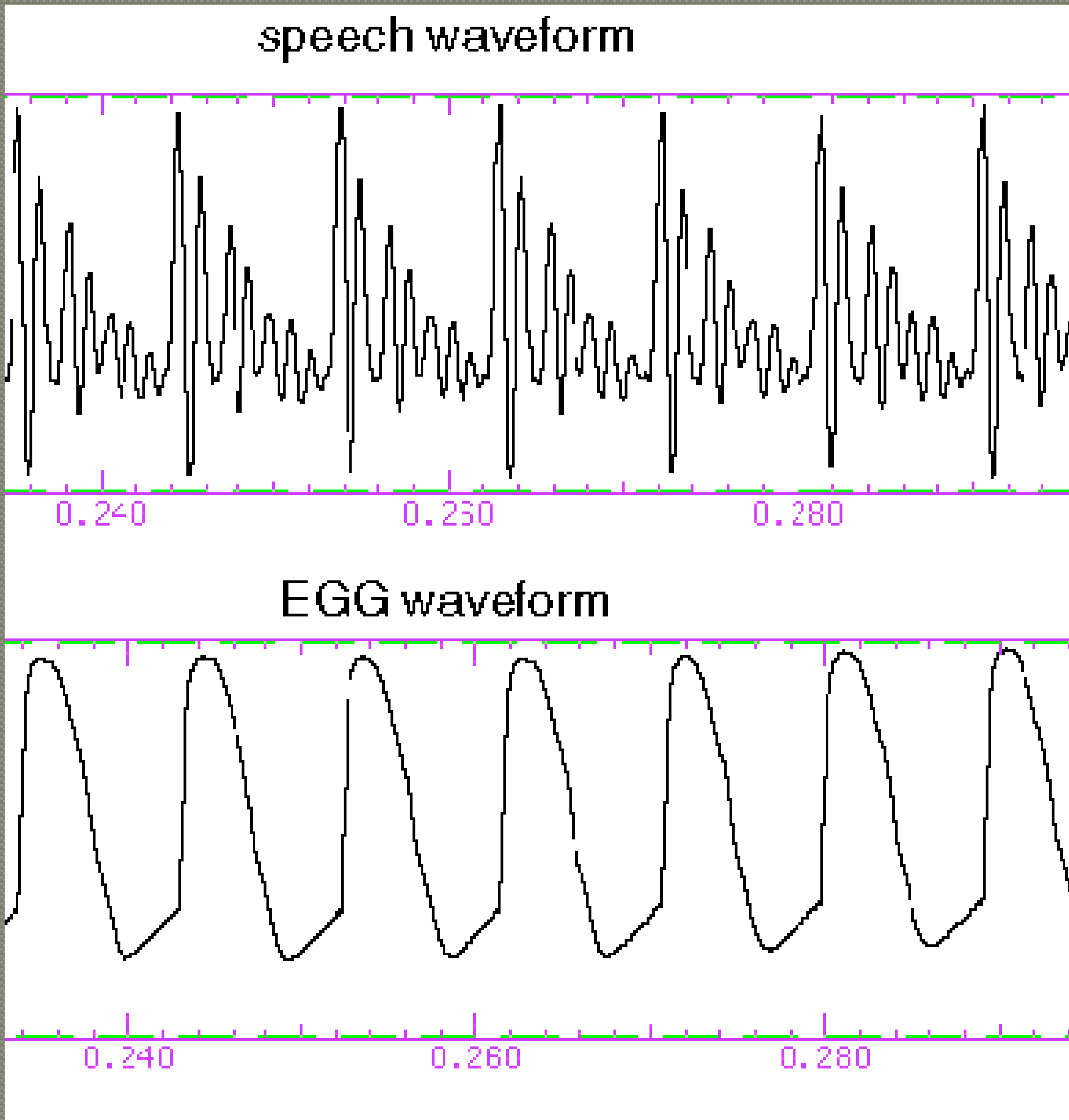
Example from Southern Yi

	Low tone	**Mid tone**
Lax phonation	be ^{21} *(mountain)*	be ^{33} *(fight)*
Tense phonation	be ^{21} *(foot)*	be ^{33} *(shoot)*

Glottal pulses: Electroglottography (EGG)

- Glottal Enterprises EG2
- 22050 Hz SR, 40 Hz high-pass cutoff
- Measures relative changes in vocal fold contact area during phonation via variation in electrical impedance between 2 electrodes placed across the larynx
- Non-invasive, suitable for linguistic fieldwork

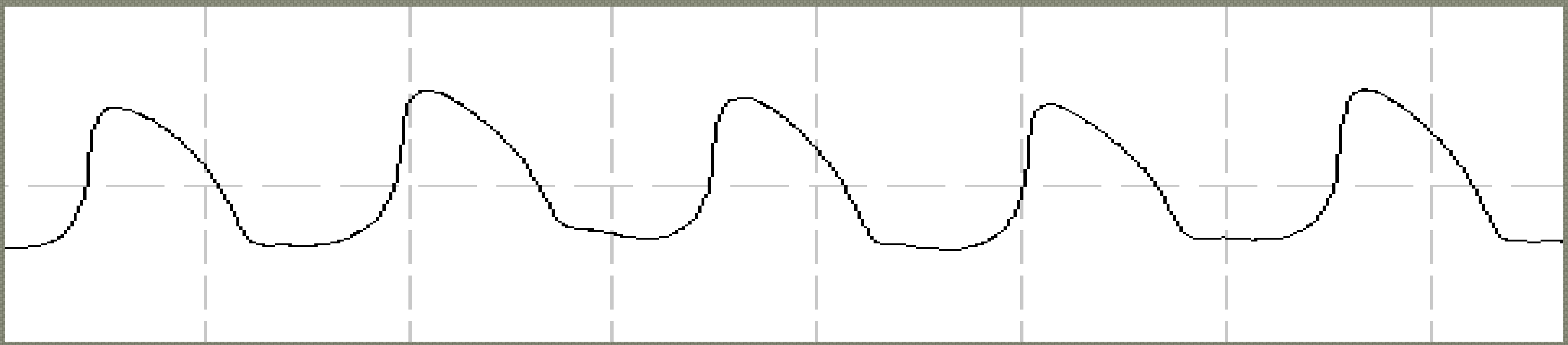
Sample EGG signal

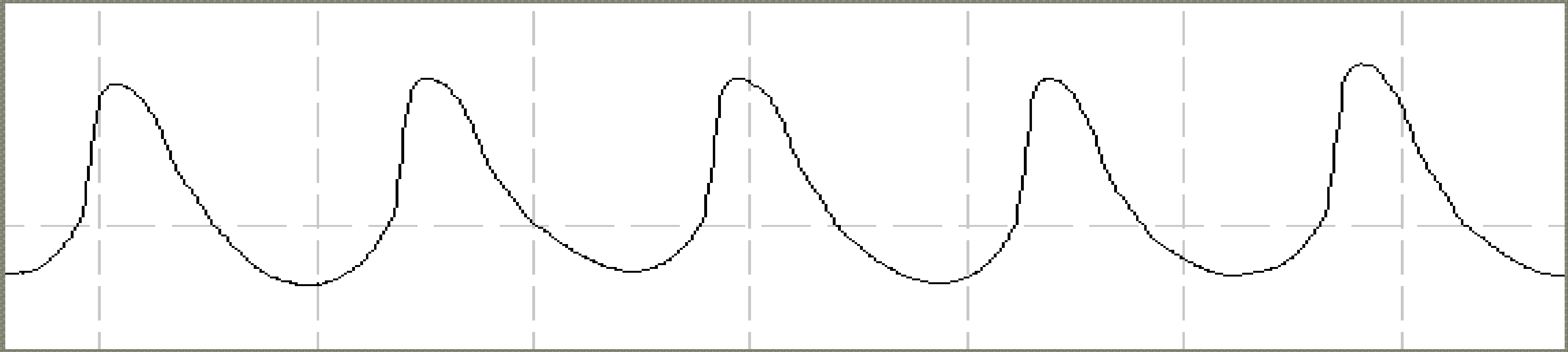


contacting

Marasek (1997)

Sample Yi pulse sequences: tense (top) and lax (bottom)



