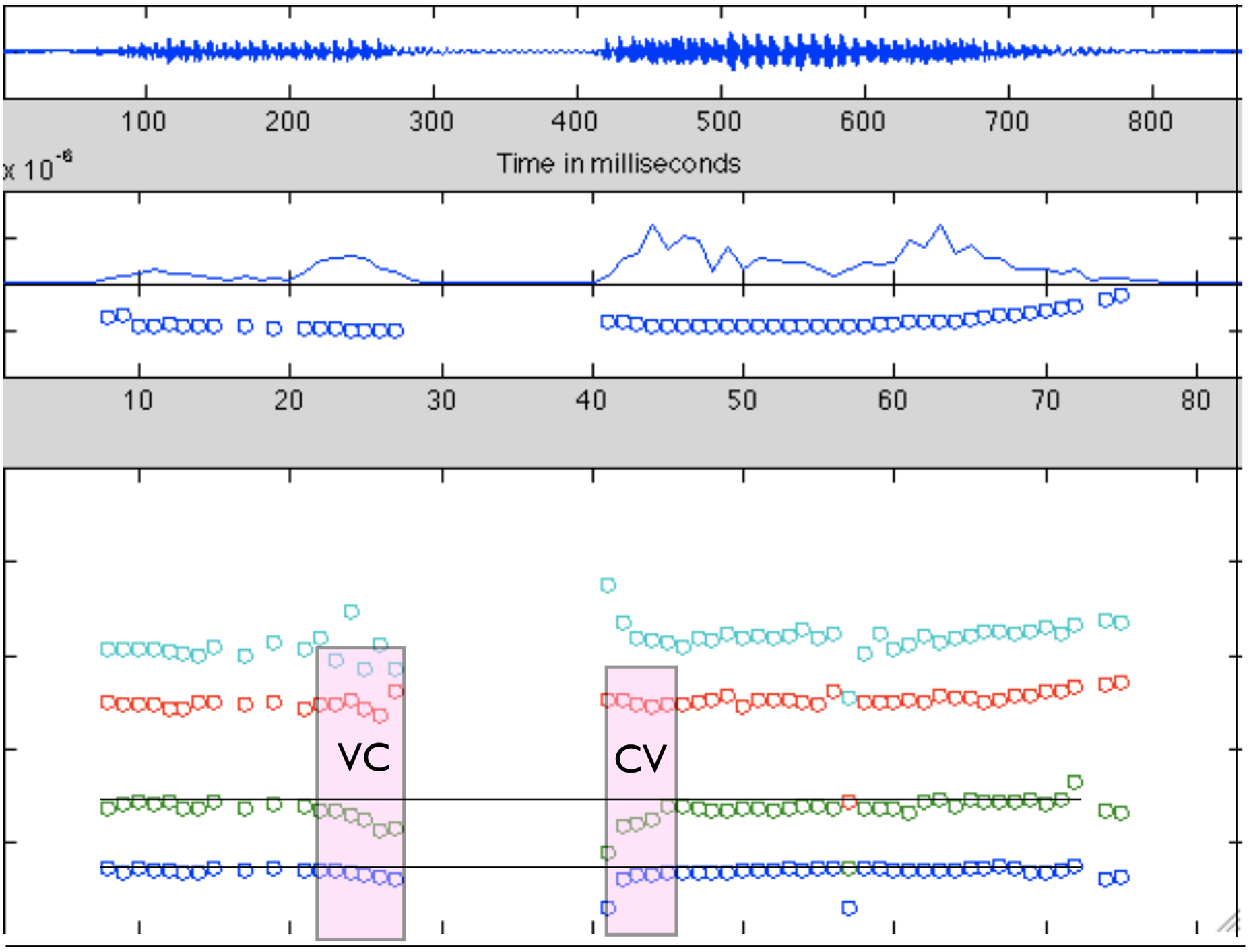
Stop Consonant Formant Transitions

Stop consonant F transitions

- When constriction is formed, resonances change.
  - Effect on formant frequencies can be understood, in part, from perturbation theory.
- In VCV, we see formant transitions (resonance changes) from V to C, then from C to V.
- If the consonant is a stop, there is silence during closure.

