Investigation of the Mechanisms of Voicing Offset.

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How does voicing stop?

- Want to consider the mechanism by which we stop the voicing
- Motivation: Therapy for people with unilateral vocal fold paralysis .

Talk structure

- Context
- Offset in running speech
- The options for voicing offset
- Theoretical modelling
- Comparison with controlled speech
- Comparison with sentence measurements
- Summary of findings

Context

- Focus in the literature mainly on phonation threshold pressure for onset and whether there is hysteresis between onset & offset pressure e.g:

  Plant, Freed & Plant (2004): Direct measurement of onset and offset phonation threshold pressure in normal subjects, JASA 116(6) 2640 -3646

  Chan, Titze & Titze (1997): Further studies of phonation threshold pressure in a physical model of the vocal fold mucosa, JASA 101(6)m 3722 – 3727

  Lucero (1999): A theoretical study of the hysteresis phenomenon at vocal fold oscillation onset – offset, JASA 105(1) 423 – 431

  Koenig, Mencl & Lucero (2005). Multidimensional analyses of voicing offsets and onsets in female speakers, JASA 118(4) 2535 - 2550

- Research Question: what is/are the articulatory mechanism(s) for voicing offset?

Three relevant studies:

- Vocal fold contact area patterns in normal speakers: An investigation using the electro-laryngograph interface system,
  Winstanley & Wright (1991), International Journal of Language & Communication Disorders, 26(1), 25 – 39
  Found consistent patterns in Lx waveform inter- and intra- speaker at voicing offset

- Fundamental frequency during phonetically governed devoicing in normal young and aged speakers
  Watson, (1998), JASA 103(6), 3642 – 3647
  offset is due to VF abduction and stiffening: evidence is F0 increase specifically in "the devoicing gesture for production of an intervocalic voiceless obstruent"

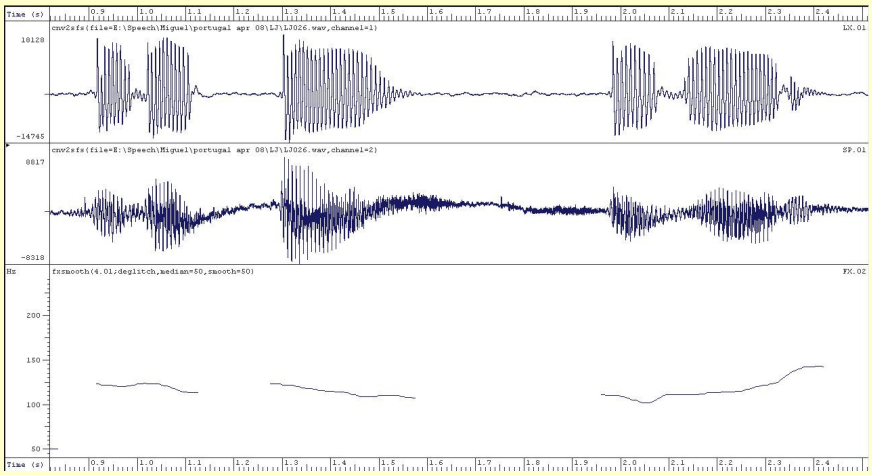
Simulations of temporal patterns of oral airflow in men and women using a two-mass model of the vocal folds under dynamic control
Lucero & Koenig (2005) JASA 117(3), 1362 – 1372 & associated studies
Considered offset in VCV sequence where C is glottal aspirate. Used 2MM to model airflow patterns observed from in vivo.