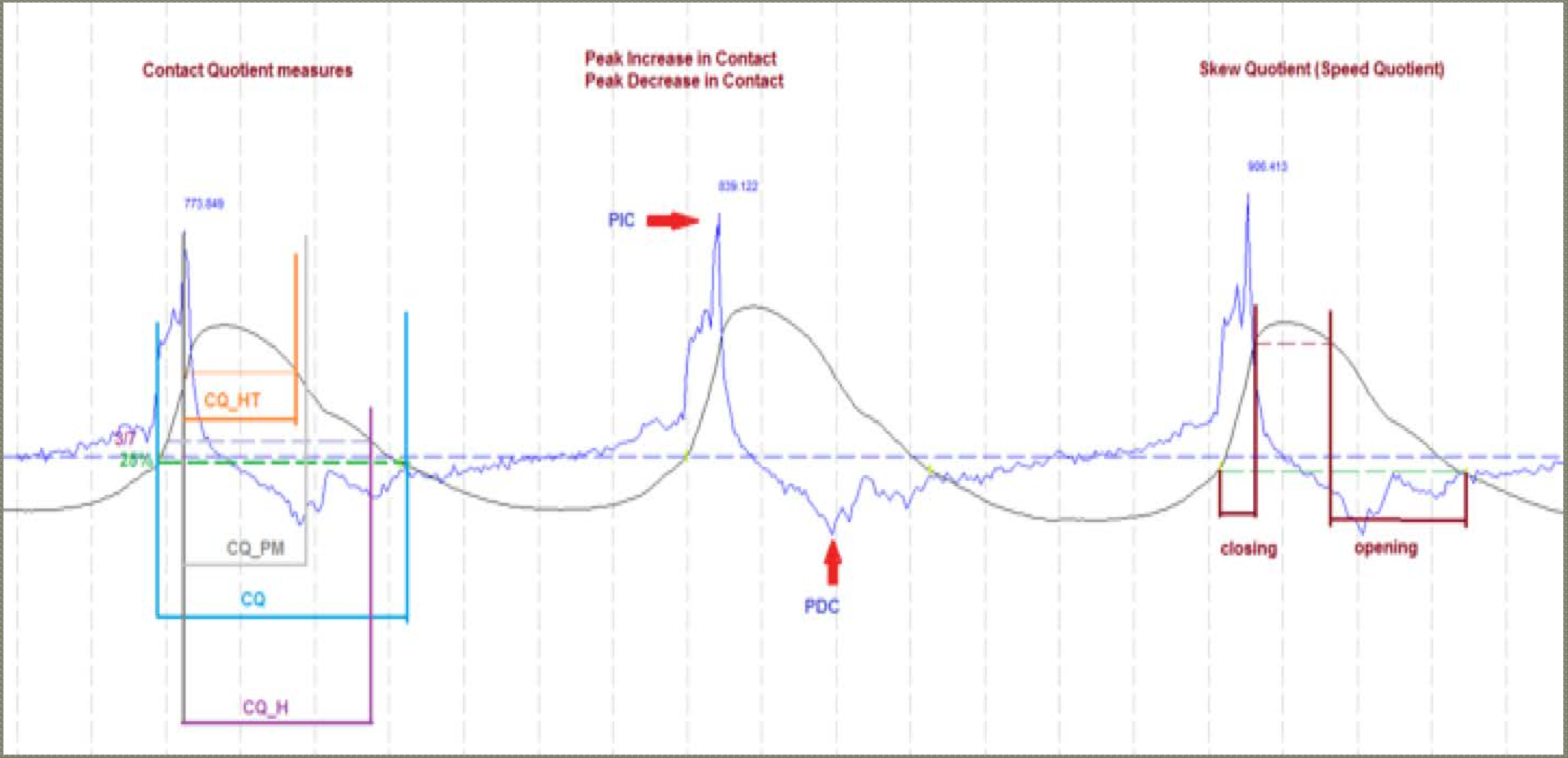


How can we capture the differences?

- Some difficulties:
  - Not calibrated, no DC component – amplitude of signal is not meaningful
  - Speaker variation

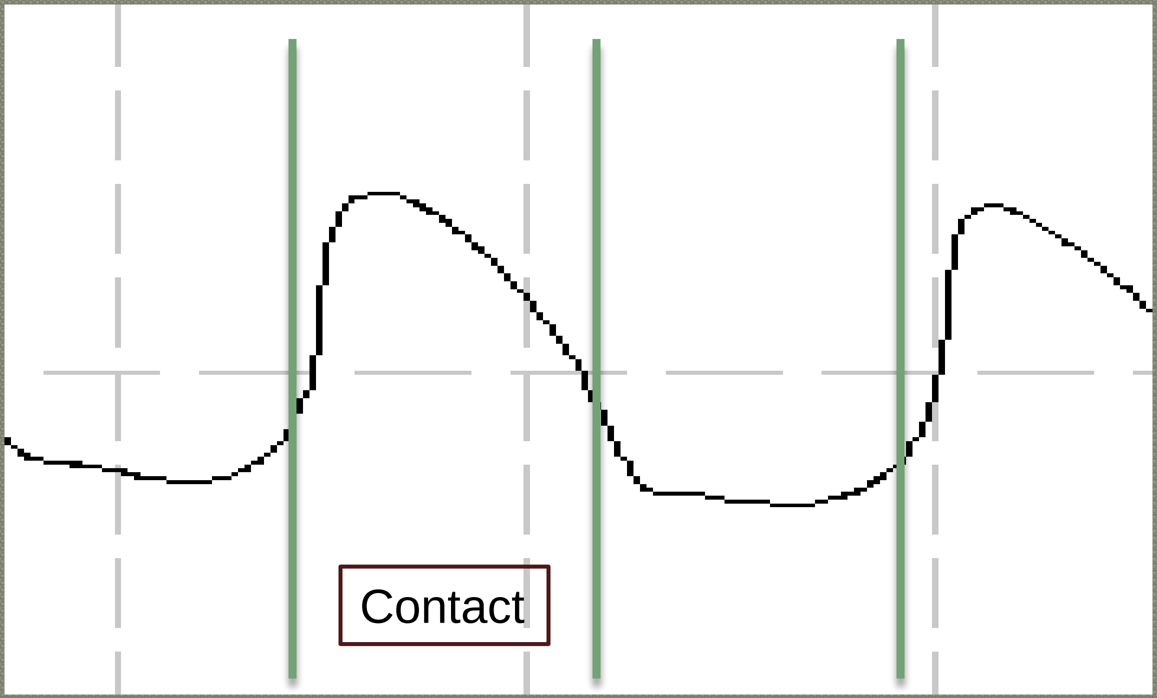
Traditional EGG/dEGG parameters:

Find landmarks in signal and compute ratios



EggWorks program from UCLA Phonetics Lab

Sample ratio measure: contact quotient



Entire pulse

Analysis I: EGG Parameters

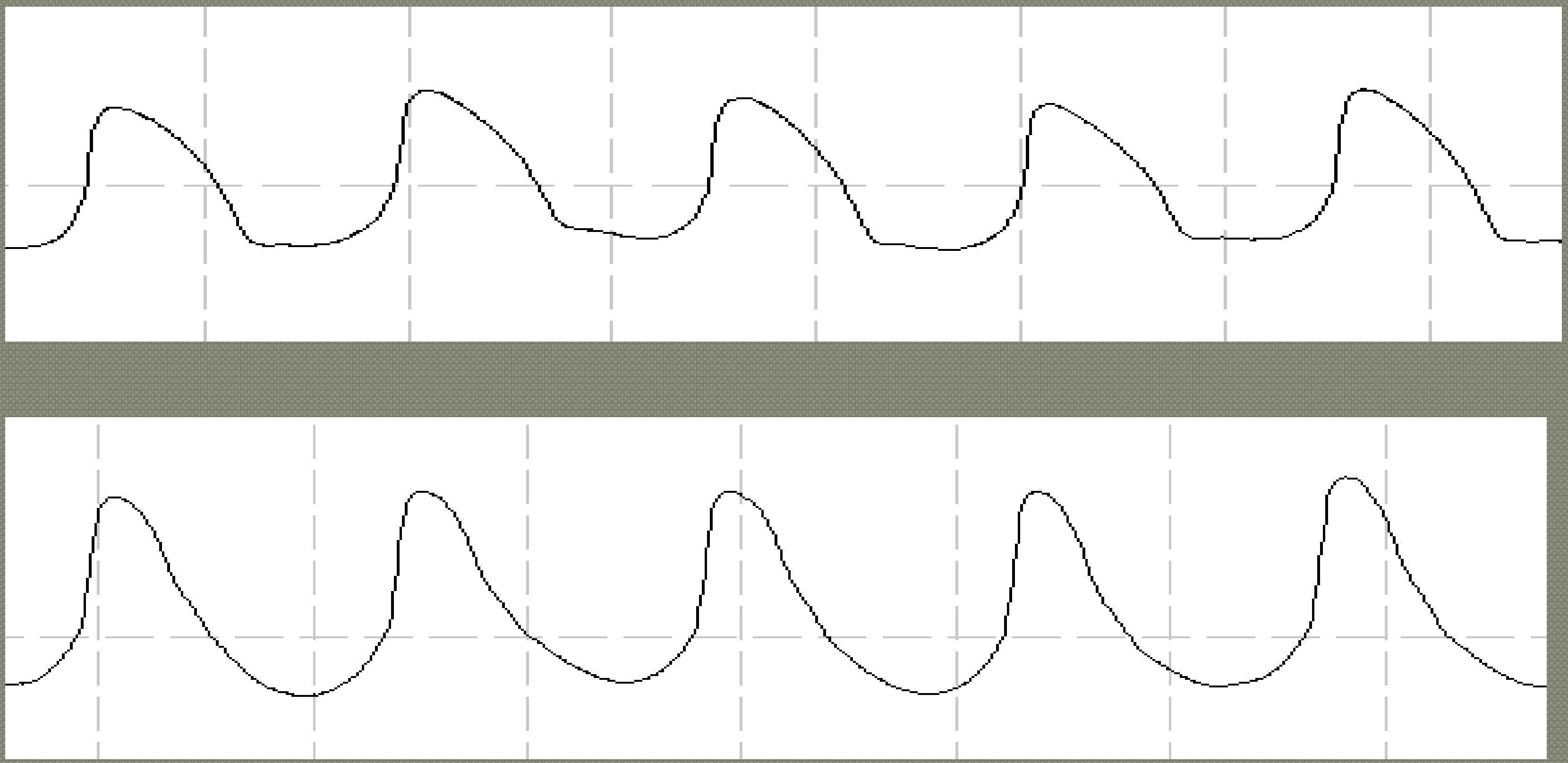
- Mixed-effect model: Phonation and tone as the fixed effects, and speaker as the random effect.
- Salient phonation effects, but tone effects