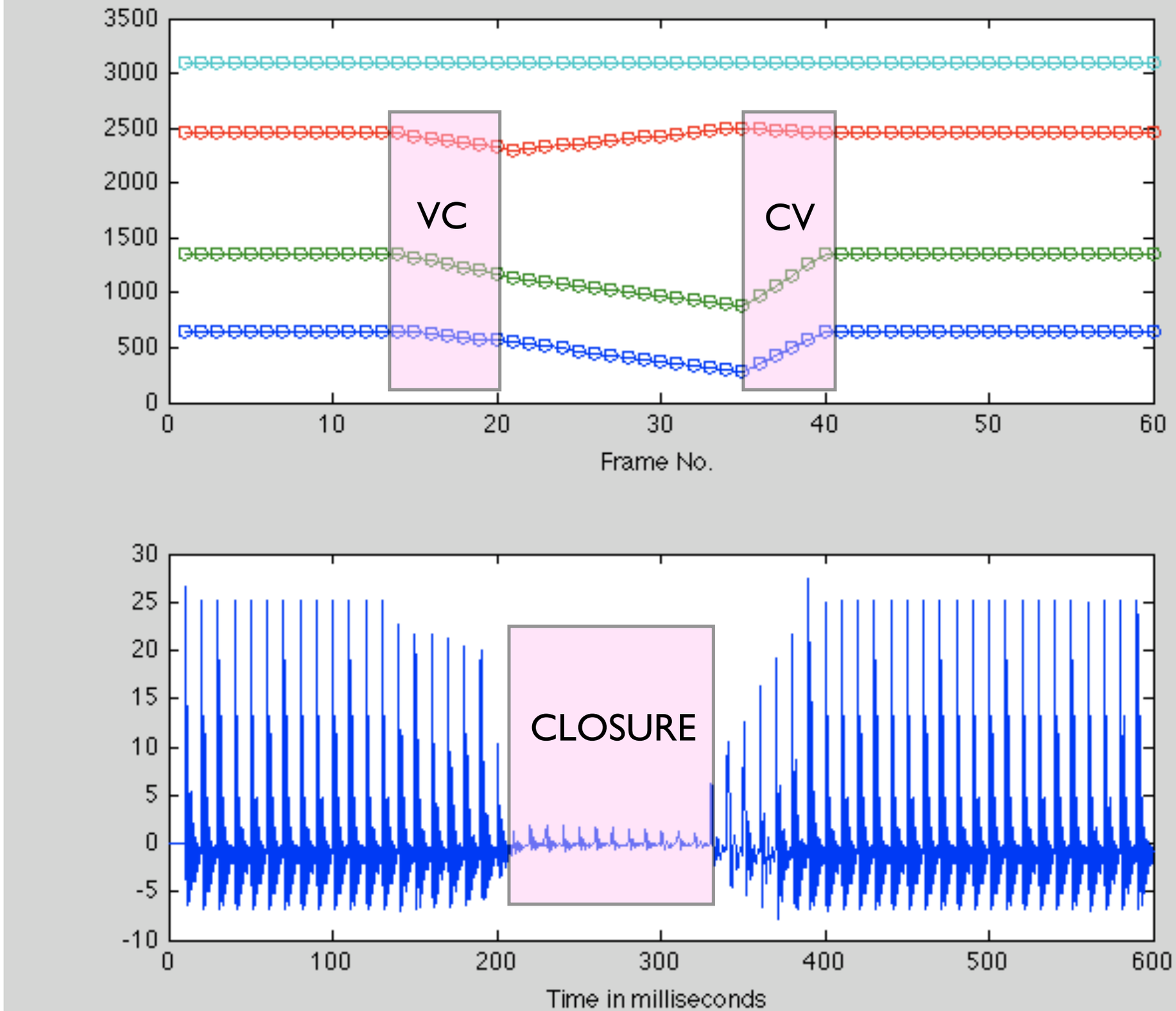
aba


100
200
300
400
500
600
700
800
x 10^-6
Time in milliseconds
10
20
30
40
50
60
70
80
VC
CV