Examples of devoicing in Portuguese Voiced Fricatives

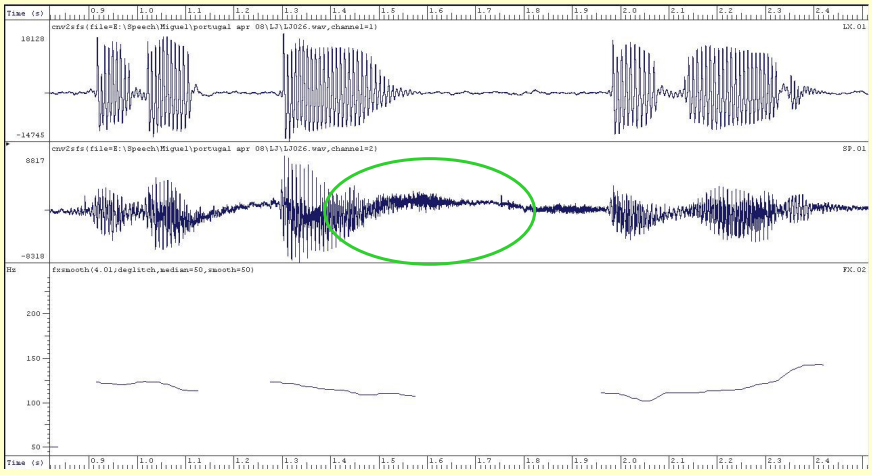
Single male EP speaker
Carrier phrase with voiced fricative that is expected to devoice
Measured speech and EGG
Used SFS to process EGG to define voicing offset region.
Tracked F0 and OQ in voicing offset region

Diga {teve / peso / pejo} {por favor / agora / ilha}

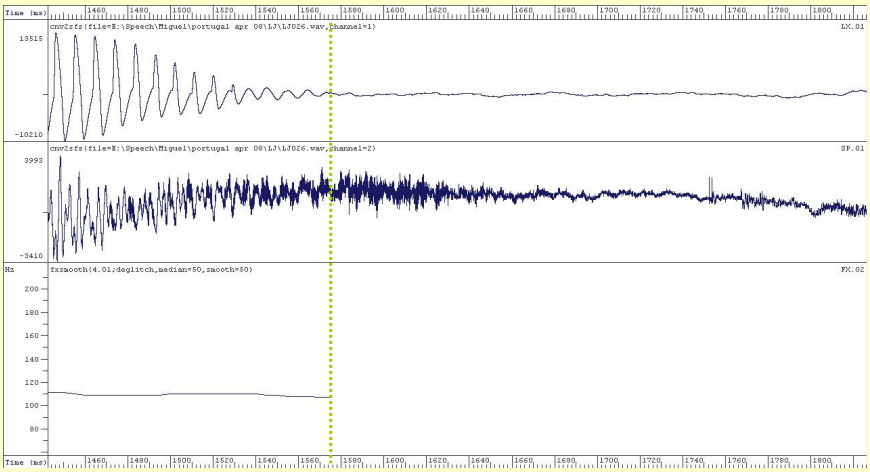
Diga peso por favor



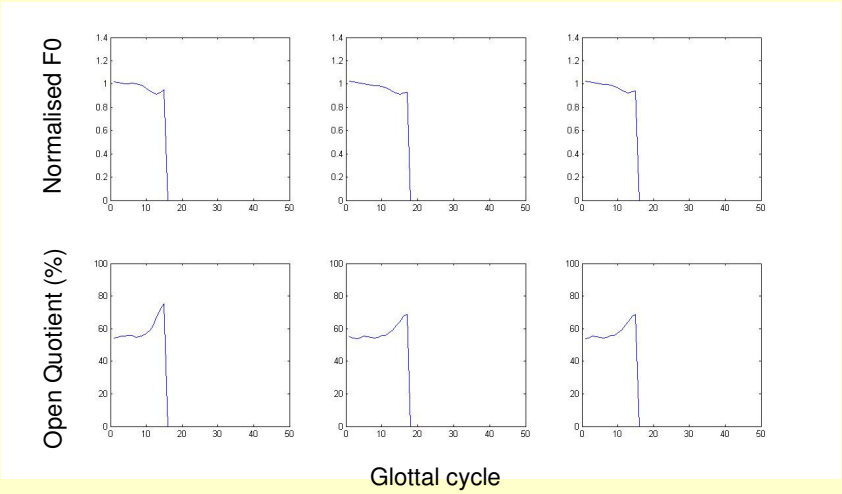
Diga peso por favor



/ z z_0 p/



FO and OQ in transition to devoicing



F0 and OQ in transition to devoicing

- F0 declines slightly
- OQ increases quite sharply.

- Offset here is a breathy decline to an unvoiced fricative
- Very consistent behaviour for all sentences tested.