	Yi	Bo	Hani
CQ	T > L	T > L	T > L
SQ	T < L	33T<33L	T < L
Closing	T < L	T < L	T < L
Opening		T > L	T < L
PIC	T < L	T < L	T < L
|**PDC**|	T < L	T < L	T < L
PIC_time	T < L	T < L	T < L
PDC_time	T < L	T < L	T < L

Overall

- Consistent cross-linguistic contrast patterns were found for almost all EGG parameters.
- Suggests that the overall shapes are different

Can we quantify the overall shape difference?



Analysis II: Functional Data Analysis

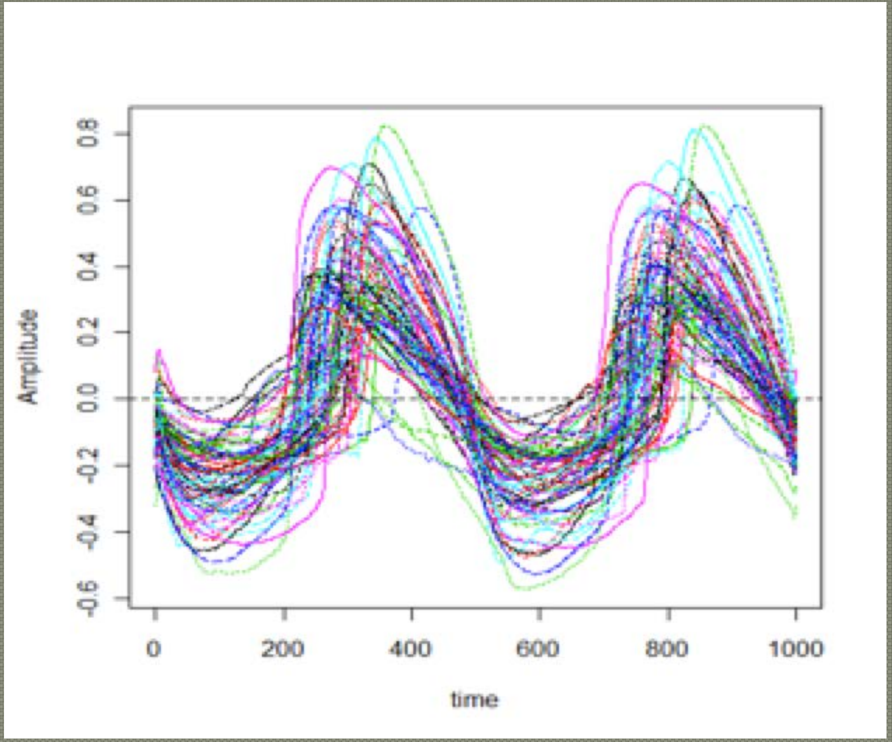
- FDA (Ramsay 1982) is a functional version of PCA that has been used to analyze articulatory movements (lips, tongue)
- Mooshammer (2010) applied to EGG signals
- Different components can reflect different influences on pulse shape

corpus

- 18 speakers (3 men + 3 women per language x 3 languages)
- 4 /be/ words shown earlier (chosen from ~ 40 minimal pairs)
- 2 EGG pulses selected from steady part of each vowel (144 tokens, 288 pulses)

Sample pulses

- Method followed Mooshammer (2010)
- For each EGG waveform file, two periods during the steady portion of the vowel were extracted.
- A 25% threshold was used to define the beginning and the end of a duty cycle.



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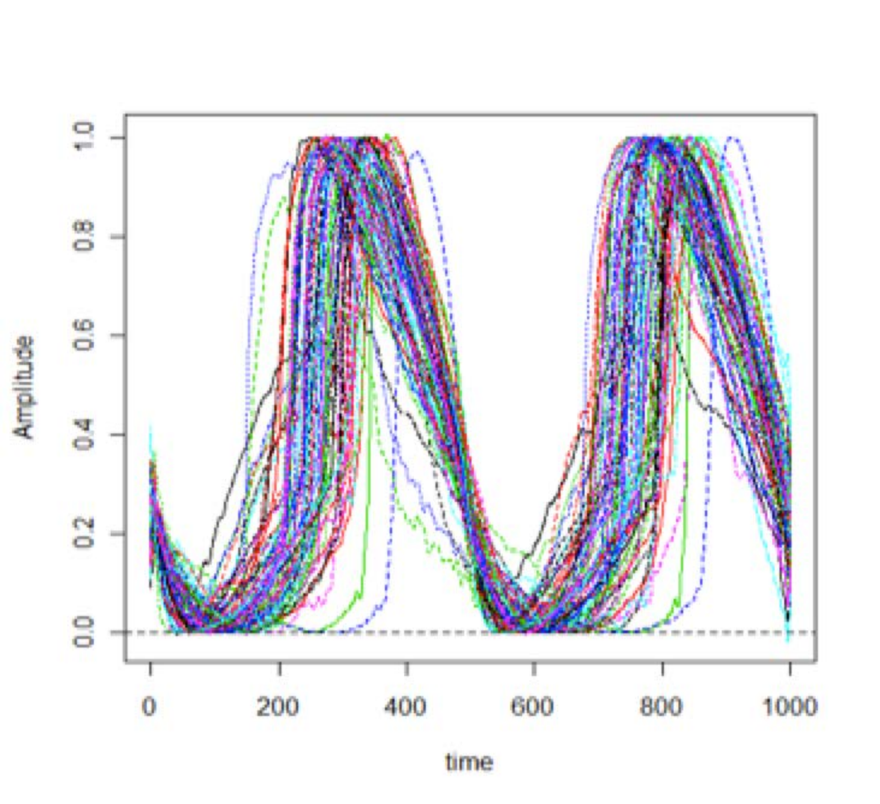
Pre-processing

- Time normalization: resample selected pulses into 1000 samples with linear interpolation
- Amplitude normalization: pulses are normalized into 0~1
- Basis function = Fourier (nbasis=200); smoothing parameter = 10E-12



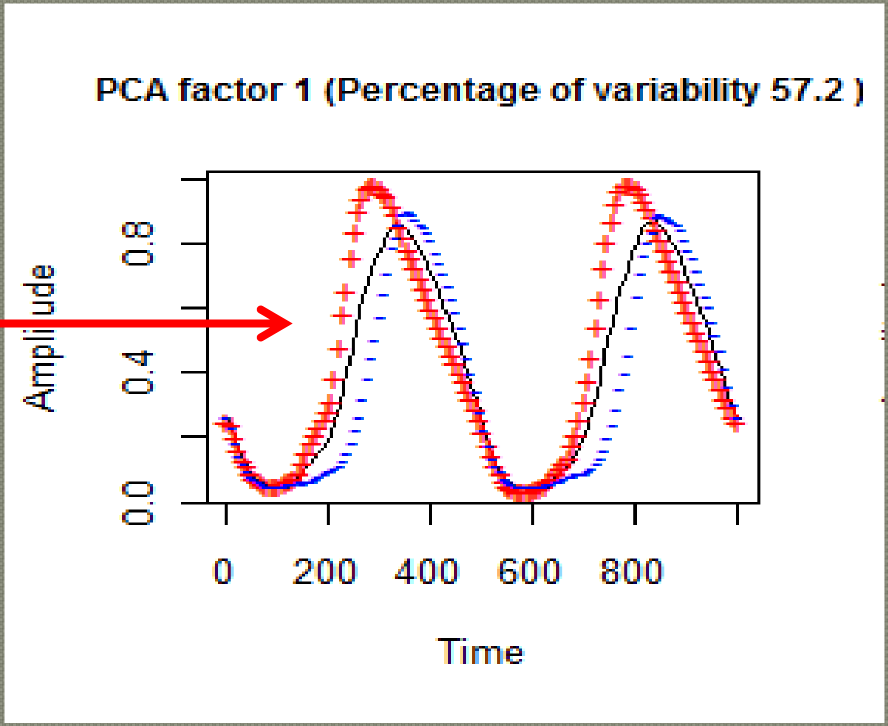
Results

- 3 principal components cover 81% of variance in pulse shapes of 144 tokens
- Correlations of each component with the experimental factors:
  - phonation category
  - tone category
  - speaker gender