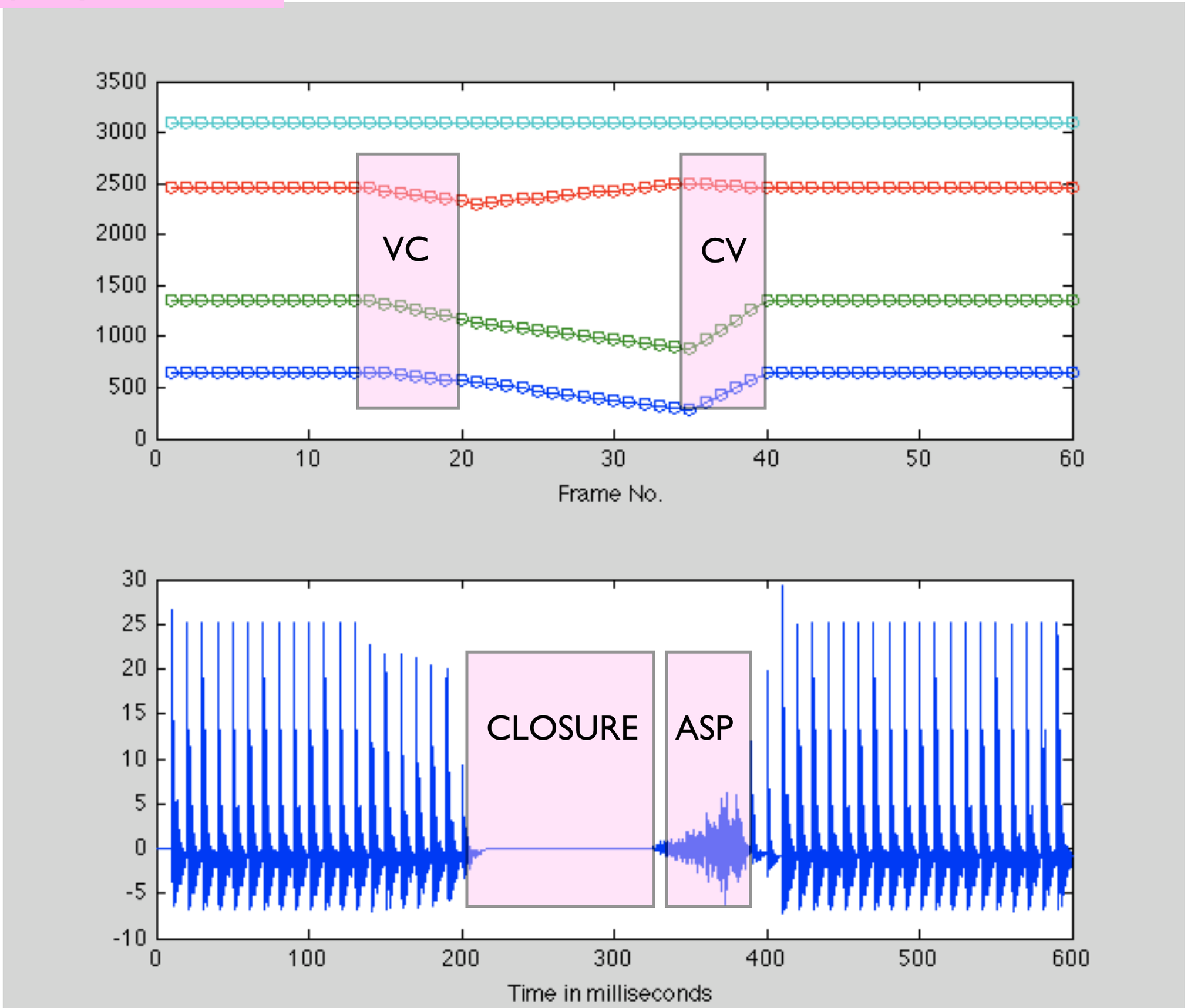
VC vs. CV

- CV transition
  - will also have release burst due to pressure buildup
  - aspirated stops will have voicelessness during CV transition

