Electroglottographic and acoustic measures of phonation across languages

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Phonation contrasts in languages of the world

- Many of the world’s languages use phonation contrastively on vowels and/or consonants – a different phonation makes a different word
- Common especially in SE Asia, the Americas, India
- Audio example next slide

Jalapa Mazatec (Mexico)
Low tone, male speakers

/jæ^{1}/ (modal) – (Engl. *boil* (noun))

/jæ̰^{1}/ (creaky) – (Engl. *manure)*

/jæ̤^{1}/ (breathy) – (Engl. *boil* (verb))

Relation of phonation to lexical tone in languages

- Some languages with phonation contrasts do not have lexical tone (pitch) contrasts
- Some languages have both phonation and tone contrasts, independently, such that different tones and phonations can co-occur
- Some languages use phonation as part of the tonal system: certain tones have their own correlated phonations

How are phonation contrasts produced?

- Not really clear yet - direct observation of such laryngeal activity is very limited to date, often not practical
- **Electroglottography (EGG)** is a non-invasive, though indirect, way of comparing glottal differences among contrastive phonations – EGG indirectly indexes vocal fold contact

This talk

- Relate EGG to acoustics in two phonation languages
- Suggest advantages of studying phonation in languages where it’s contrastive:
  - Speakers share goals, i.e. the language’s phonological categories [Ladefoged]
  - Likely to see a wide range of values on phonation measures, so any relations among them are likely to be clear

Languages we have EGG recordings from

- **Hmong** (White Hmong, Laos) [with Christina Esposito]
  - 1 lexical tone is Breathy, 1 Creaky, others modal
- **Yi** (Yunnan province, China, Southern dialect)
  - Lax vs. Tense voice, crossed with Low and Mid lexical tones
- Bo (Yunnan province, China)
- Hani (Yunnan province, China)
- Black Miao (Guizhou province, China)
- Gujarati (Standard Gujarati) [with Sameer Khan]
- Mandarin (Standard Beijing) [with Kristine Yu]
- Zapotec languages (Santiago Matatlán, San Juan Guelavia, Santa Ana del Valle) [with Christina Esposito]

Yi fieldwork in Yunnan

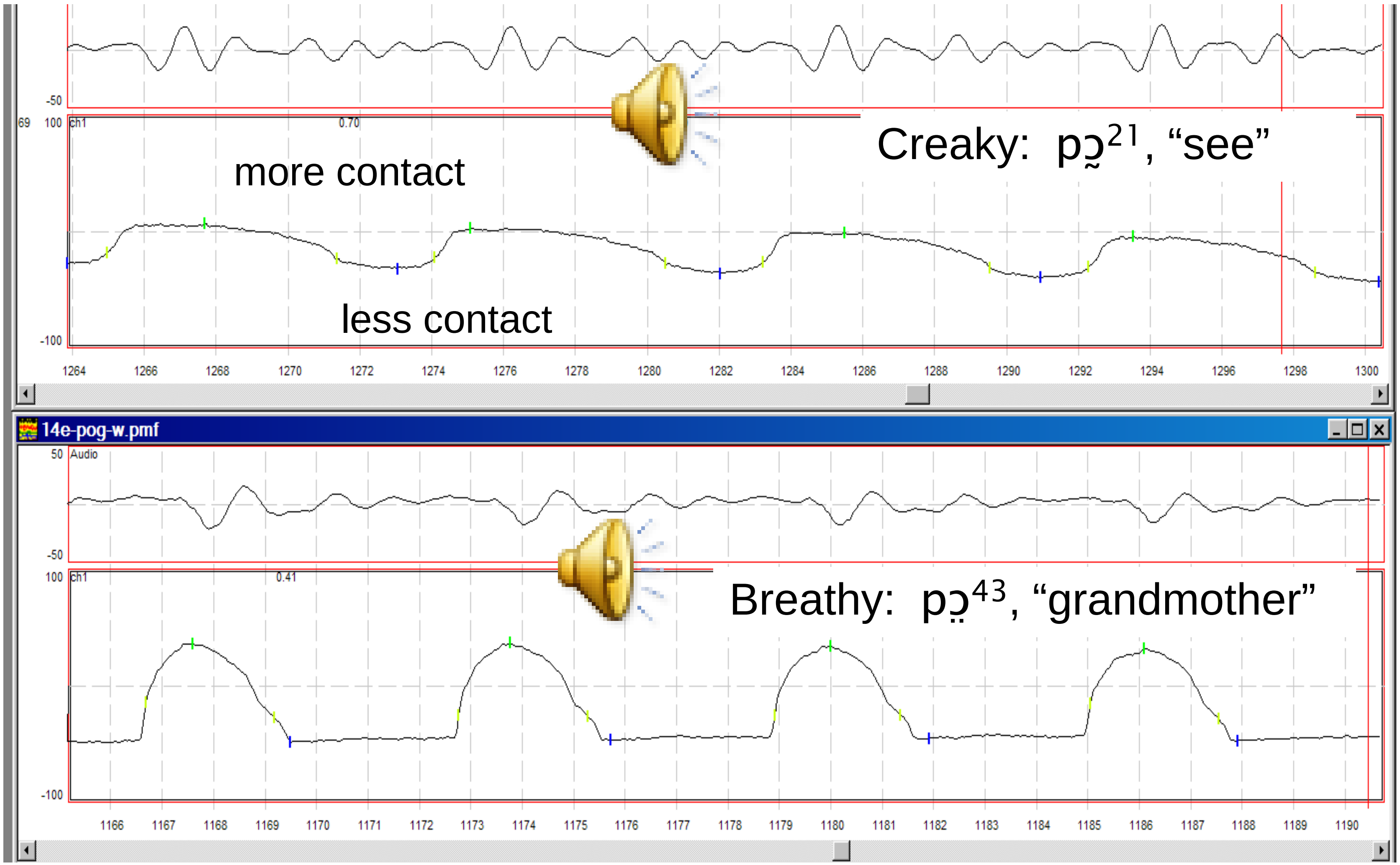
Hmong fieldwork

in Minnesota

[by Christina Esposito]