Results: First shape component

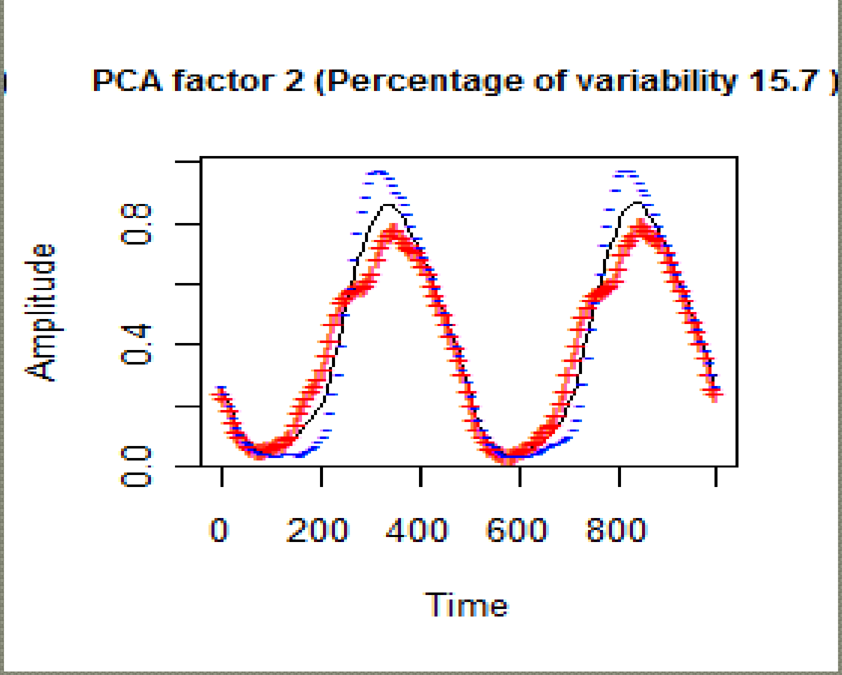
PC1 ~ phonation (+++ line ~ tense)

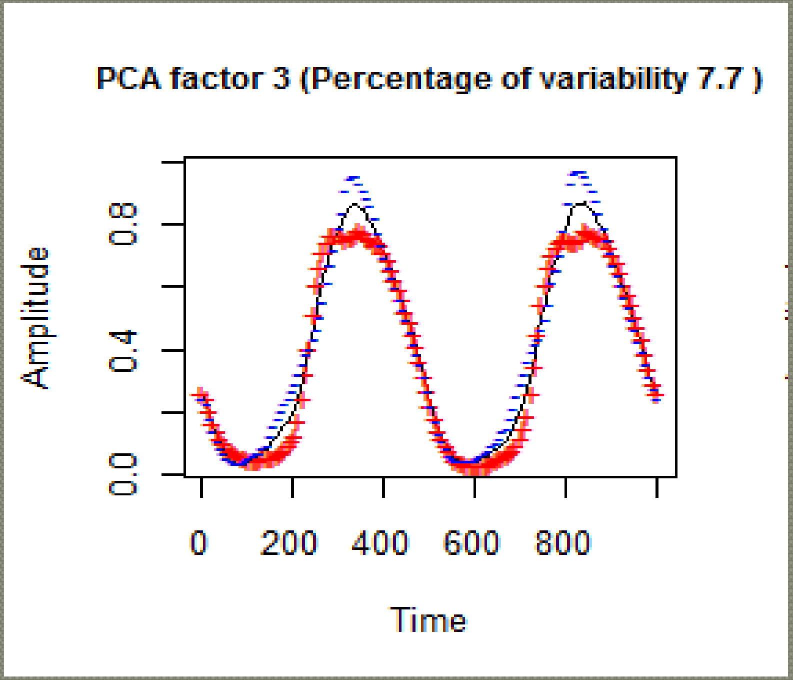
Red and blue (tense and lax components) differ mostly in their contacting phases: duration/rate and extent



Results:
Second & third shape components

PC2,3 ~ mostly gender (+++ line ~ male)





Overall

- PC1 shows that phonation is the most important influence on shape, more than gender
- Tone (f0) has almost no influence on shape
- Each experimental variable affects different components

Benefits of FDA

- Despite the great variability among speakers, there is essentially only one underlying articulatory pattern involved in the tense vs. lax contrast.
- Various EGG parameters are the consequences of the one articulation pattern shown by PC1.

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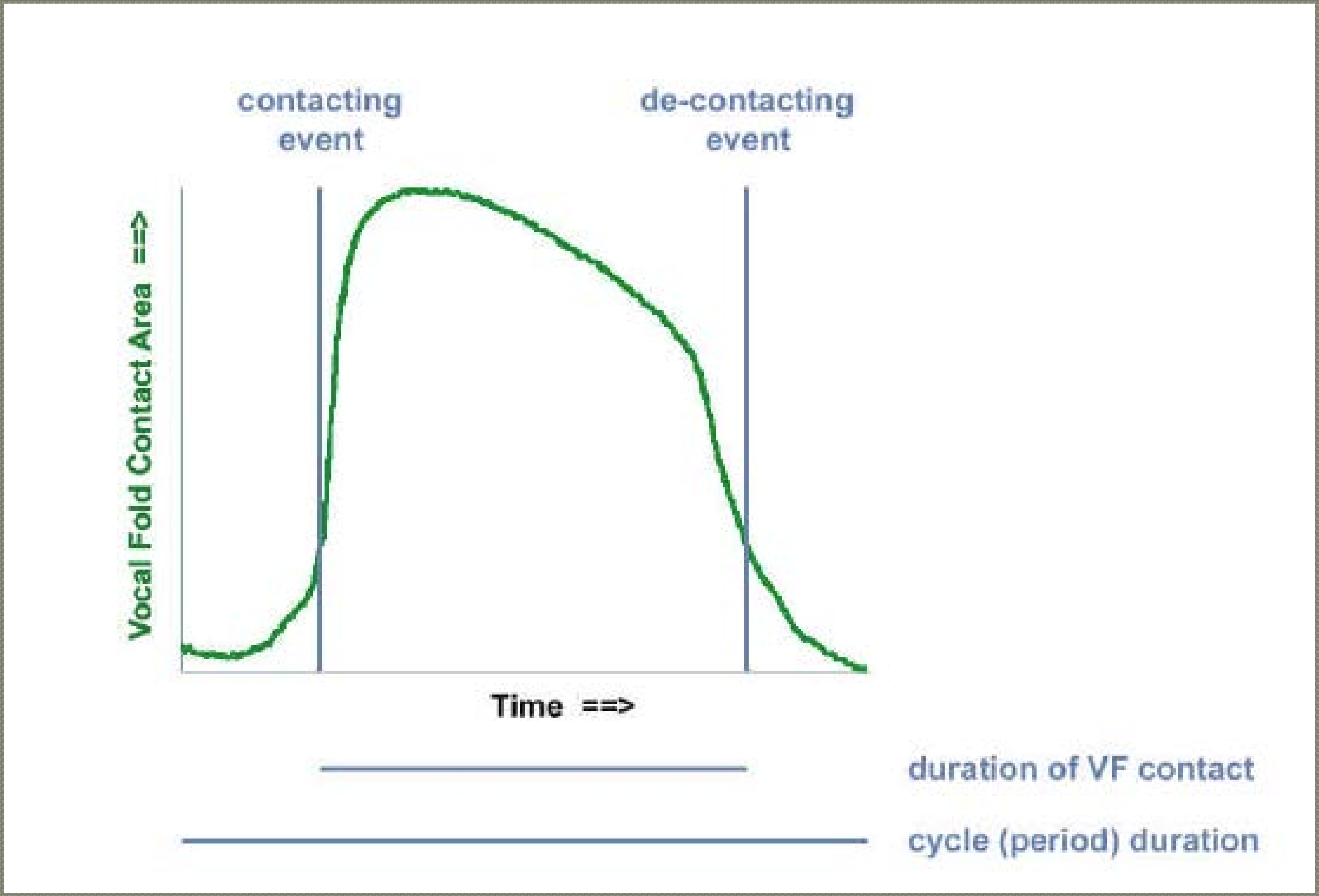
- H. Tehrani for EggWorks
- Fieldwork help: Prof. Jiangping Kong and Feng Wang