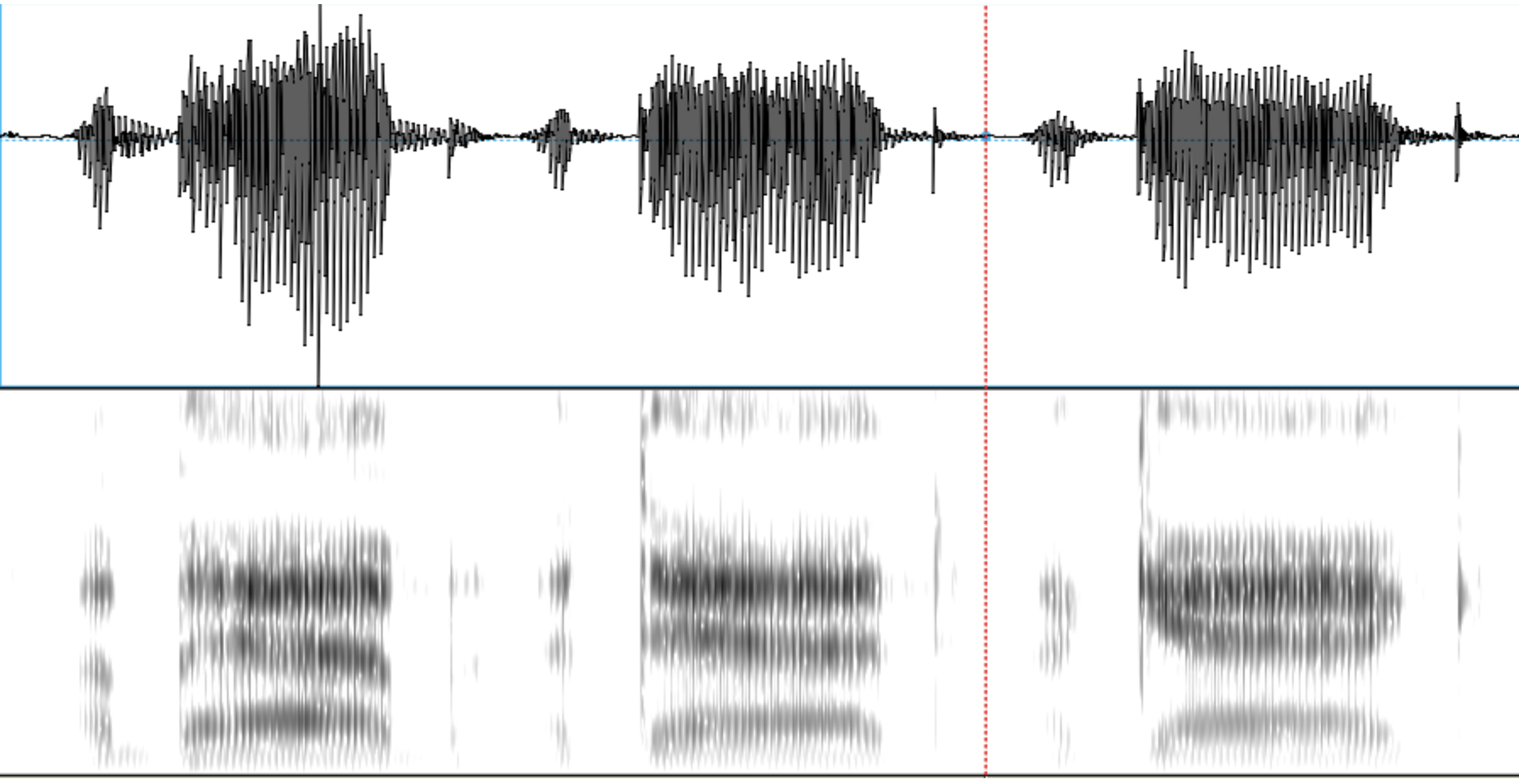
aba synthesized



apa synthesized



Place and F transitions



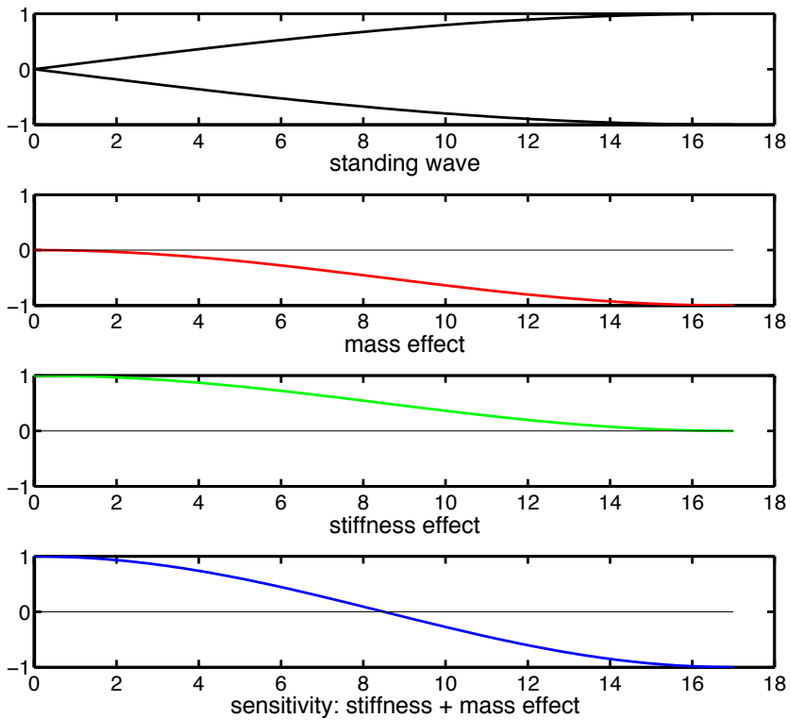
“a bab"

“a dad"

“a gag"