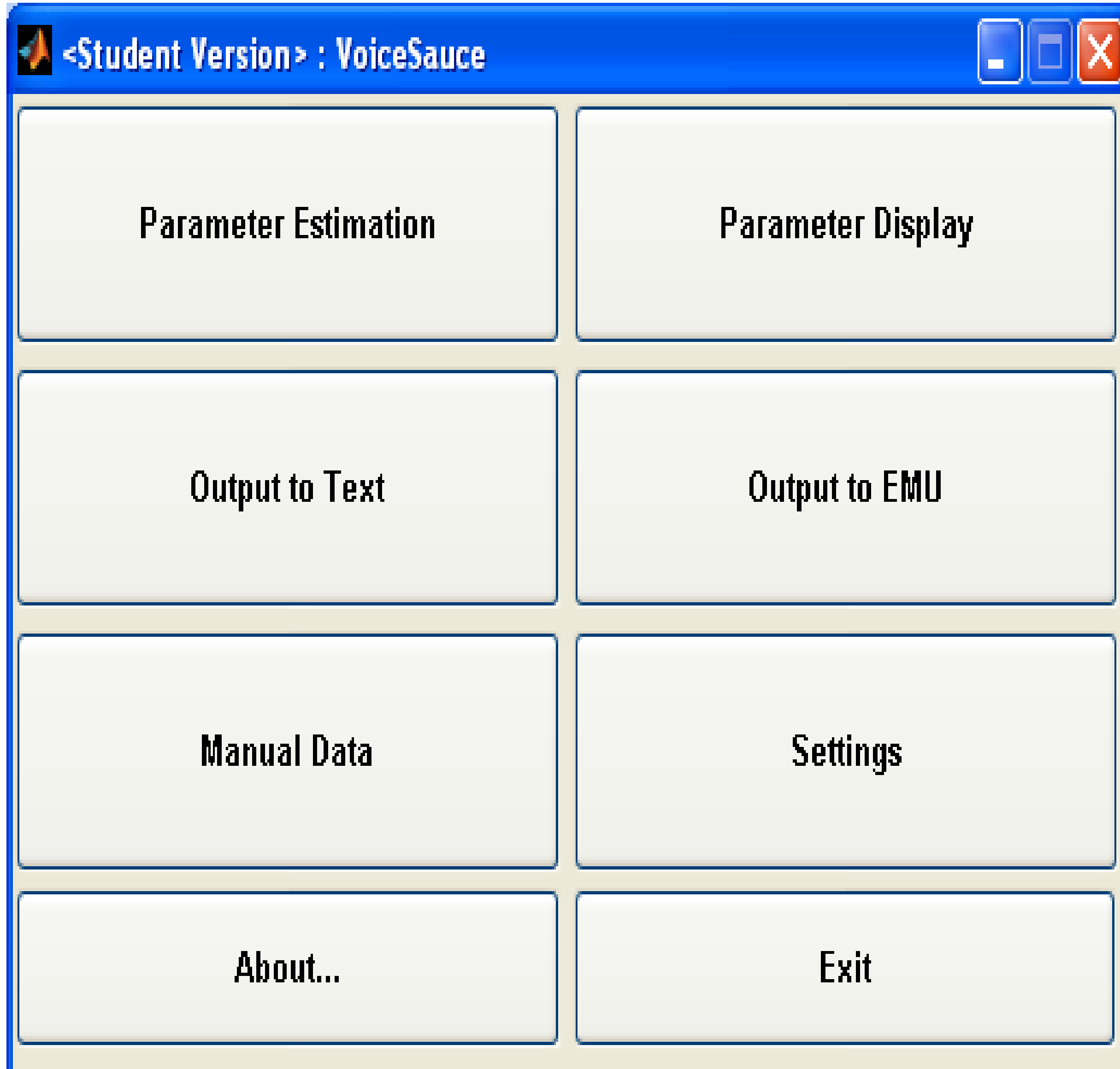
Hmong EGG example, Creaky vs. Breathy

1 female speaker
1 rep each word

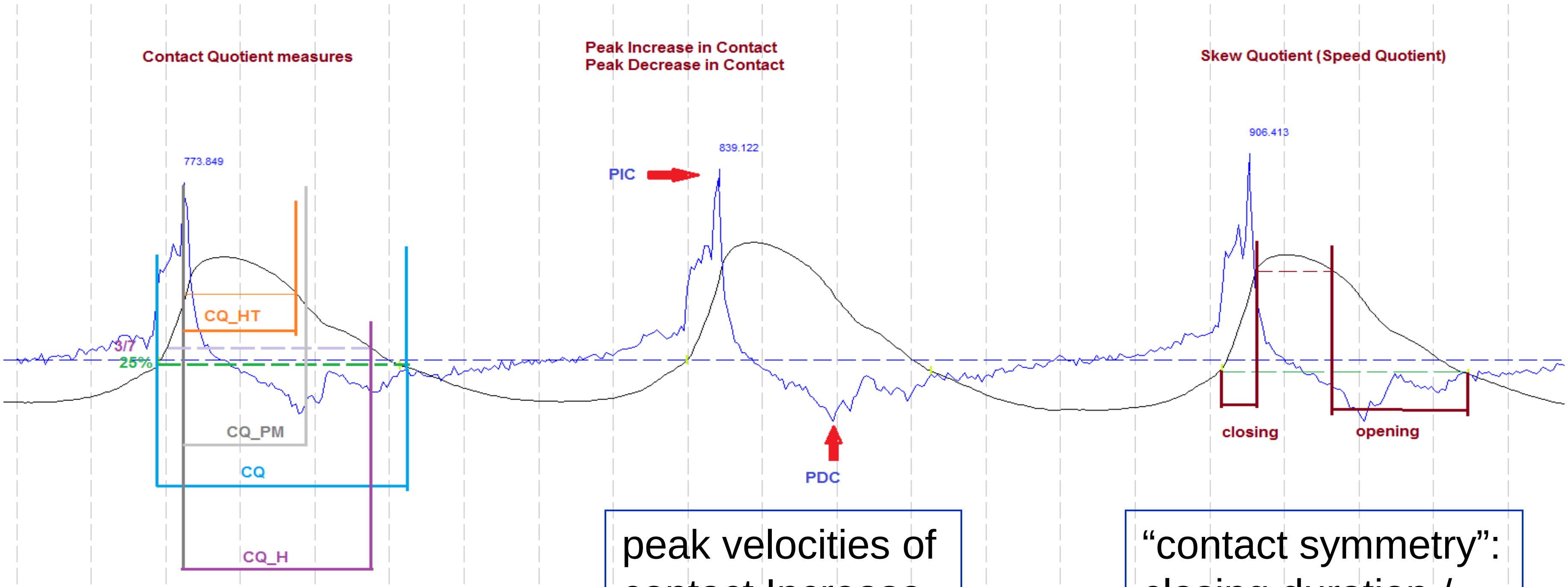


UCLA analysis tools

- **EggWorks** (Tehrani 2009)
- **VoiceSauce** (Shue 2010, Shue et al. 2011)
- Free by downloading



EGG measures



“relative contact duration”:
Contact Quotient CQ
4 methods
from EGG signal

peak velocities of contact Increase and Decrease from dEGG

“contact symmetry”: closing duration / opening duration from EGG signal

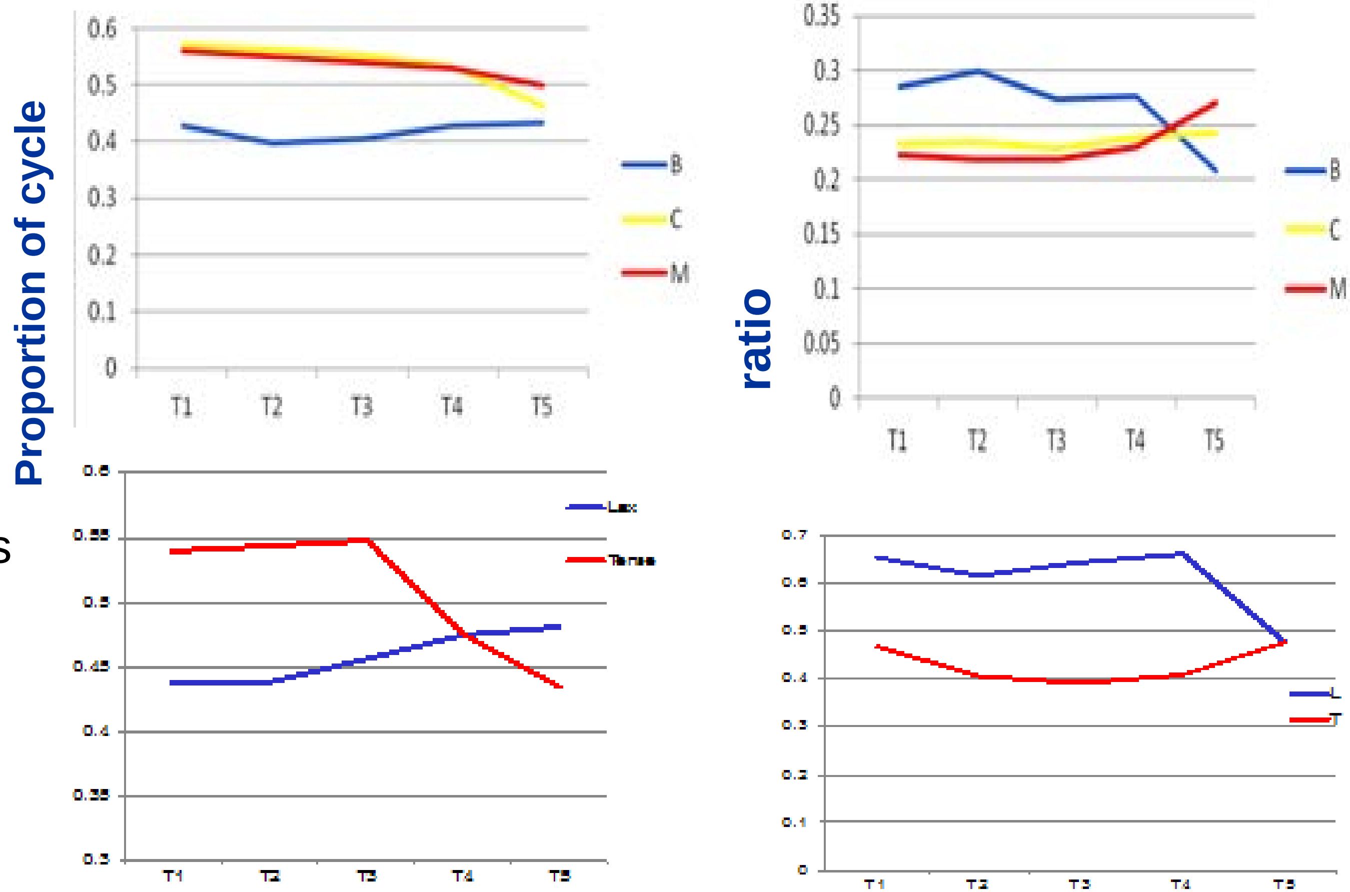
EGG results: Quotients Contact (left) and Skew (right)