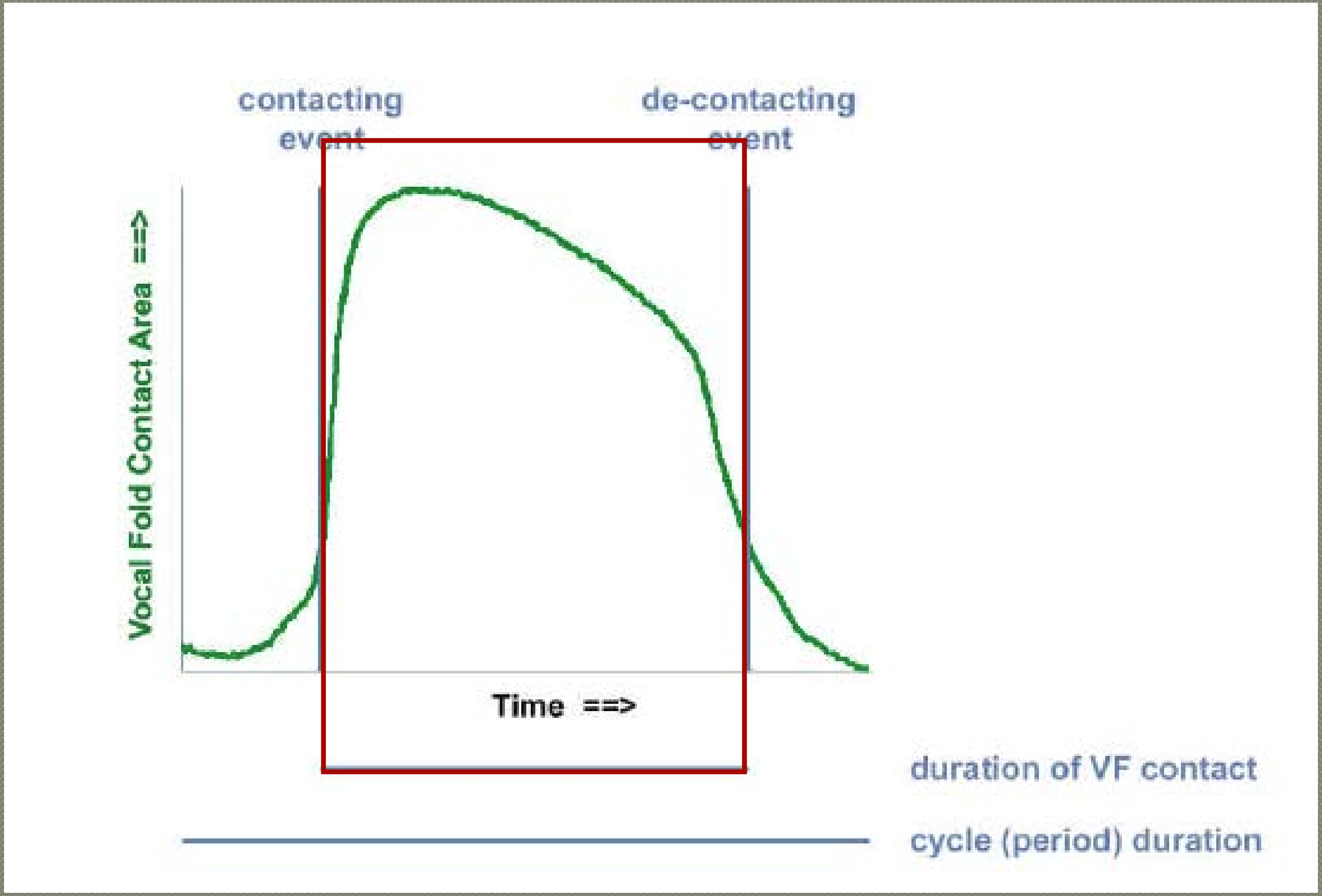
EGG parameters

- Finds landmarks in signal and computes ratios
  - Contact Quotient -- relative contact duration (ratio between "contact duration"/duration of the entire cycle)
  - Skew Quotient (ratio between contacting and decontacting phases)