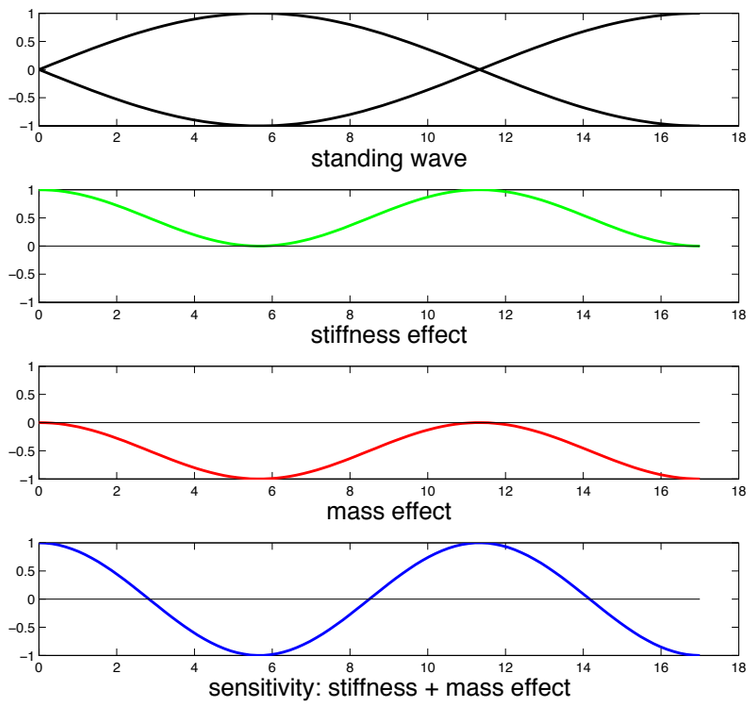
Sensitivity Functions

F1



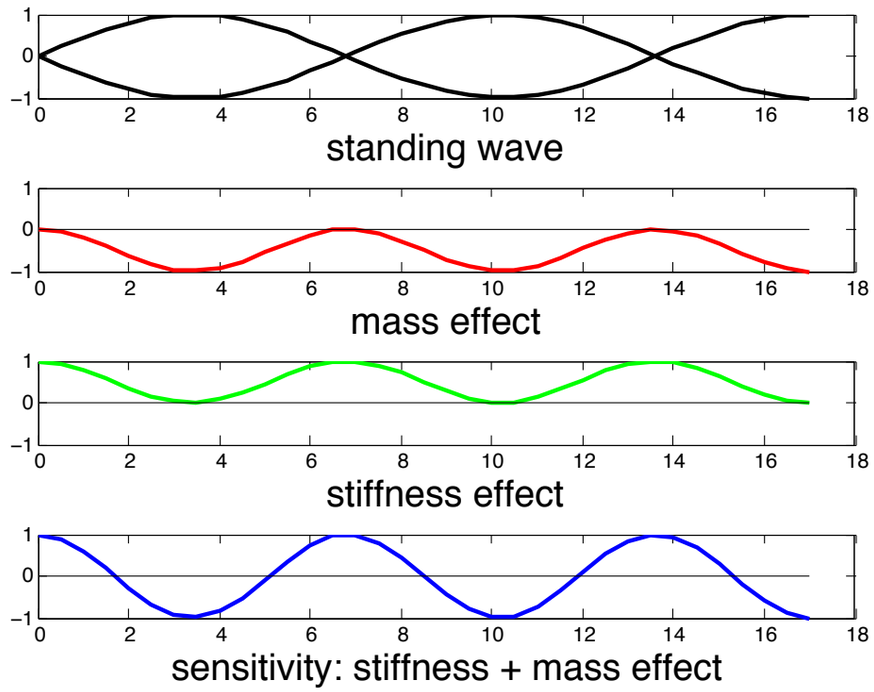
glottis lips

F2



glottis lips

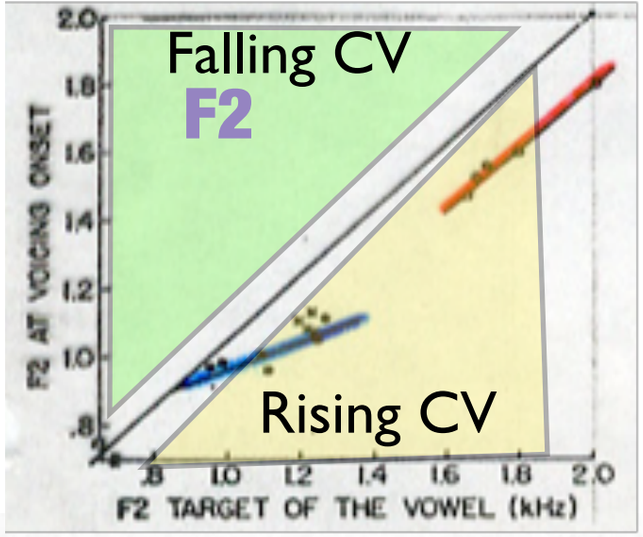
F3