Hmong: 8 male speakers

- CQ and SQ pattern similarly (inversely), distinguish Breathy from Creaky, Modal phonations

Yi: 3 male speakers

- CQ, SQ can distinguish Lax vs. Tense phonations



(5 time intervals)

Peak Increase (left) and Decrease (right) in Contact

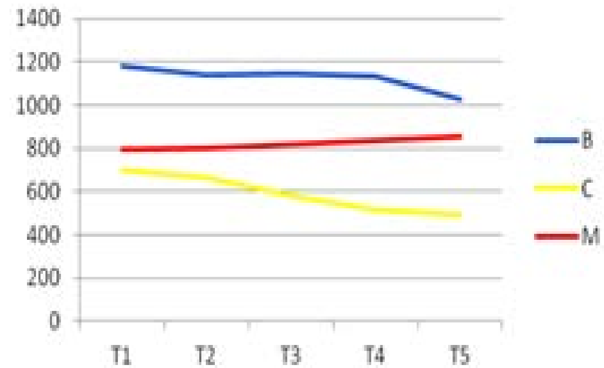
Hmong: 8 male speakers

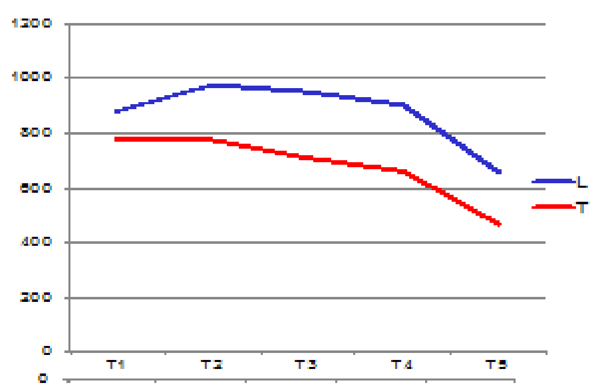
- PIC and PDC pattern similarly (inversely), distinguish all phonations, especially at vowel-end

Yi : 3 male speakers

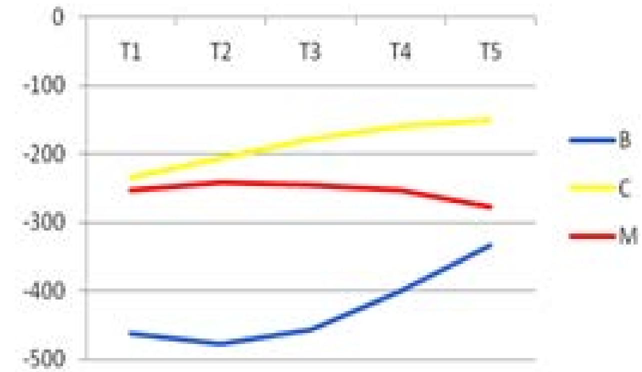
- PIC and PDC distinguish Lax vs. Tense phonations (inversely)

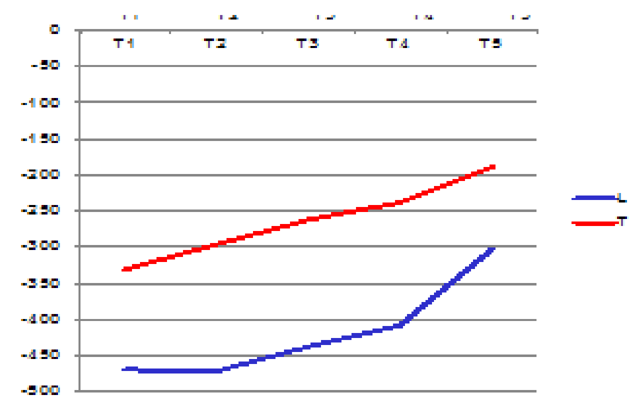
PIC





PDC



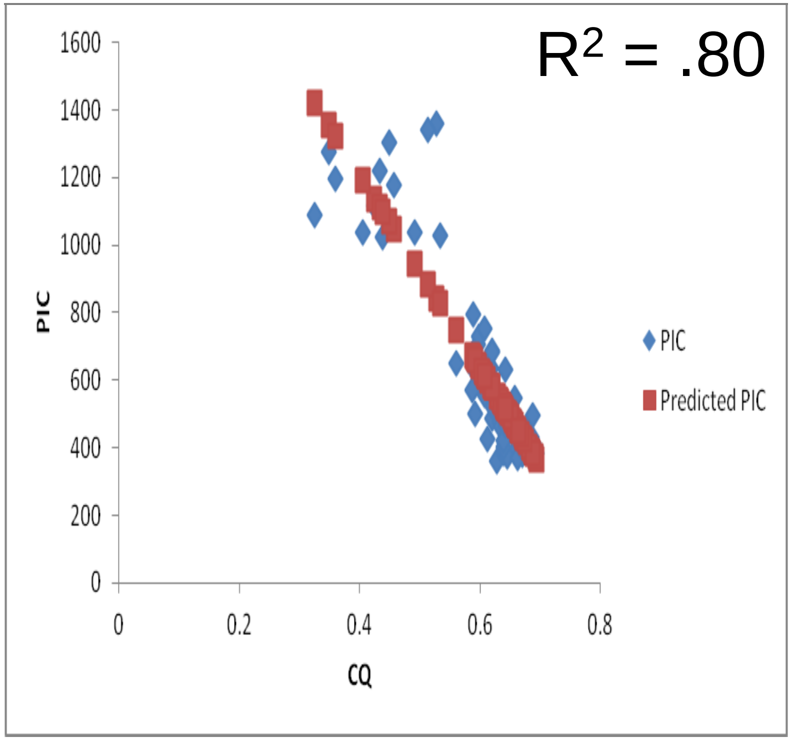


(5 time intervals)

Contact Quotient inversely related to rates of change

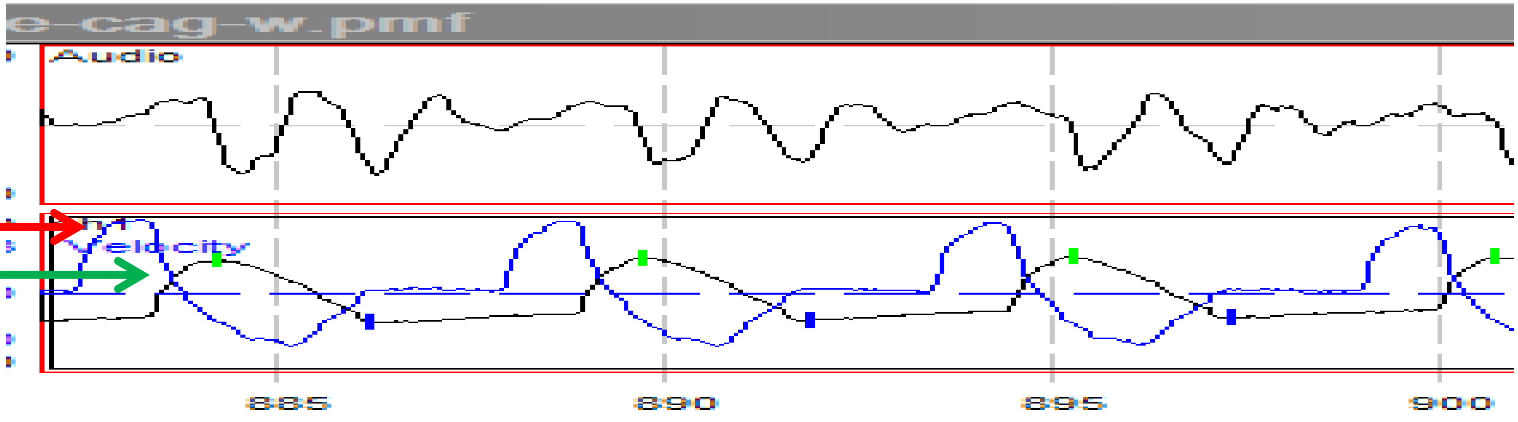
- Greatest rates of change are in Breathy voice, which has lowest CQ values
- Moderate correlations across speakers, better within speakers
- Possibly related to amplitude change within a pulse: “the further the faster” (next slide)