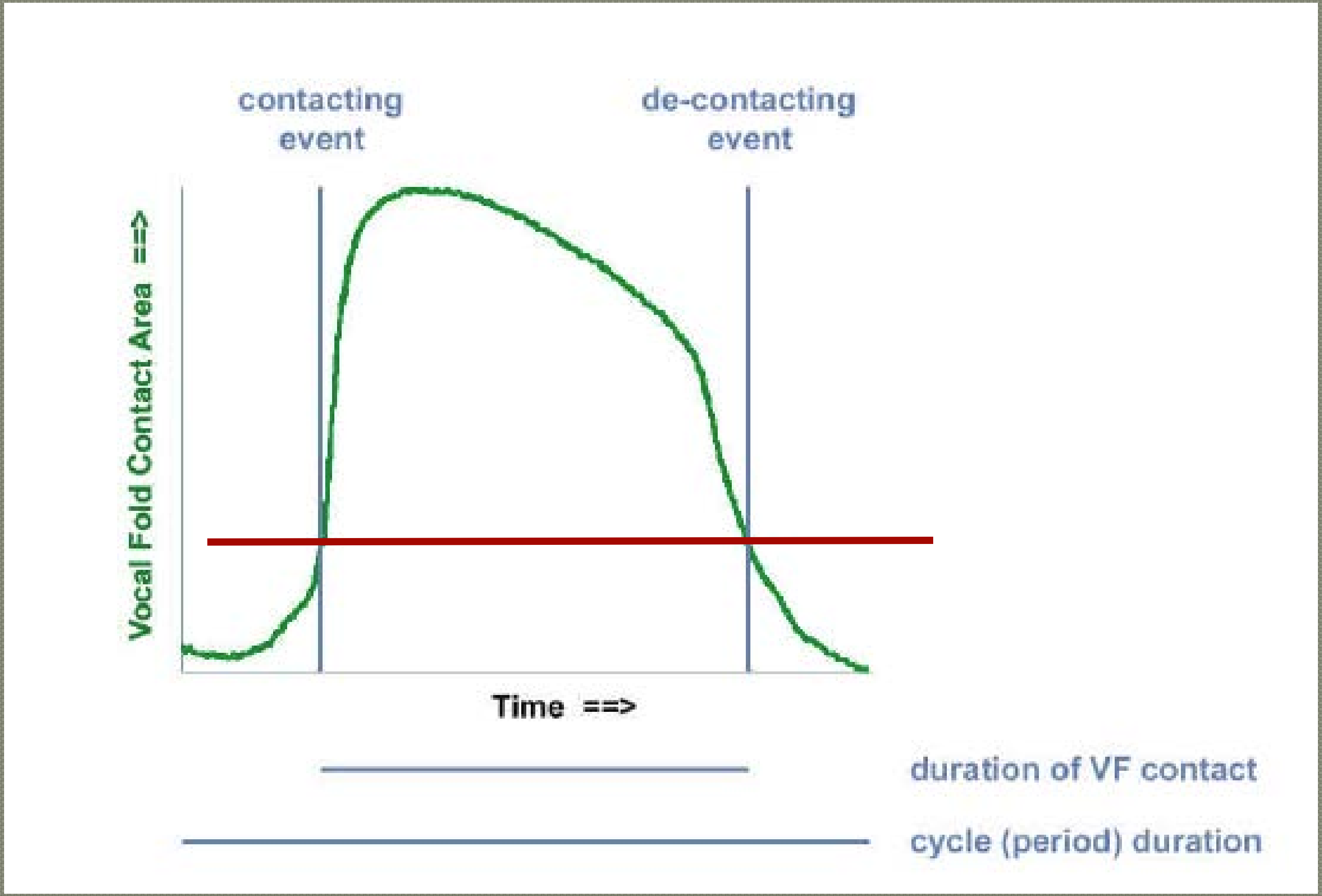
Defining Contact Quotient



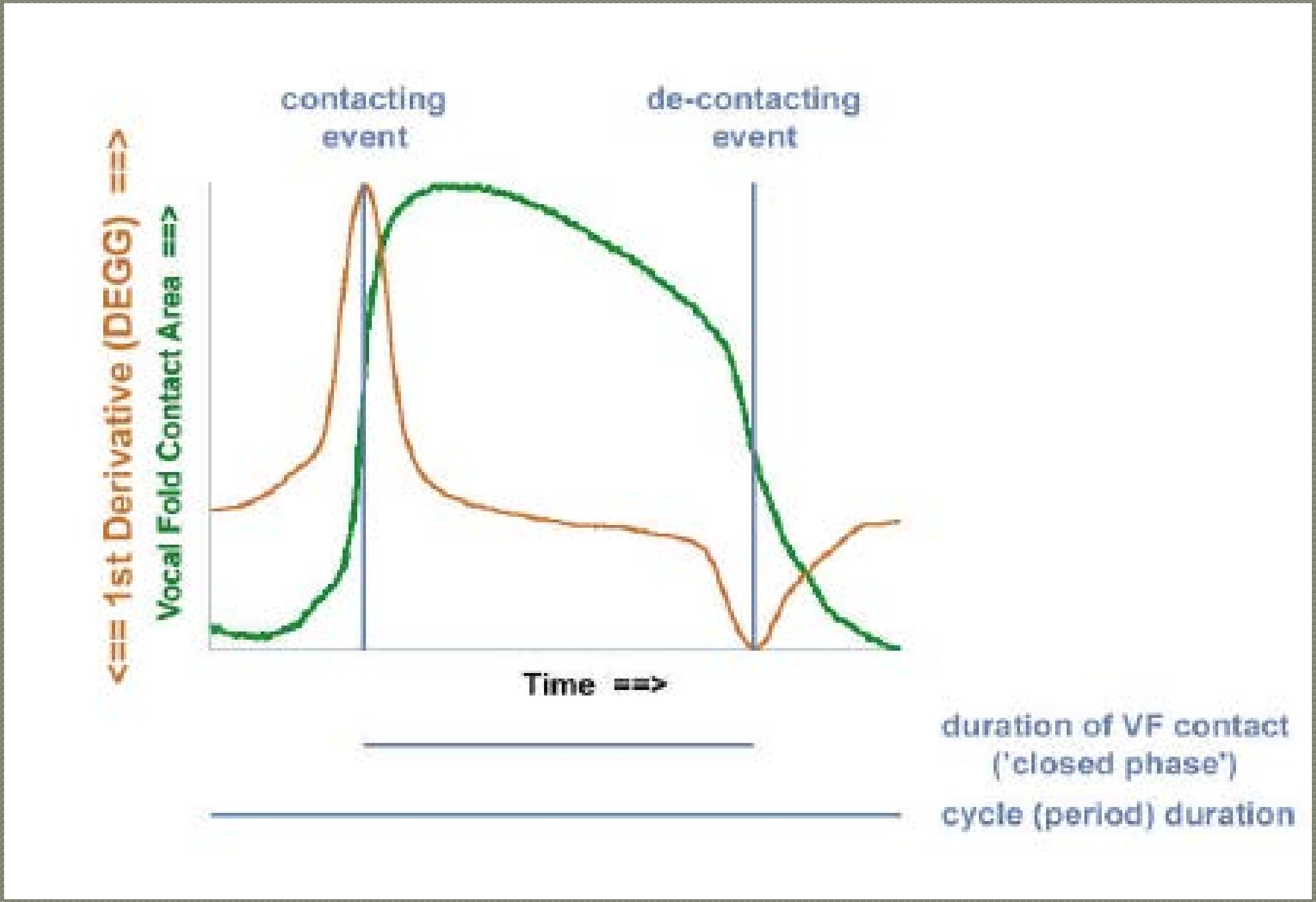
Defining Contact Quotient



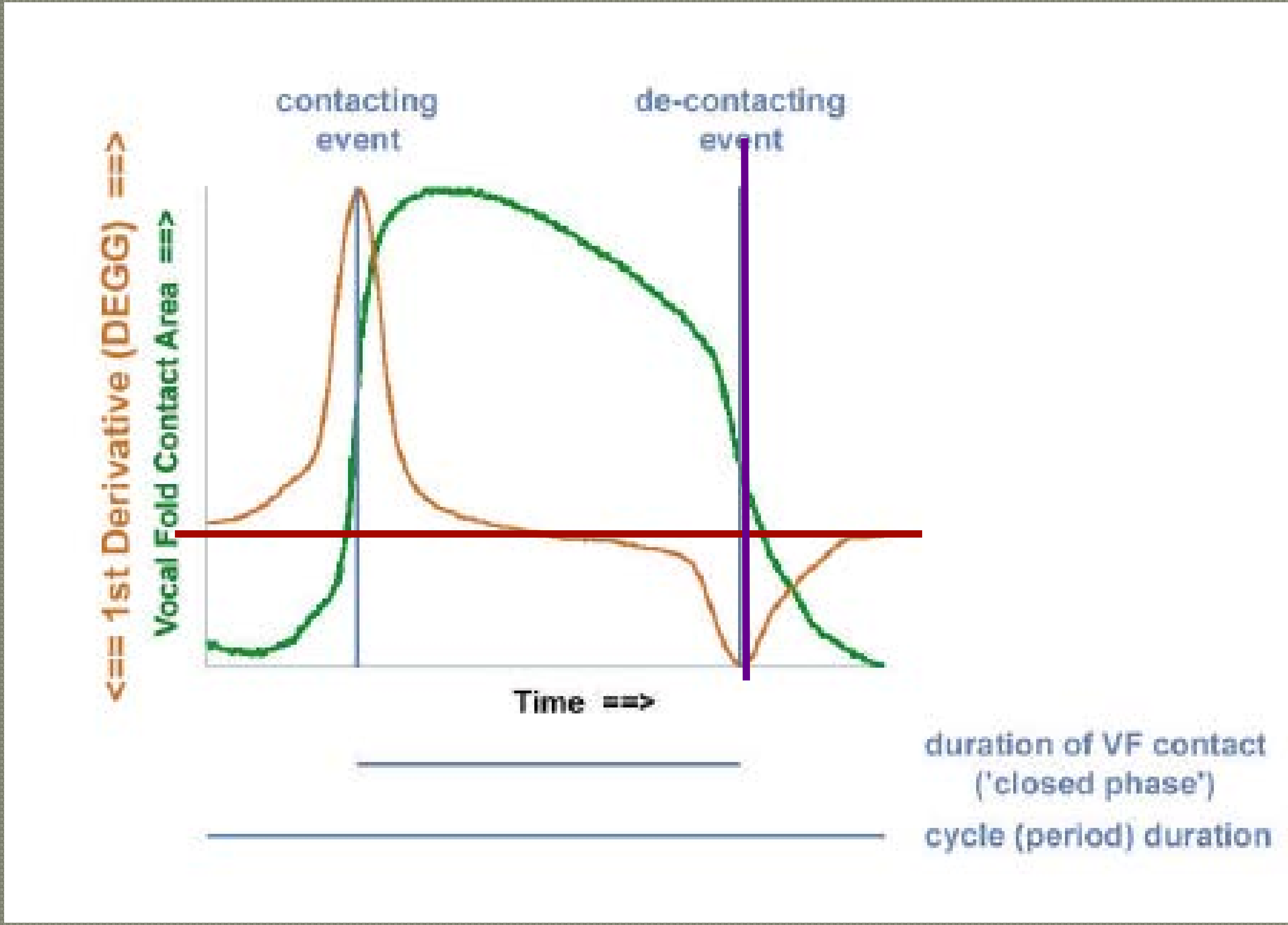
Defining Contact Quotient -- Threshold



Defining Contact Quotient -- dEGG peaks

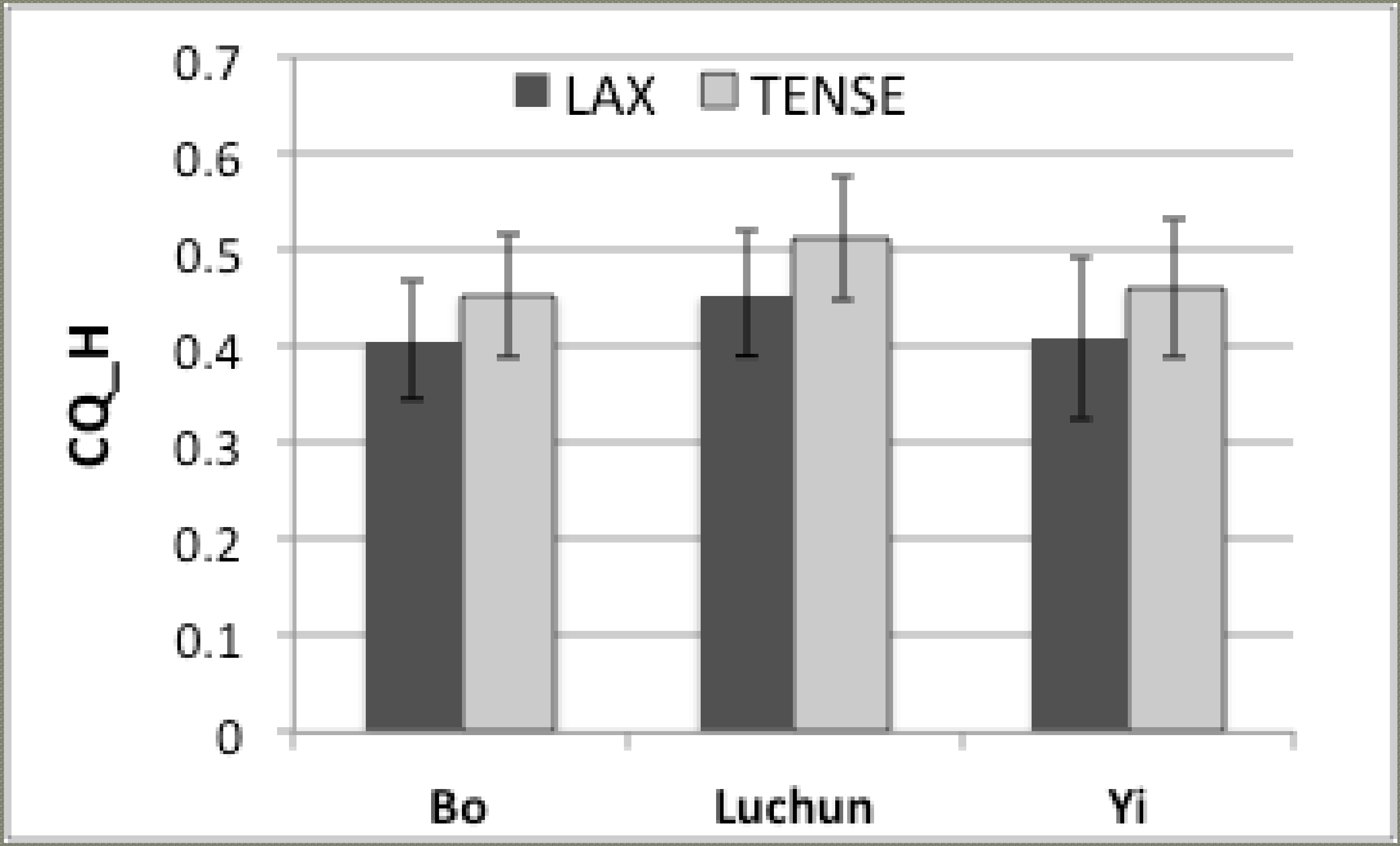


Defining Contact Quotient -- hybrid: dEGG + threshold

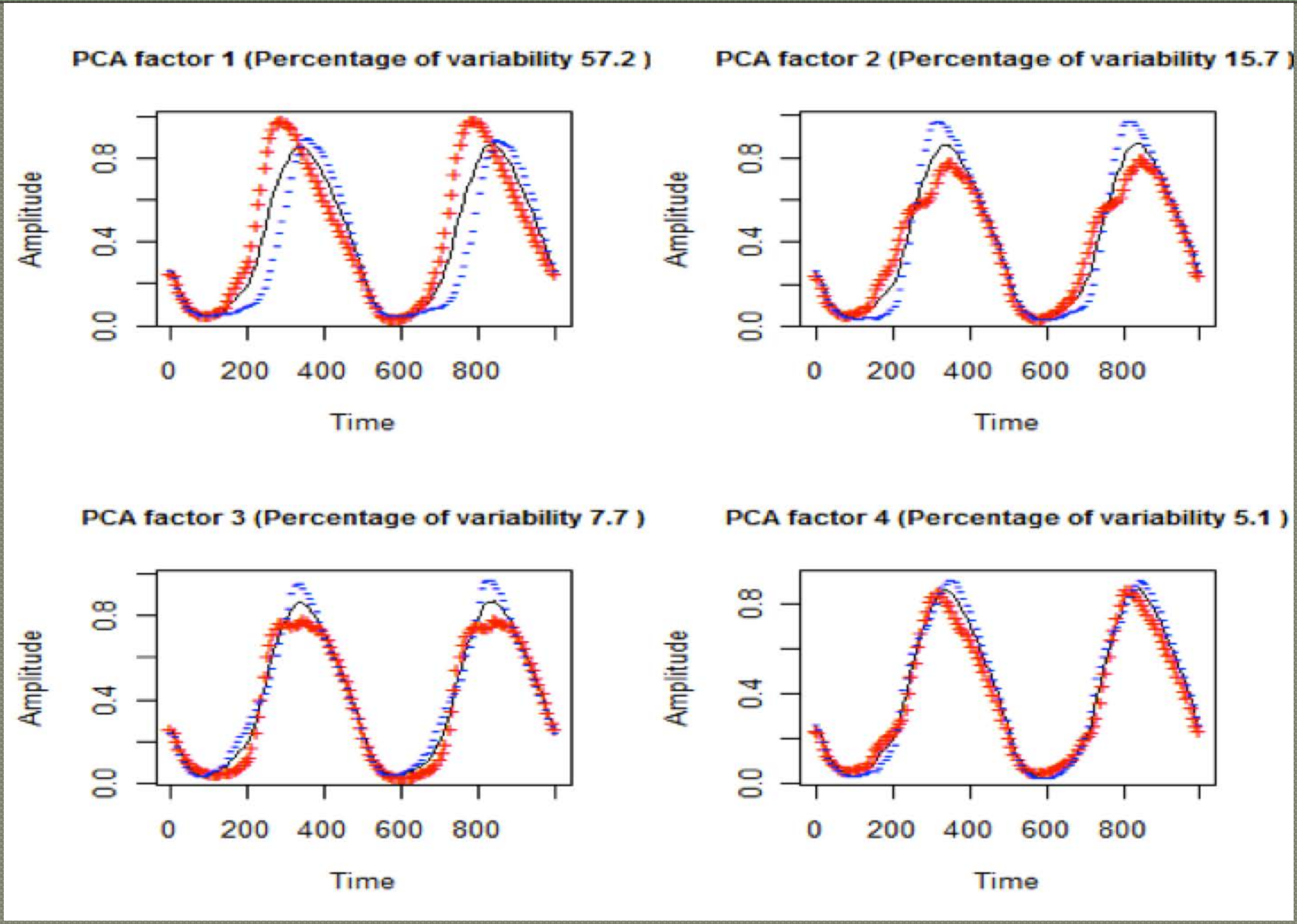


- Problems with CQ
  - Ambiguous: different phonations can have same CQ values
  - Little knowledge about how contact is made
  - Landmarks: Different phonations are sensitive to different CQ methods

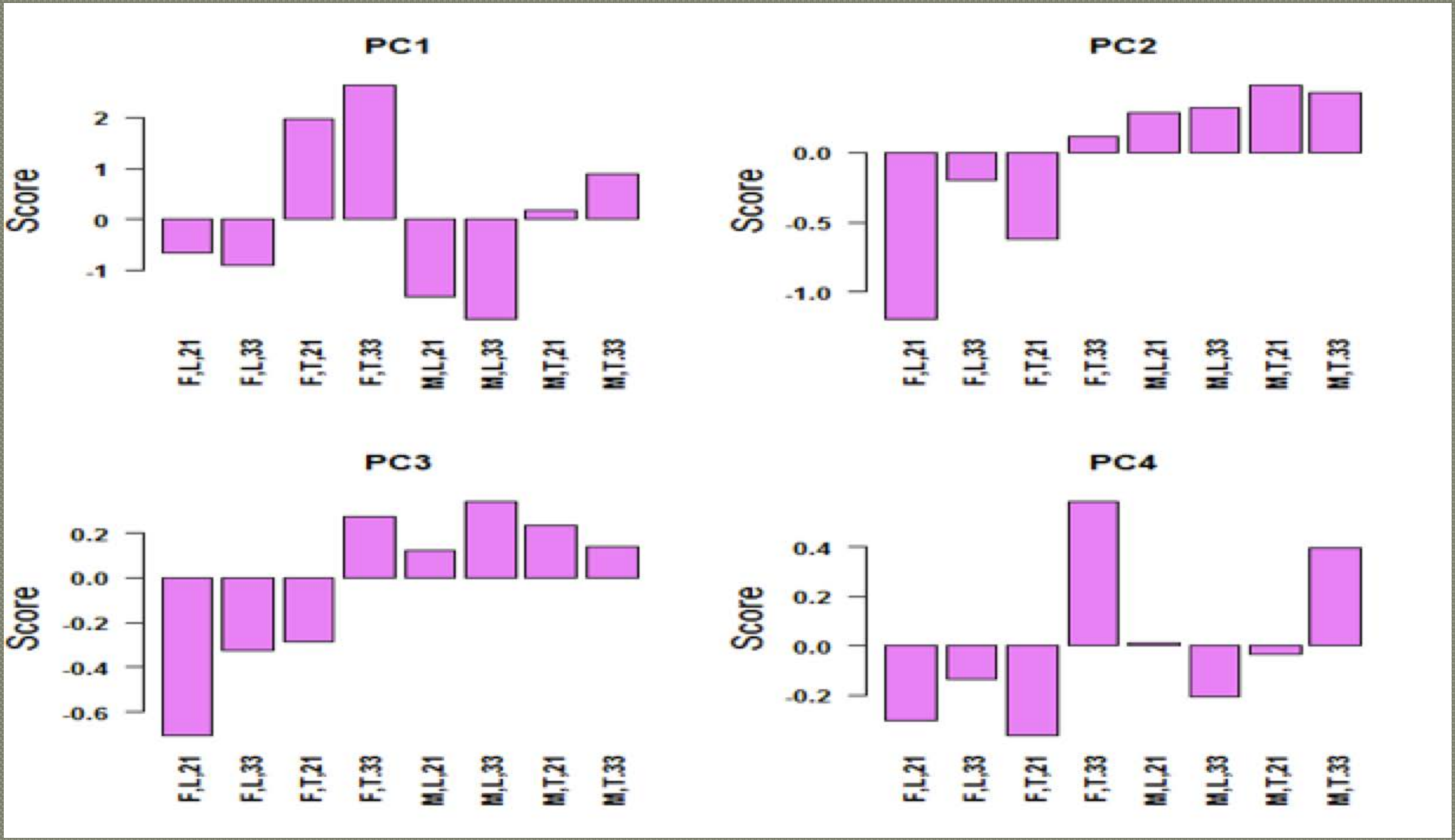
Close to modal voice



The first four PCs



Scores for factors in each PC



Correlations between PCs and factors

	Language	Phonation	Tone	Gender
PC1	-0.10	**0.46**	0.05	-0.19
PC2	0.06	-0.03	-0.08	**-0.19**
PC3	0.05	0.06	0.08	**0.23**
PC4	0.06	-0.15	**-0.18**	-0.12

Glottal activity in this contrast

- Tense phonation involves greater change in relative contact and more abrupt contact
- From other EGG measures: more overall contact, lower peak rates of change, and shorter duration of contacting – suggest a smaller vibratory movement
- Together suggest overall close adduction and more contact past closure