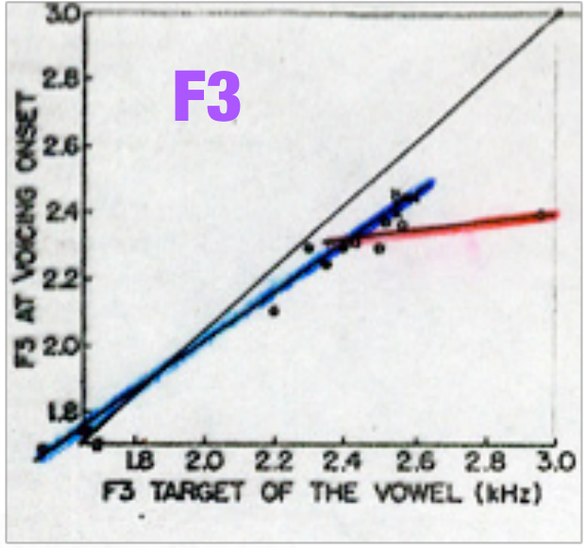


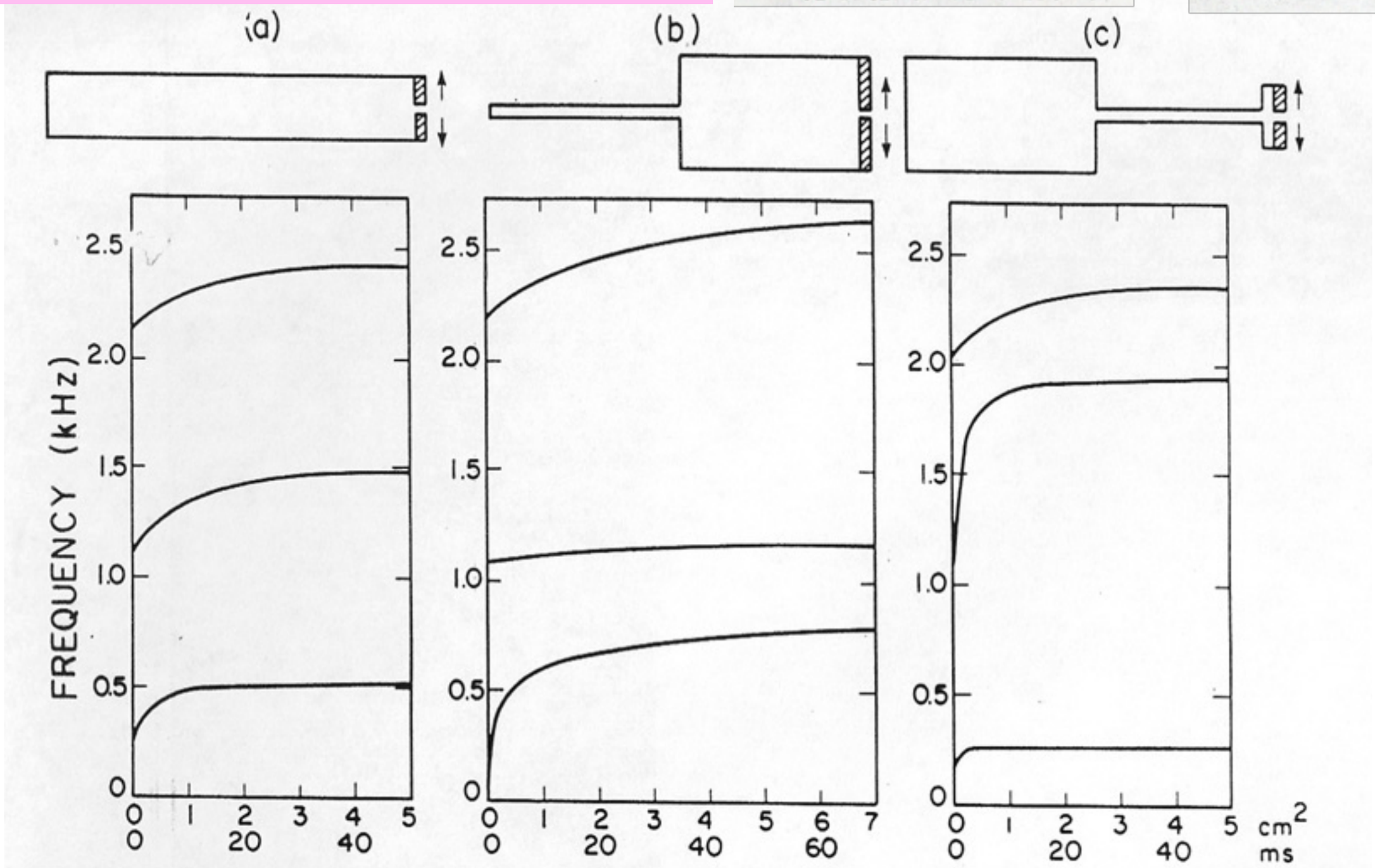
glottis lips

Labial Stops

- Constriction at lips lowers all F (sensitivity functions)
- Effect greater for front cavity resonance?