1 Hmong speaker: PkIncrCont vs. CQ

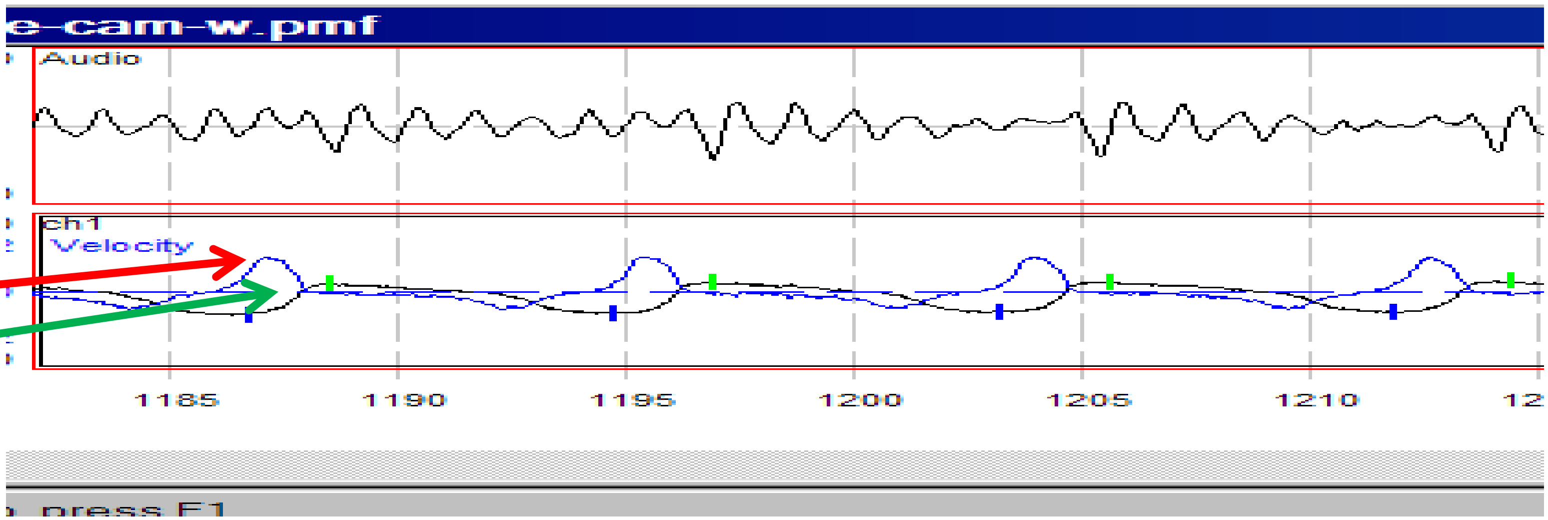


Hmong Breathy vs. Creaky example (EGG=black, dEGG=blue)

Breathy:
faster
larger



Creaky:
slower
smaller



Lower ContactQ with *faster* contacting

- Breathy phonation has lower ContactQ and greater rates of change, but also more gradual closing as seen in high speed imaging of glottal area (e.g. Shue 2010)
- Thus it appears that peak rate of contacting from EGG is not the same as abruptness of closing in glottal pulse

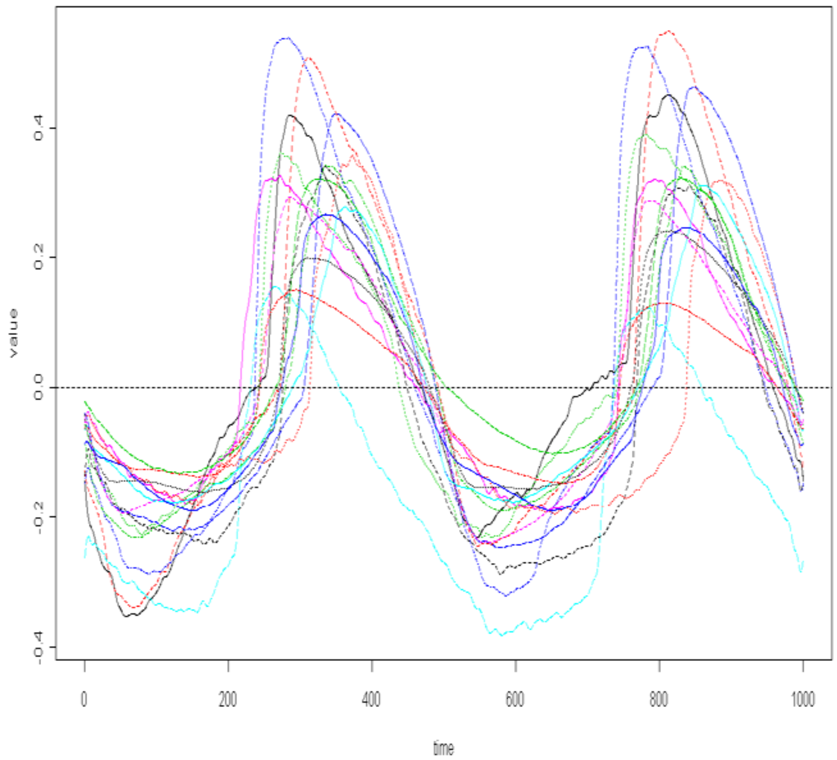
EGG results: relation to F0

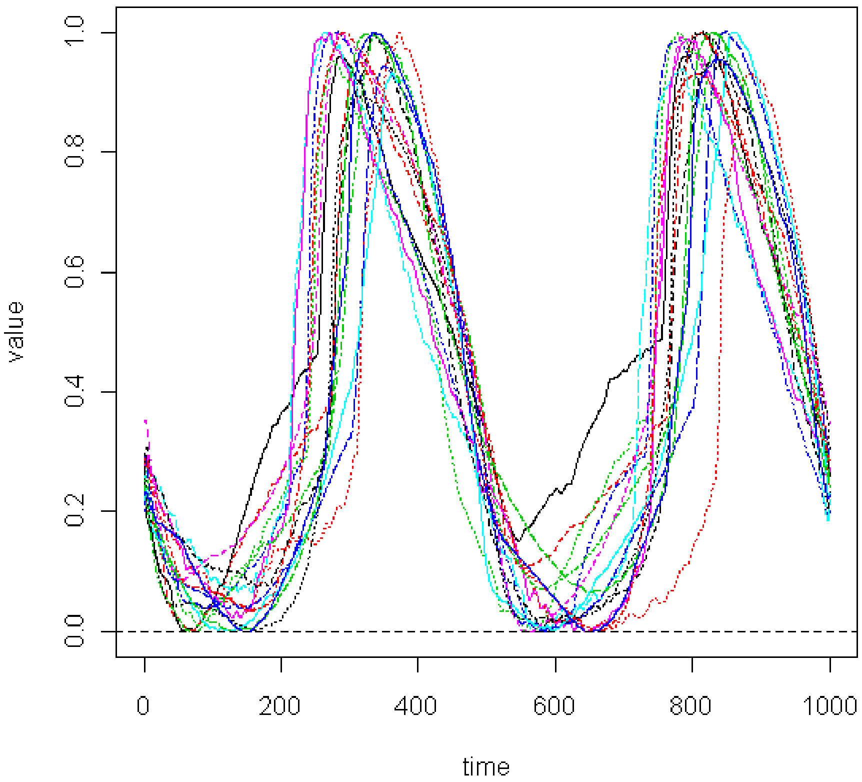
- In Hmong, F0 cannot predict any EGG parameters above R^2=.08, either across phonations or just in Modal
- In Yi, F0 accounts for ~20% variance in PeakIncreaseCont, PeakDecreaseCont, and contact rise time: higher F0 has faster, shorter increase in contact and slower decrease in contact
- Especially in Lax phonation

Functional Data Analysis of Yi glottal pulse shapes

- An alternative to traditional measures (Ramsay & Silverman 1997/2002; Mooshammer 2010) = functional version of principal component analysis (FPCA) using the R package FDA version 1.2.4
- Pairs of pulses extracted from Yi vowels with Tense and Lax phonation types and with Low and Mid tones (3 males)
- Pulses time-normalized 0-1000 and amplitude-normalized 0-1 (next slide)