Benefits

- Traditional EGG parameters (mainly CQ) tell little about how contact is made: abruptness of contact
- PC1 in shape analysis does

Interpretation of EGG pulse

a: lower margins of the vocal folds make initial contact

b: upper margins make initial contact

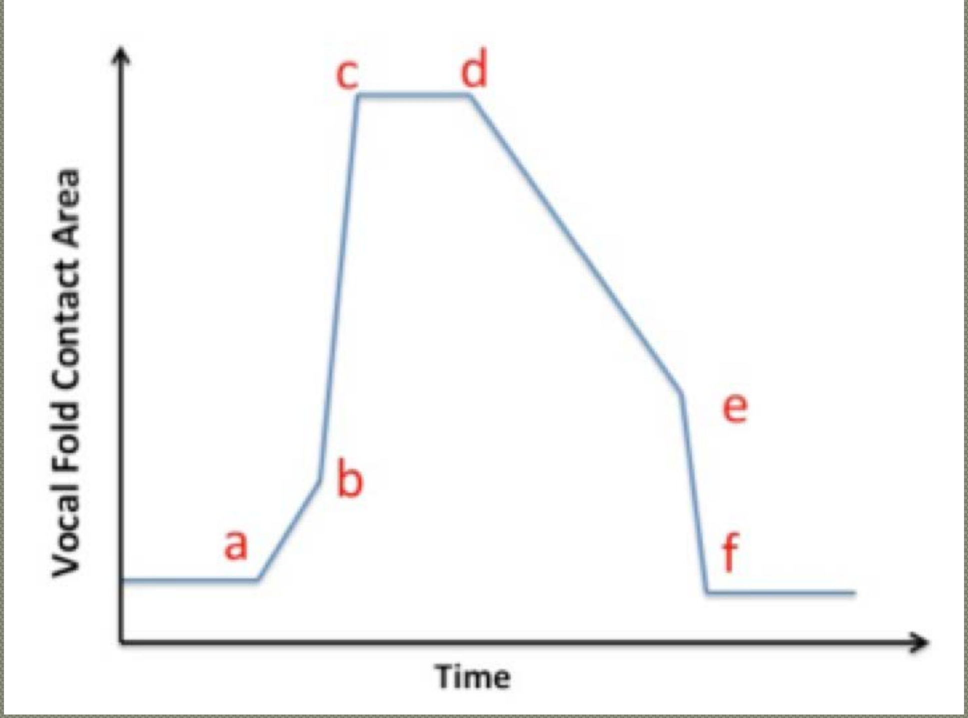
c: contact of upper margins completes

c-d: contact remains maximal

d: lower margins begin to separate

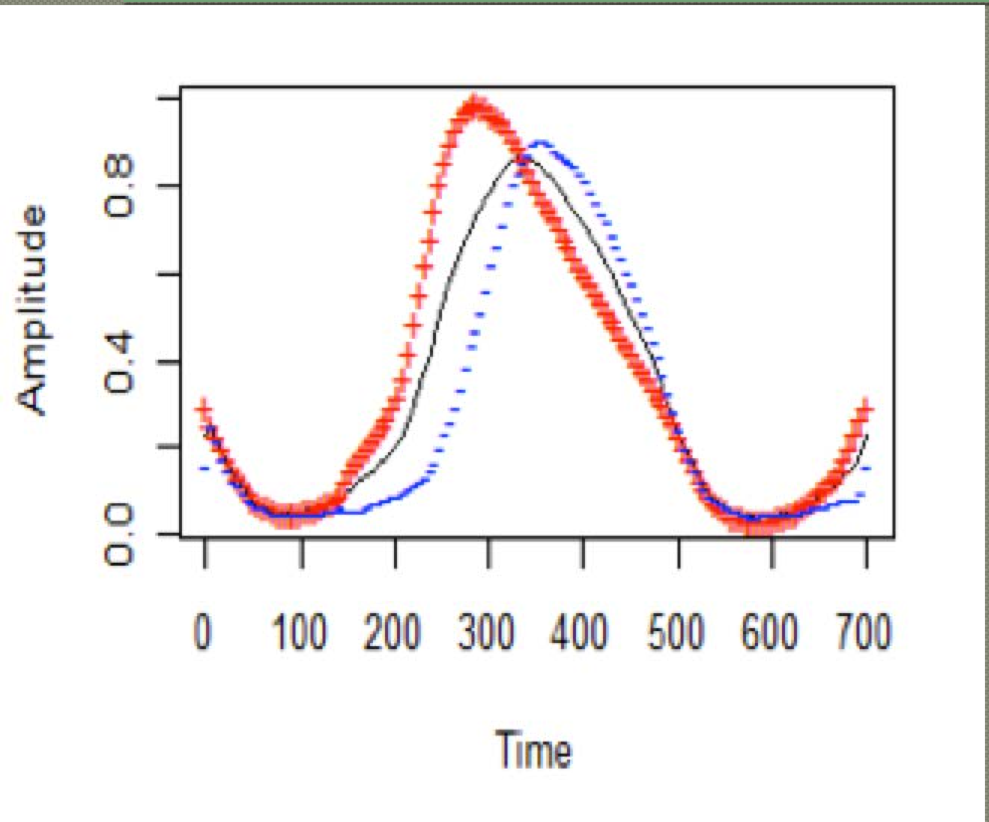
e: upper margins begin to separate

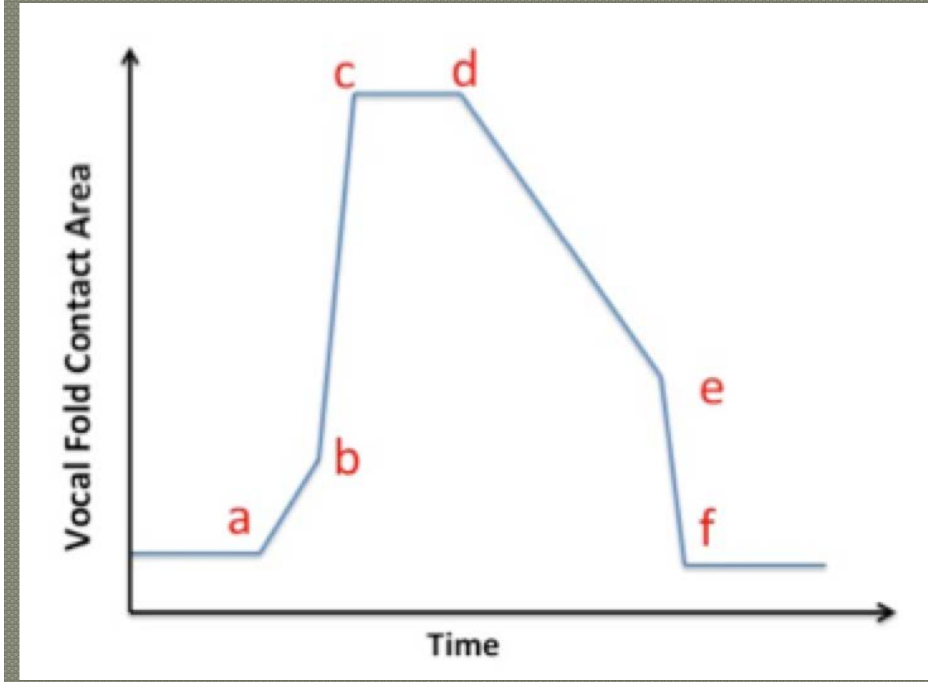
f: separation of upper margins completes



Anastaplo and Karnell, 1988; Karnell, 1989; Baer et al., 1983a,b; Childers *et al.*, 1990; Berke *et al.*, 1987; Herbst and Ternström, 2006; Henrich *et al.*, 2004

Abruptness of contact





Conclusions about Yi tense/lax contrasts

- This is phonation independent of pitch
- Phonation difference results from difference in glottal vibrations
- Neither phonation category is extreme

Electroglottography (EGG)

- Advantages: Non-invasive; Not interfere with natural speech → fieldwork
- Plays important role in documenting non-modal phonations in various under-described languages:
  - Maa (Guion et al., 2004), Santa Ana Del Valle Zapotec (Esposito, 2010), Tamang (Mazaudon and Michaud, 2006, 2009), Takhain Thong Chong (DiCanio, 2009), Gujarati (Khan, 2012), and White Hmong (Esposito, 2012)

Speech corpus

- From recordings of 30 speakers from 5 Yi villages in Yunnan province, China:
- Tone, phonation, and speaker (gender and language) vary within the sample

Glottal activity in this contrast: inferences

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Relation to perception

- Data from previous AXB perception study of contrast in Southern Yi (Kuang 2011) – average accuracy 65%
- Same EGG analysis applied to stimuli; very similar results
- Acoustic analysis of stimuli also available
- Other EGG measures also available
- Correlate perception scores with all of these measures

Result

- Perceptual accuracy is correlated with PC1 (r=.49) and weakly with PC3 (r=.13)
- This is stronger than the best acoustic measure's correlation (H1*, r=.28) and the best traditional EGG measure's correlation (Contact Quotient, r=.35)