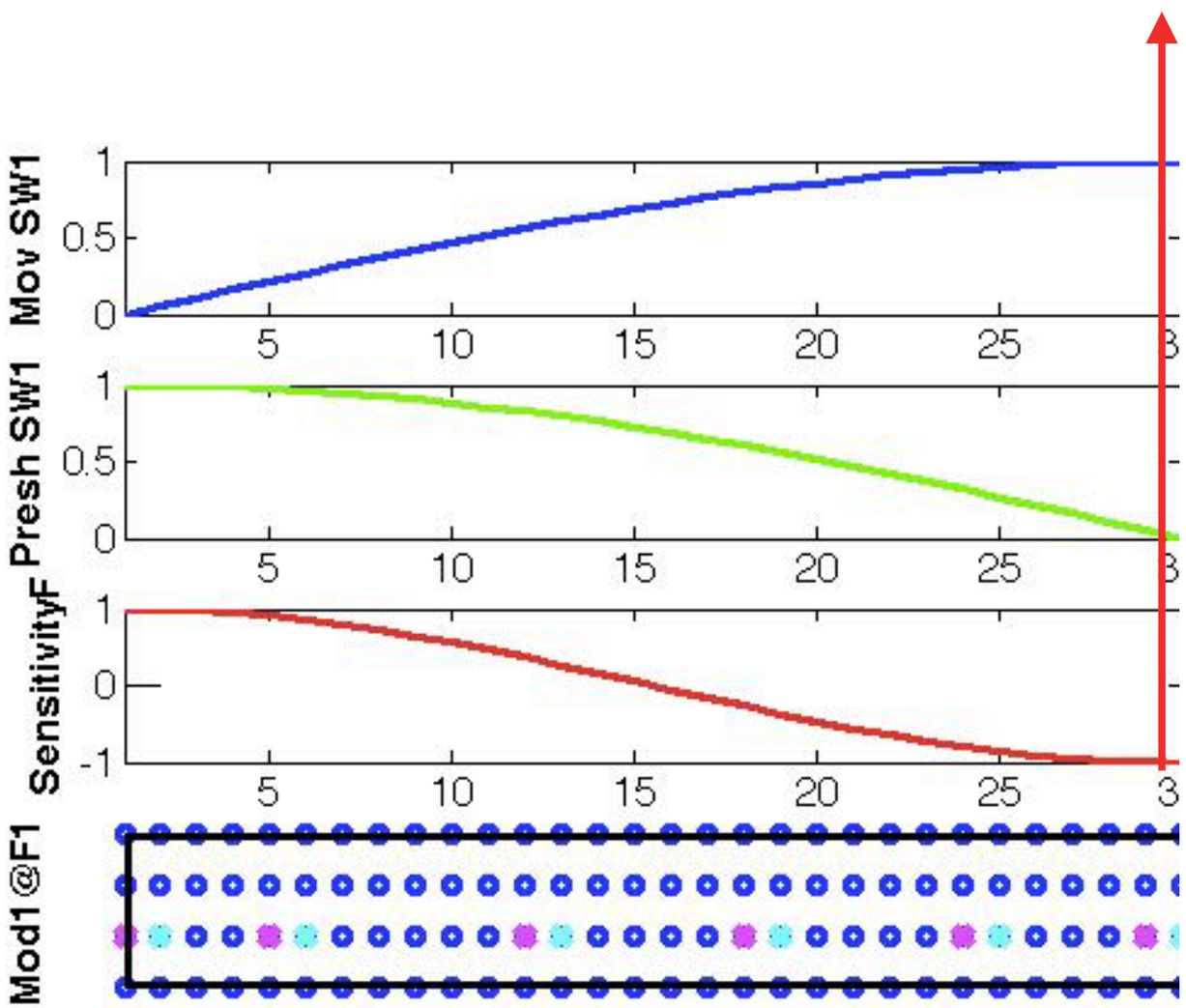




Labial constrictions

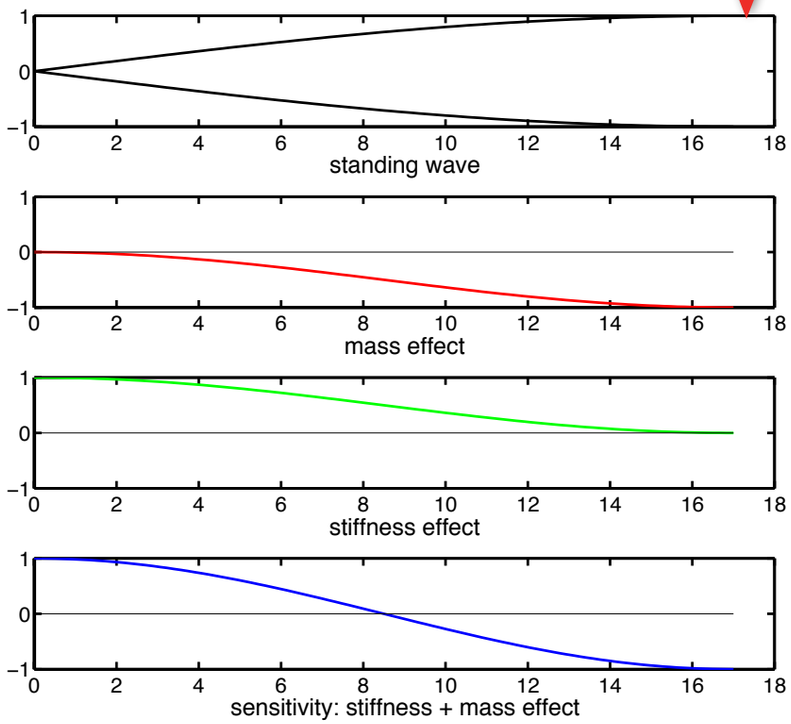
F1

F2



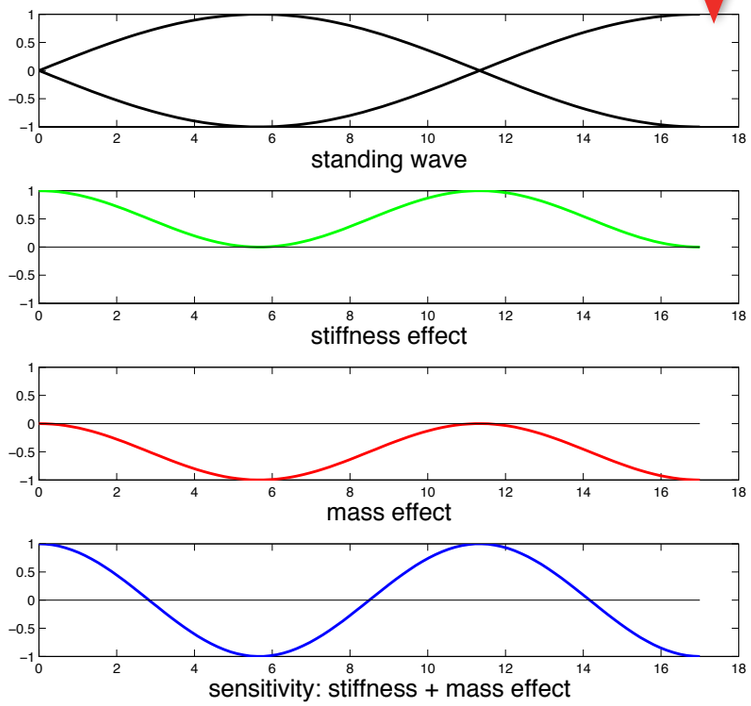