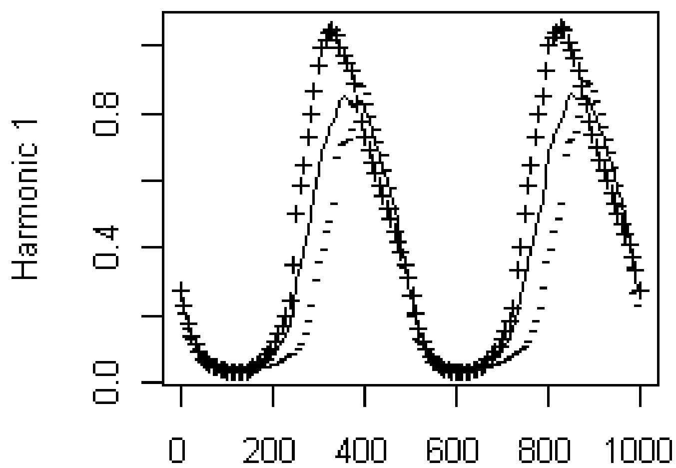
Pulses before and after amplitude normalization



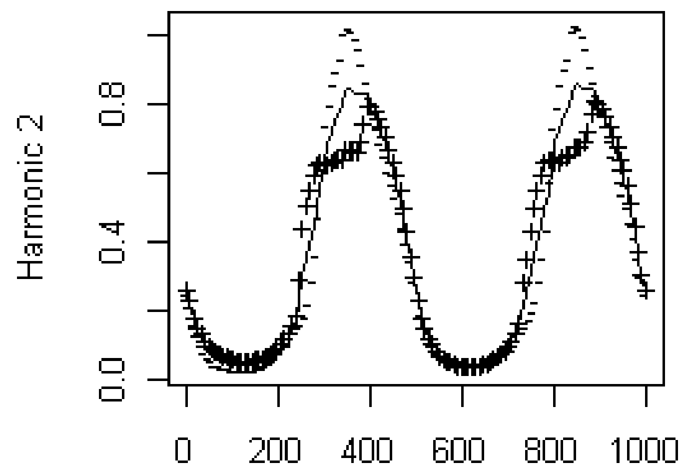


1st two principal components for Yi tense/lax pulses (87% of variance)

PCA function 1 (Percentage of variability 66.6)



PCA function 2 (Percentage of variability 19.2)



contacting phase:
- varies mostly with phonation type, not with tone

maximum contacting :
- varies w/ phonation type, but mostly for Low tone

(3rd principal component varies with tone, not phonation type; 4th is minor, more about individual speaker differences)

Relation (r) of 4 PCs to standard EGG measures

	PC1	PC2	PC3	PC4
ContactQ_Threshold	**.9**	**.09**	**.13**	**.33**
ContactQ_Hybrid	**.81**	**.24**	**0**	**.01**
PkIncreaseContact	**-.77**	**.03**	**-.12**	**-.19**
PkDecreaseContact	**.91**	**-.11**	**.10**	**-.16**
SkewQ	**.06**	**-.23**	**.28**	**.66**

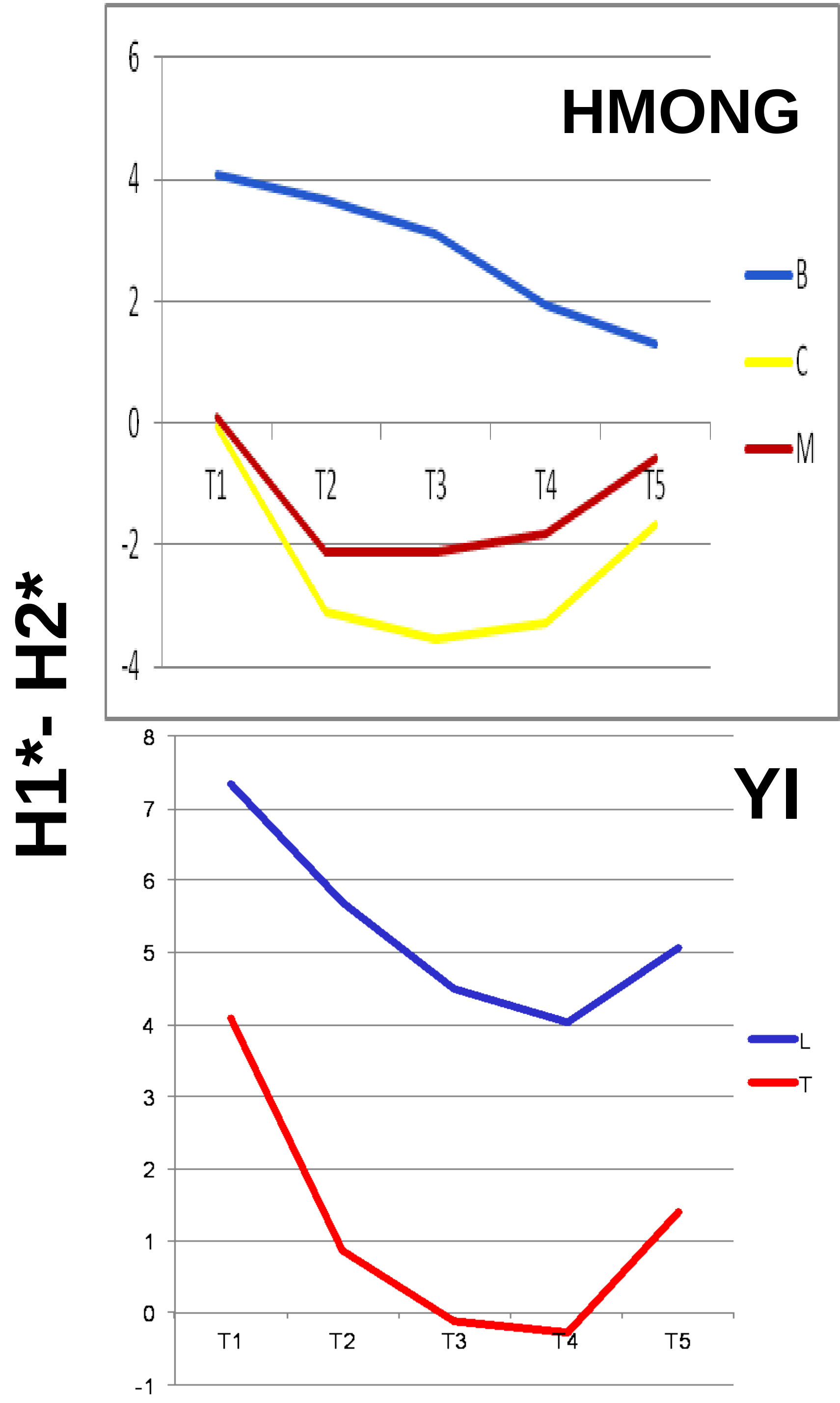
weaker

Summary of EGG

- EGG measures generally distinguish the phonation types; are not strongly related to F0
- Peak Decrease in Contact (neg peak in dEGG), not a standard measure, is very distinctive here
- Peak changes in contact perhaps related to pulses as “the further the faster”
- Most variation in Yi EGG pulse shape is related to the phonation types, and mostly in terms of the shape of the contact increase and peak
- In Yi, EGG pulse shape is most strongly related to Contact Quotient and to Peak Decrease in Contact

Acoustic correlates

- Many acoustic measures distinguish 2 or even 3 phonation types
- **H1*-H2***, shown here, does so across languages: H1*-A2* is another very distinctive measure