Mechanisms for voicing offset

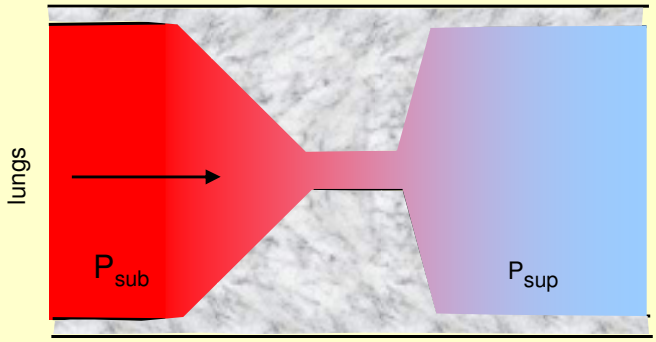
To stop voicing we need to:

- reduce the transglottal pressure drop to below the threshold level for voicing offset

Or

- To change the mechanical properties of the folds so that the transglottal pressure drop is no longer sufficient to sustain voicing.

Mechanisms of voicing offset: aerodynamic



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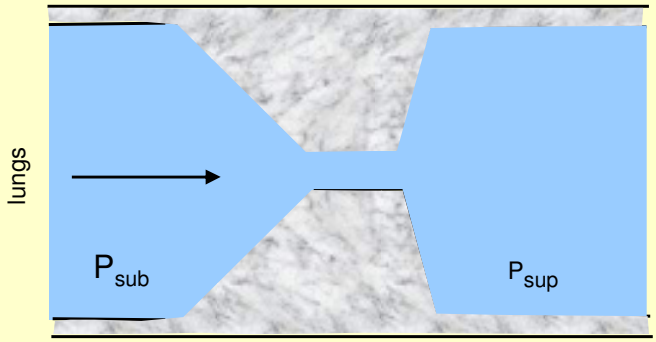
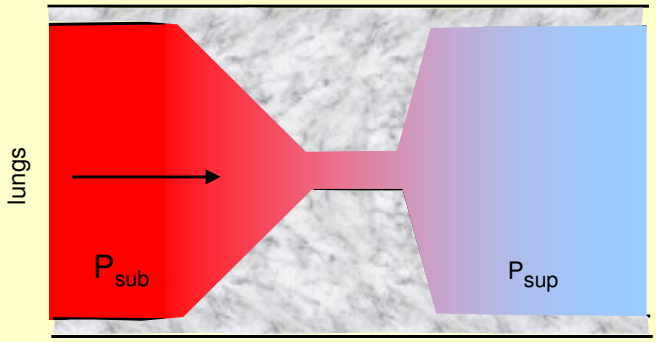


1. Reduce Sub-glottal pressure

Mechanisms of voicing offset: aerodynamic



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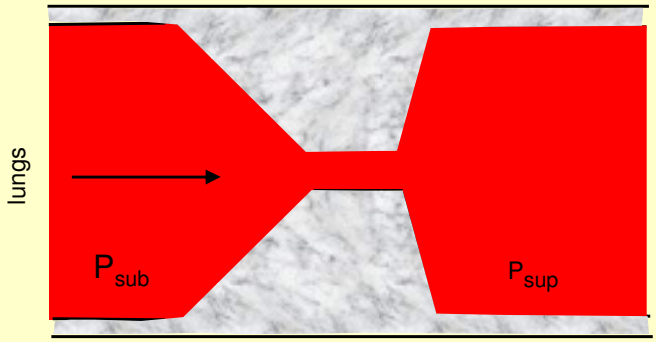
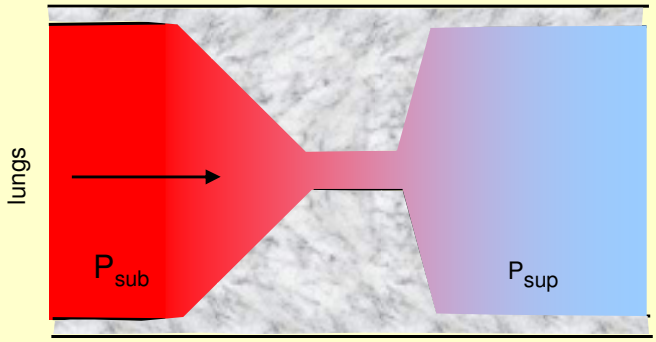