Relations of EGG and acoustic measures

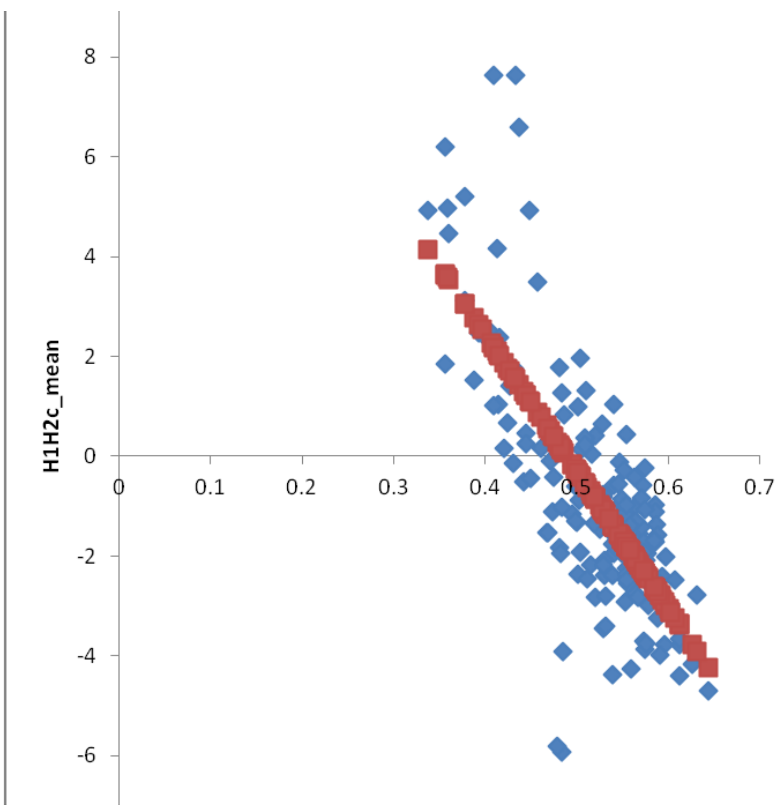
Questions of interest: re H1*-H2*

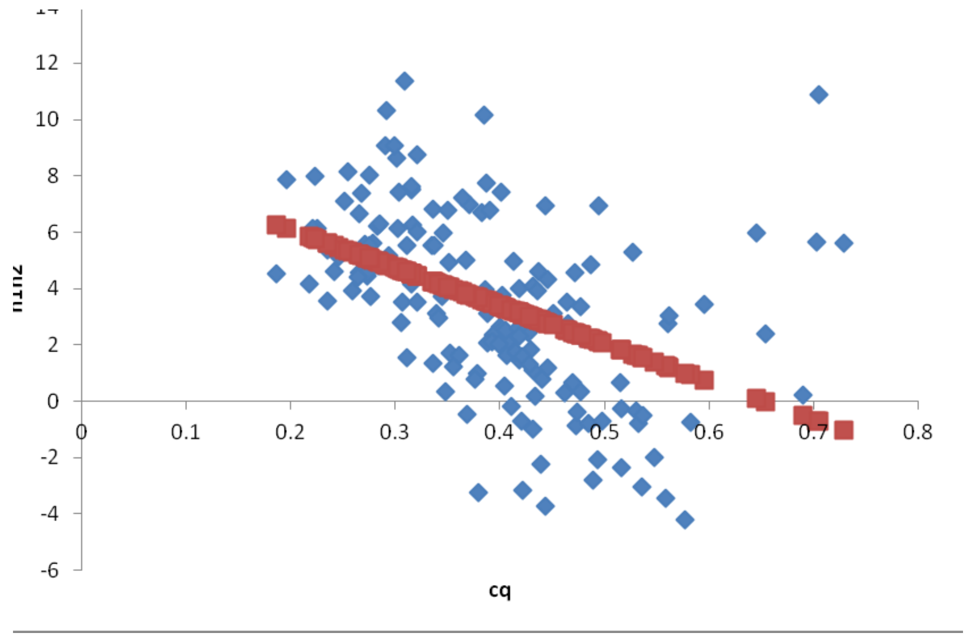
- Given uncertain relation of *OQ* (in flow or area) to H1-H2 – how does *CQ* pattern?
- Given the robustness of H1-H2 as a phonation type measure, what does it reflect physiologically?

From CQ to H1*-H2*: languages differ

HMONG: R^2 =.56

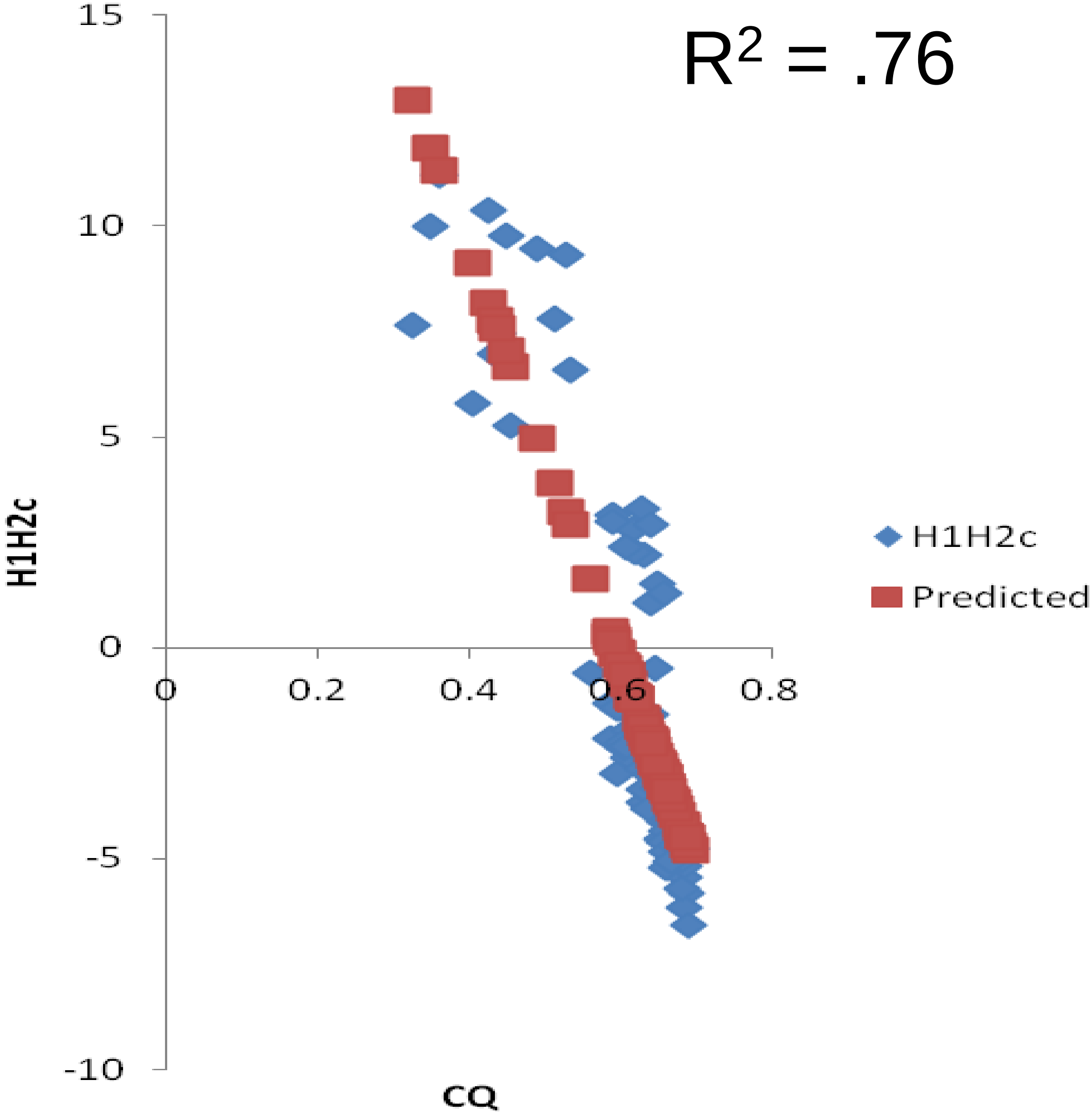
YI: R^2 =.20





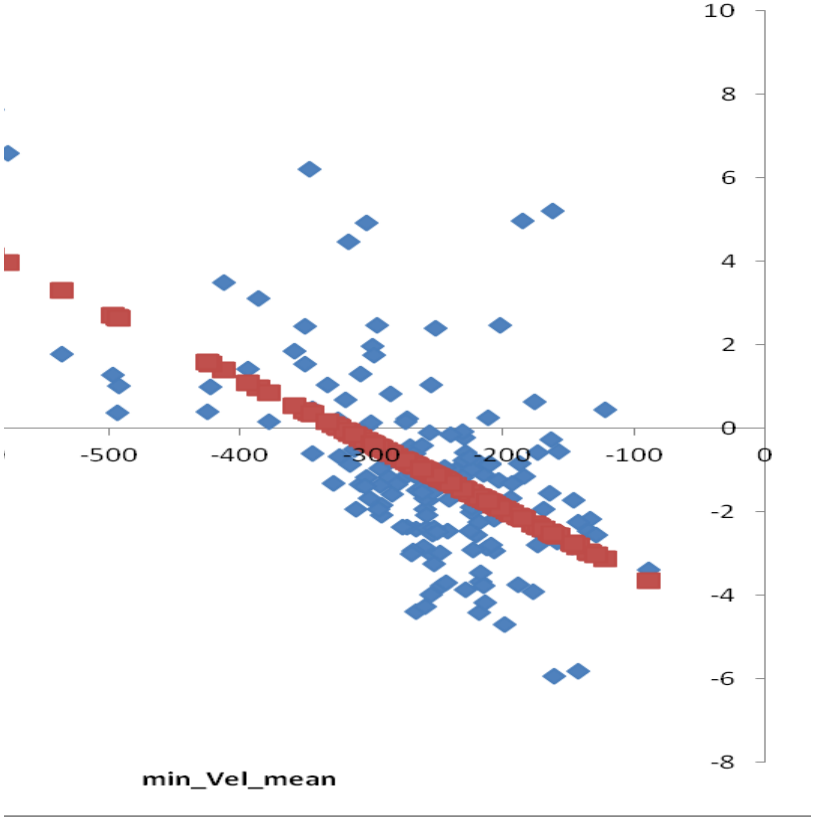
(R^2 increases to .30 when only CQs from .4 to .6 are included)