2. Increase Supra-glottal pressure

Mechanisms of voicing offset: aerodynamic



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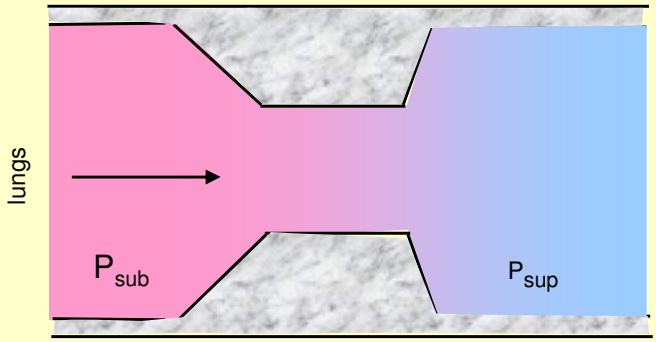
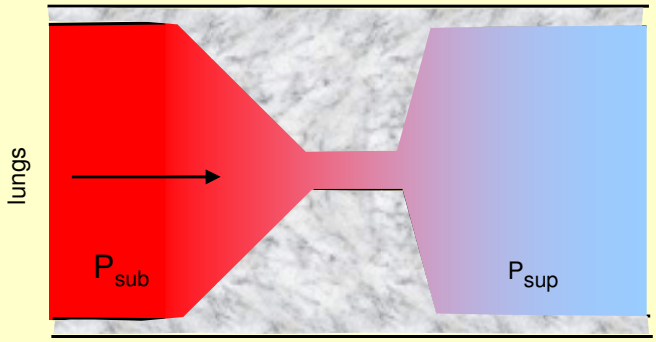


3. Abduct vocal folds

Mechanisms of voicing offset: mechanical



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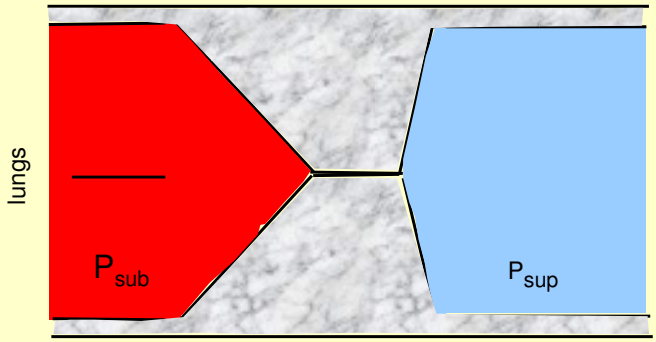
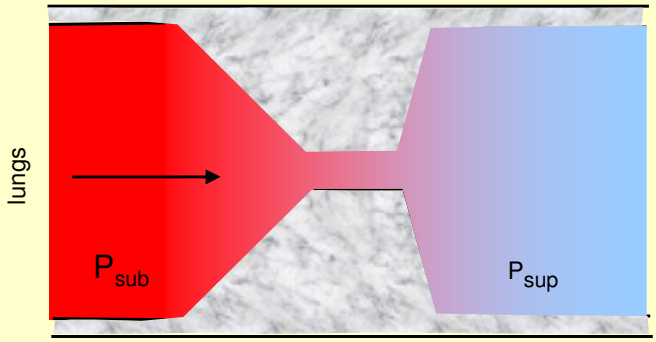


4. Adduct vocal folds

Mechanisms of voicing offset: mechanical



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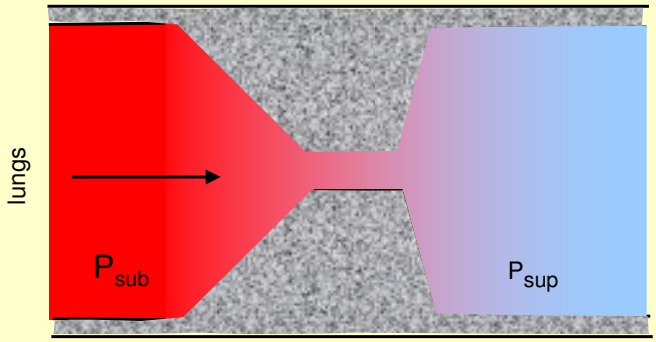
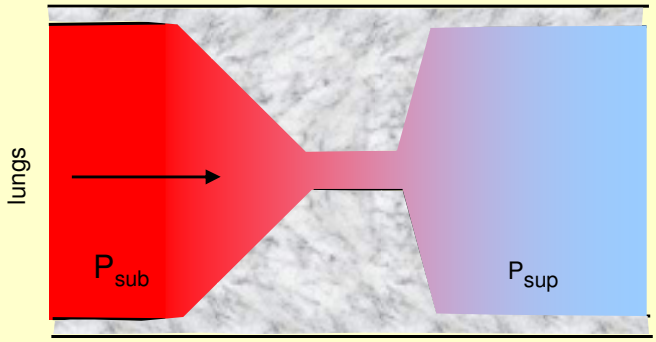


5. Stiffen vocal folds

Mechanisms of voicing offset: mechanical



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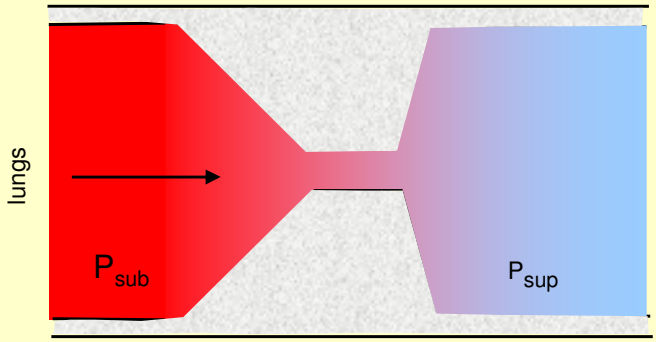


6. Relax vocal folds

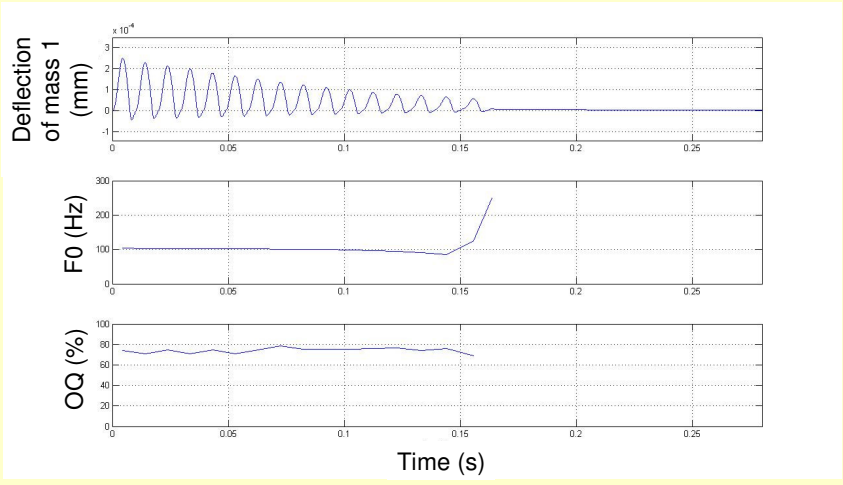
Model data

- Modelling the different cases by adapted version of two-mass model of Lous et al.

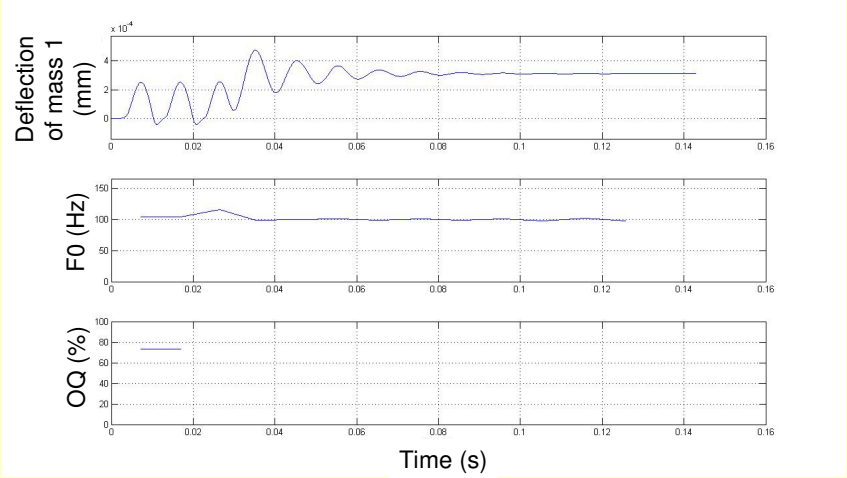
  Symmetrical Two-Mass Vocal-Fold Model Coupled to Vocal Tract and Trachea, with Application to Prosthesis Design, Lous; Hofmans; Veldhuis; Hirschberg, Acta Acustica united with Acustica, 84(6),1998, 1135- 1150.