This relation of H1*-H2* to CQ in Hmong can be very strong for individual speakers: here, 1 male, a larger dataset

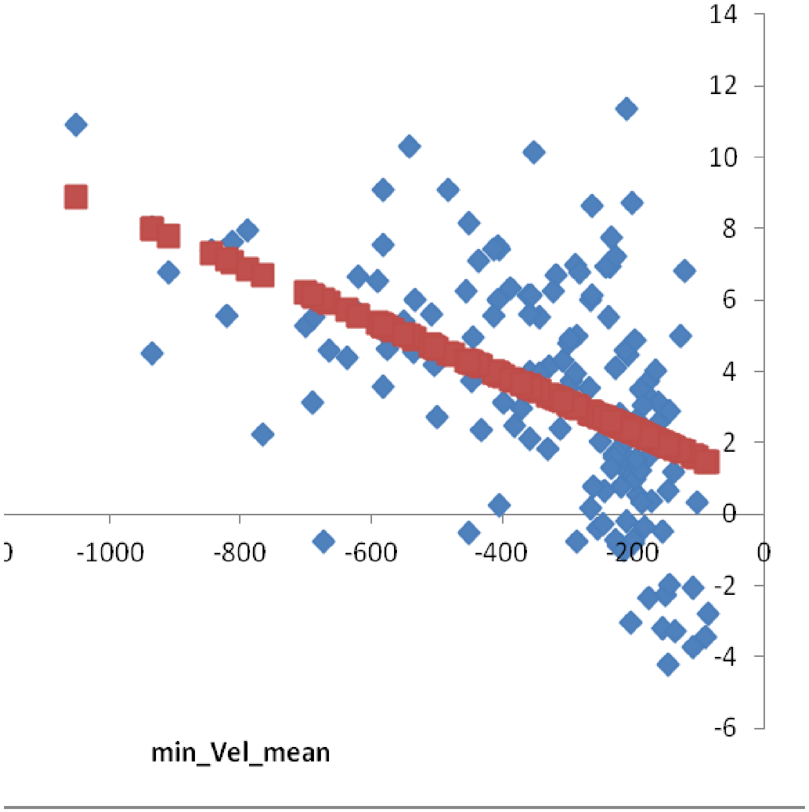


From Peak Decrease in Contact to H1*-H2*

HMONG: R^2 =.40

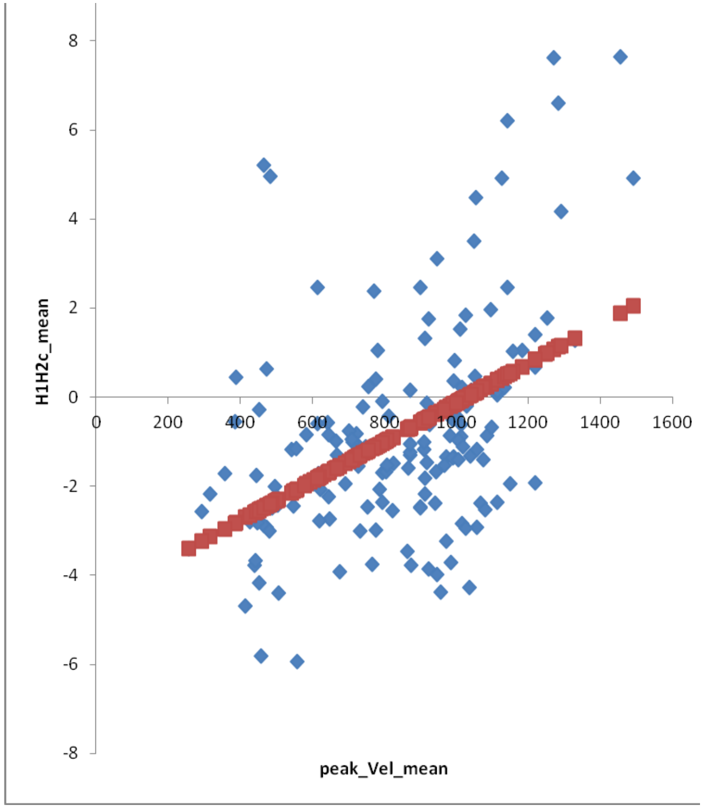


YI: R^2 =.27

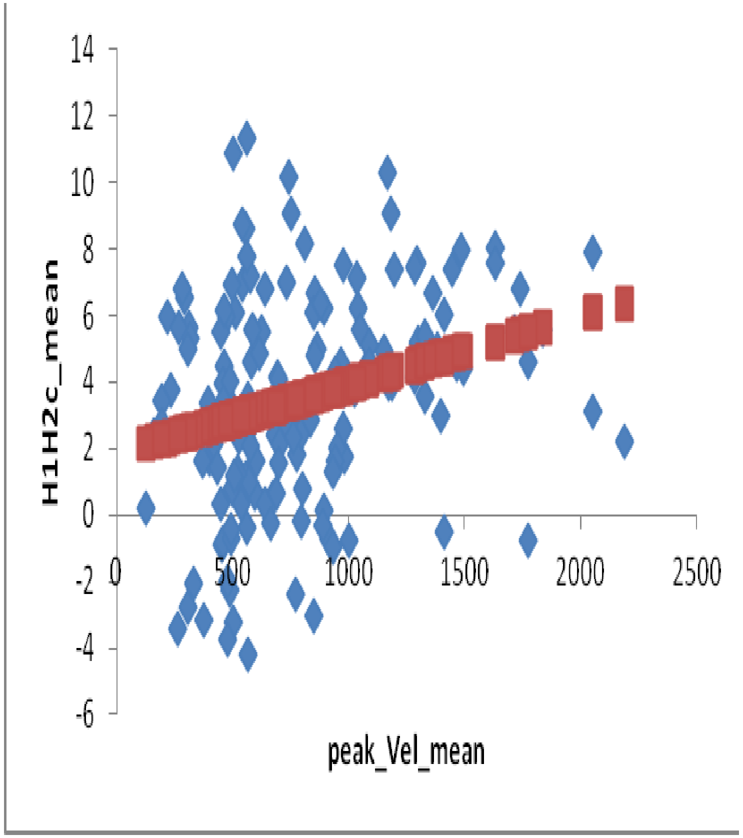


From Peak Increase in Contact to H1*-H2*

HMONG: R^2 =.22

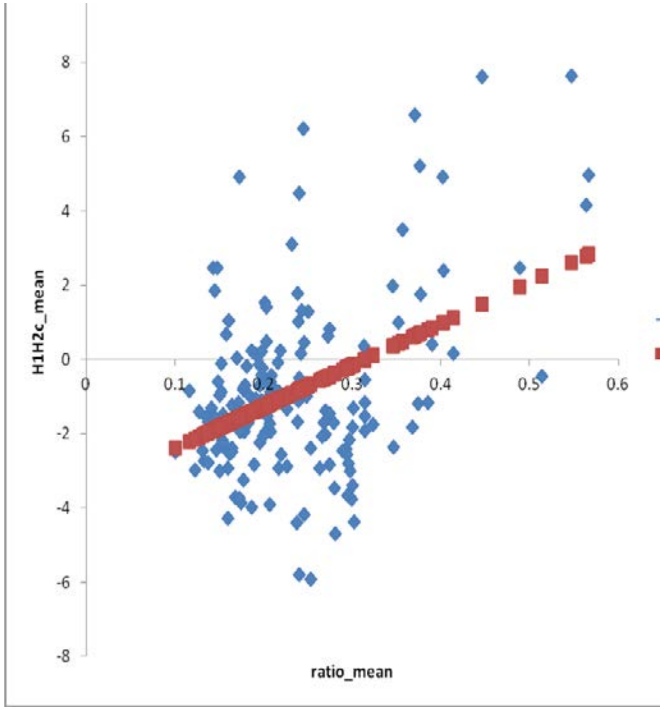


YI: R^2 =.07

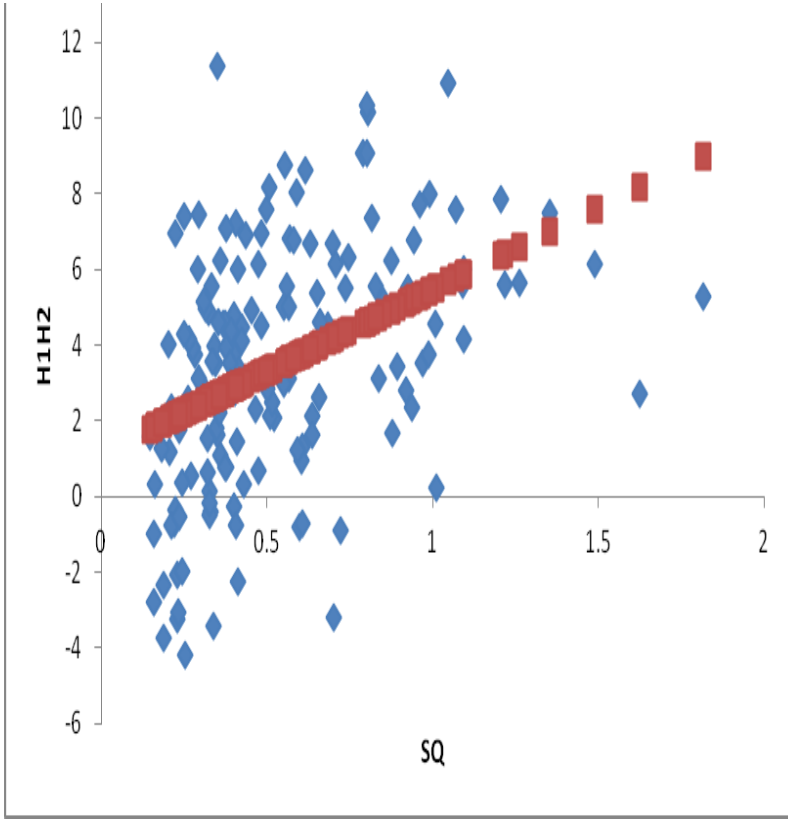


From Skew Quotient to H1*-H2*

HMONG: R^2 =.17



YI: R^2 =.18



From FDA Principal Components to acoustic measures (in Yi)

- 1^{st} principal component is most strongly related to H1*-H2* (r=-.7)
- 2^{nd} principal component is less strongly related to H1*-H2* (r=-.48); also to bandwidth of F2 (r=-.5)

Conclusions - 1

What do we learn from EGG about these languages' phonation categories?

- In Yi, Contact Quotient is the most distinctive EGG measure, both directly and by its strong relation to those principal components of pulse shapes that relate to phonation
- In Hmong, the two rate-of-change EGG measures (Peak Increase in Contact, Peak Decrease in Contact) are most distinctive