- Allows dynamic change of pressure and/or mechanical properties of the folds

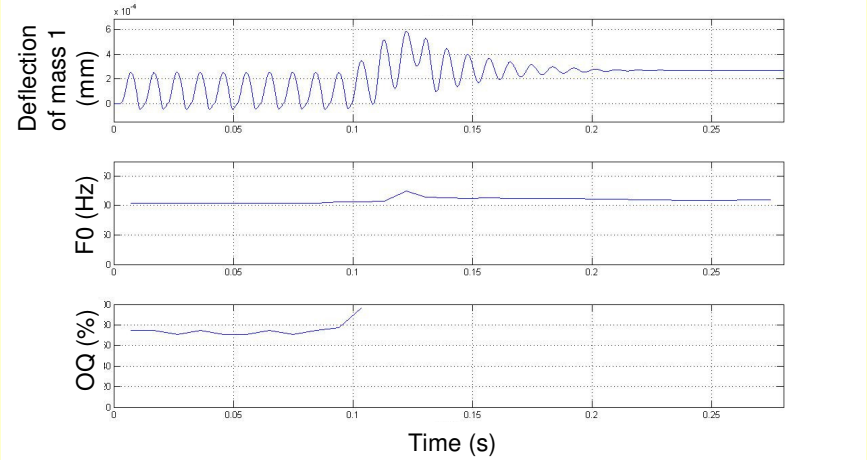
Decreasing Psub



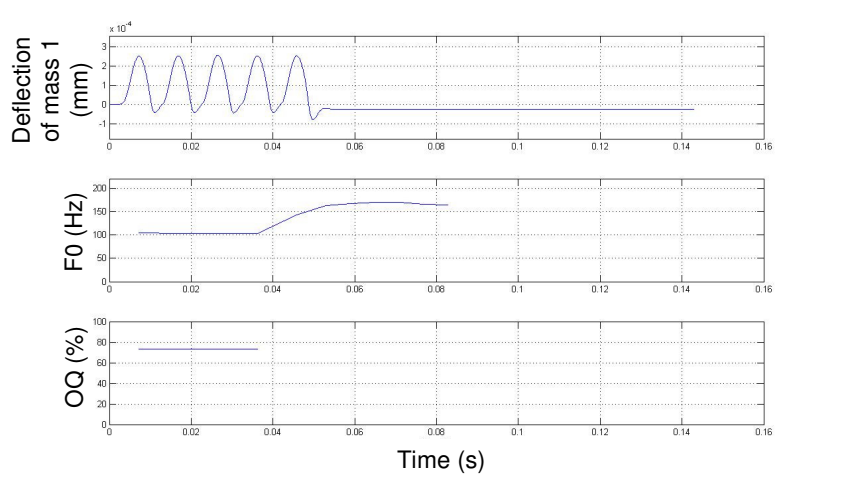
Increasing Psup



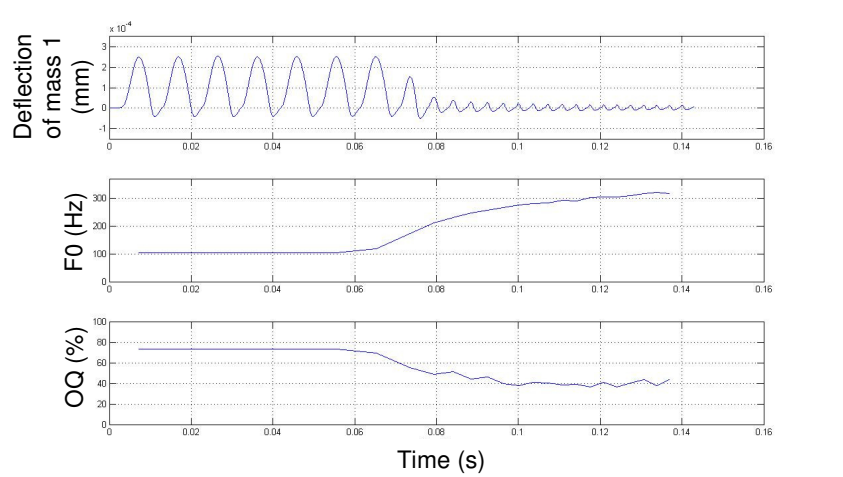
Abduction



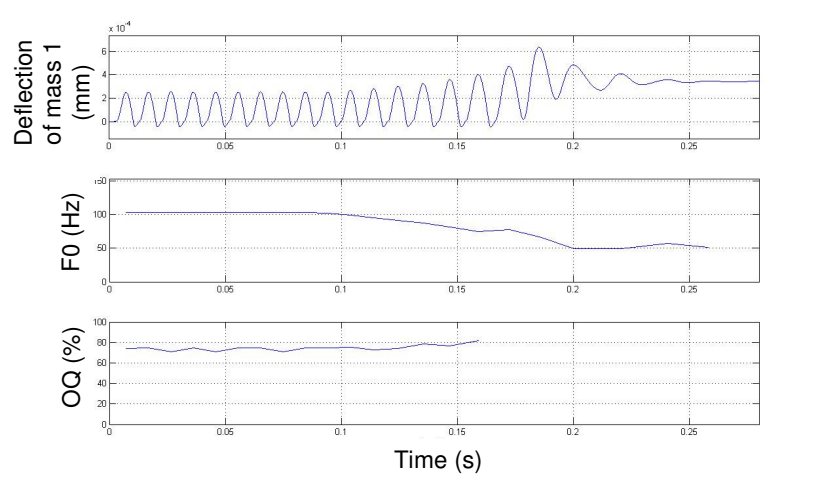
Adduction



Stiffen folds



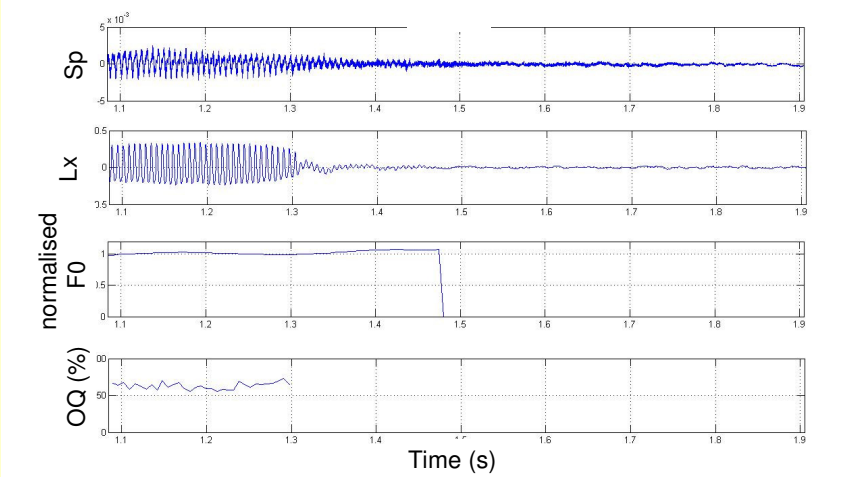
Relax folds