Conclusions - 2

What do we learn from EGG about H1-H2, especially re Contact Quotient?

- H1*-H2* is correlated at least modestly with *all* the EGG measures (even ones we didn't present here), and with PC1 and PC2 of Yi EGG pulse shape, suggesting it's related to many aspects of pulse shape and timing
- In Hmong, H1*-H2* is most strongly related to CQ. In Yi, PC1 of pulse shape is related to both CQ and H1*-H2*, but these measures are not strongly related to each other.

Conclusions - 3

What do we learn from Functional Data Analysis of EGG pulse shape in Yi?

- (Not so important for Hmong, where some standard EGG measures already work well)
- But in Yi, no EGG measures account for much variance in acoustic measures – standard EGG doesn't tell us much
- Yet in Yi, PC1 and PC2 are related to H1*-H2*, and to the phonation contrast – here, the shape of the contacting part of pulse is crucial, which only FDA could tell us.

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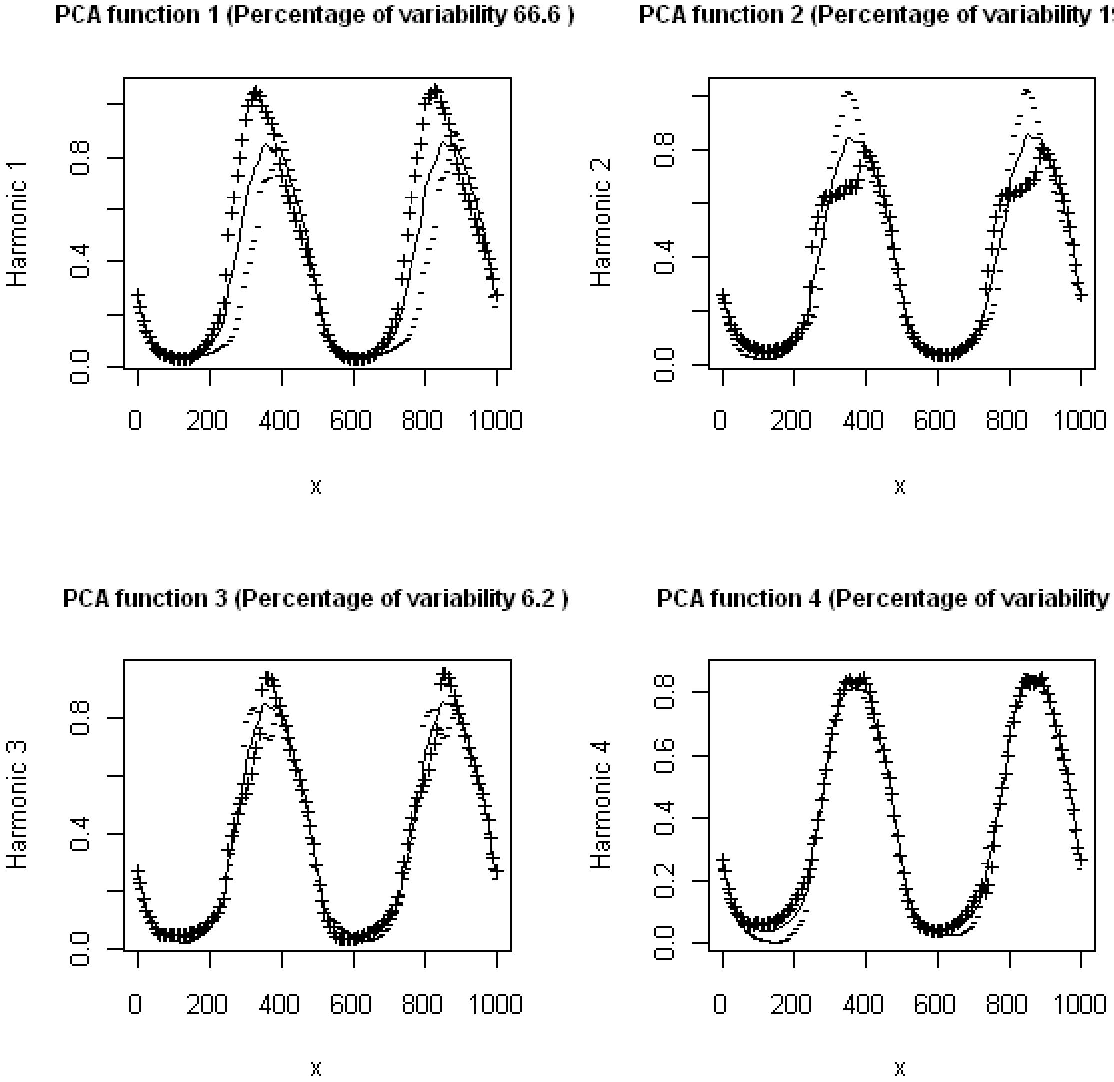
- Collaborators Christina Esposito, Marc Garellek, Sameer Khan

Extra slide – all 4 Yi PCs



Extra slide: Yi audio

- bə^{21}
- b$\underline{\text{ə}}^{21}$