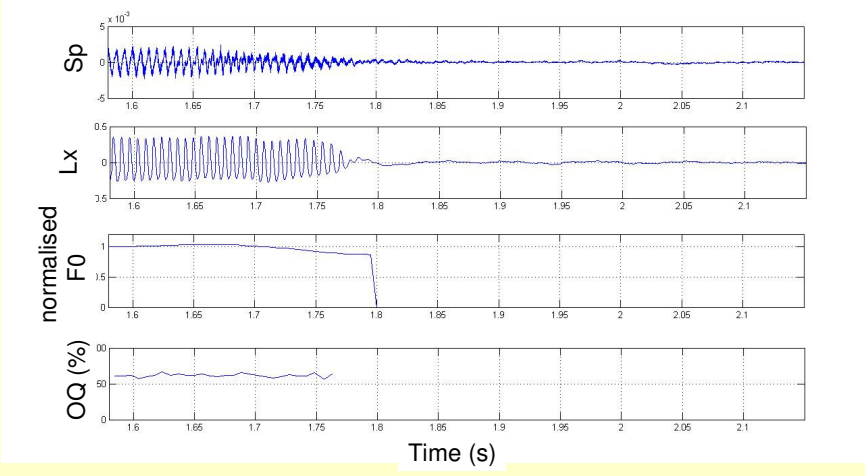
In Vivo Data

- Two speakers: one female speech scientist British English speaker & one male SLT European Portuguese speaker
- Attempt to achieve phonation offset by each method in isolation during a voiced fricative /v/, /z/ or /Z/.
- Relax diaphragm; close mouth; abduct folds, adduct folds
- Unable to reliably stiffen or relax folds in isolation from abduction/adduction

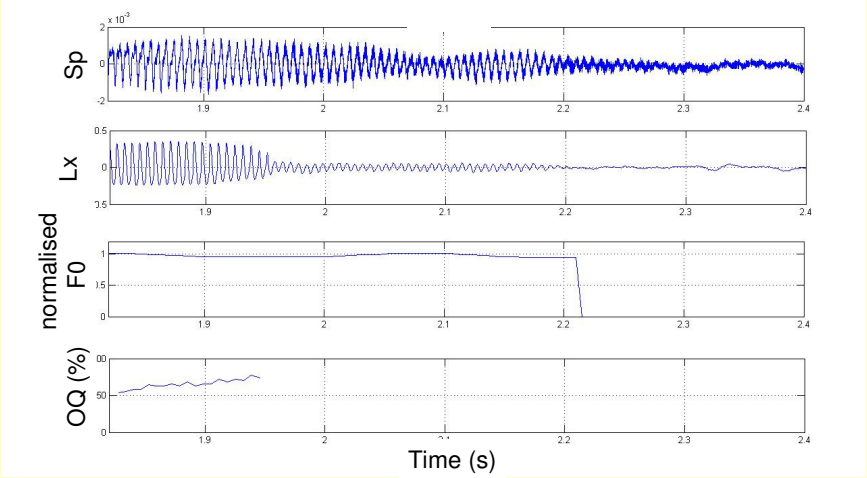
Decrease Psub



Increase Psup



Abduct Vocal Folds



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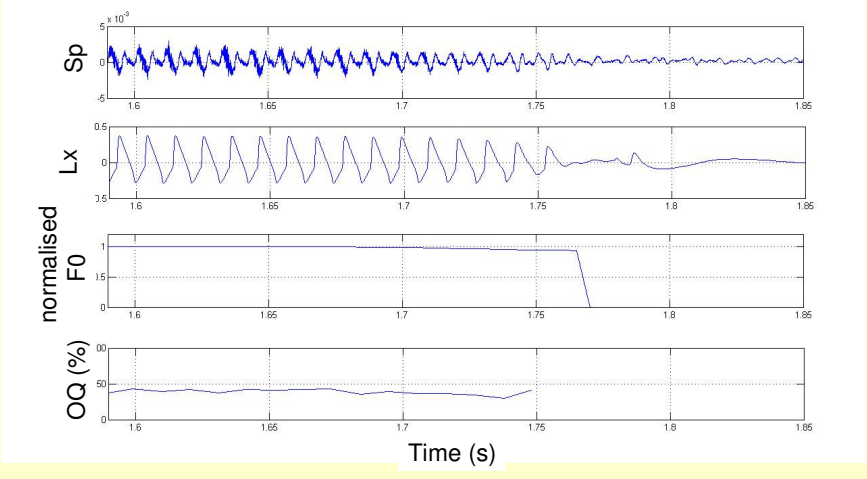

Comparison

SS	F0	OQ
Psub	Increase	Flat
Psup	Decrease ↑	Flat
Abduction	Flat	Increase
Adduction	Decrease ↑	Decrease →
SALT		
Psub	Flat ↑	Increase →
Psup	Decrease →	Increase →↓
Abduction	Flat	Increase
Adduction	Decrease ↑	Flat

Arrows indicate corresponding behaviour in 2MM

Match to Sentence data

- Closest match of two mass model to European Portuguese voiced fricative devoicing is when the folds are relaxed.
- Closest match of controlled speech samples to European Portuguese voiced fricative devoicing is when Psup is increased.

Conclusions

- Match between 2mm and controlled speech generally not good. Difficult to be certain subjects make the required articulation in isolation from other compensatory manoeuvres
- Maybe different people do different things to achieve same result
- Different mechanisms likely to be used for different phonological outcomes
- EP devoicing for fricatives may be due to a combination of relaxing the folds and increasing Psup by decreasing constriction size

- Future work – UVFP patients and more data for normal subjects