Sensitivity Functions Labial

F1



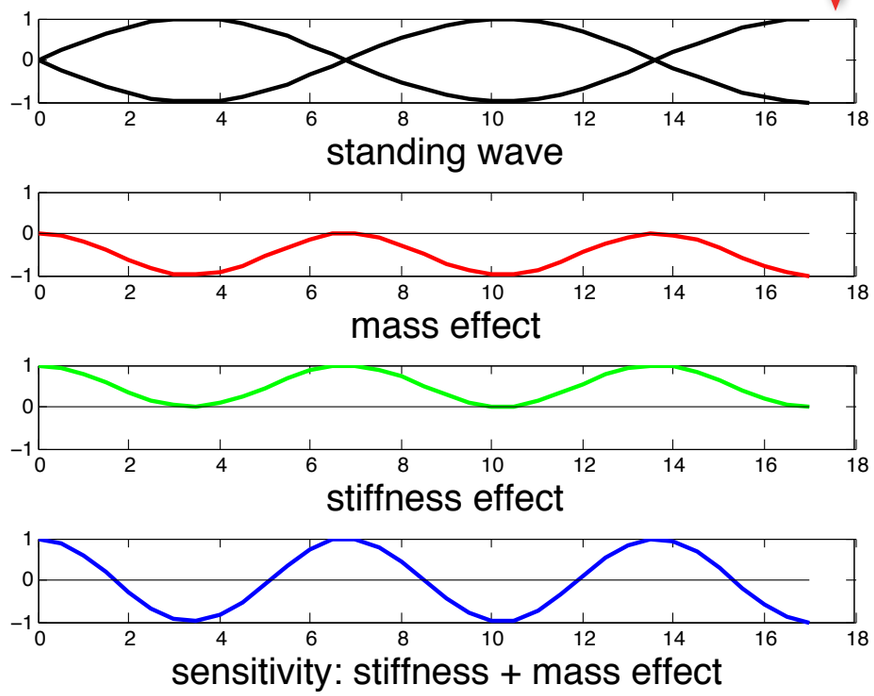
glottis lips

F2



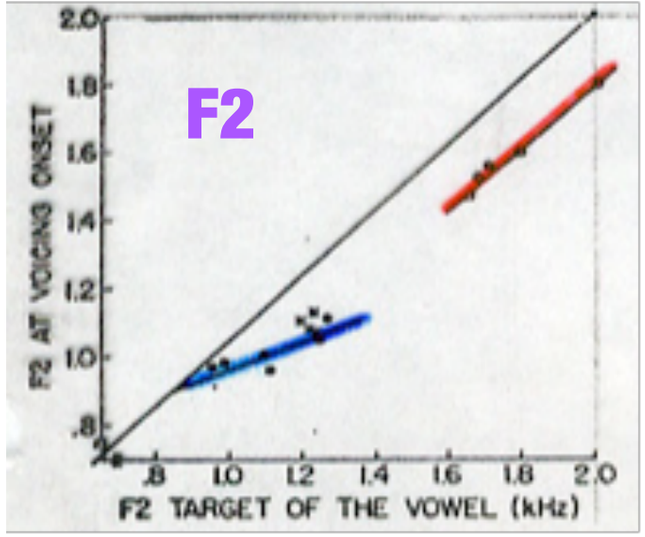
glottis lips

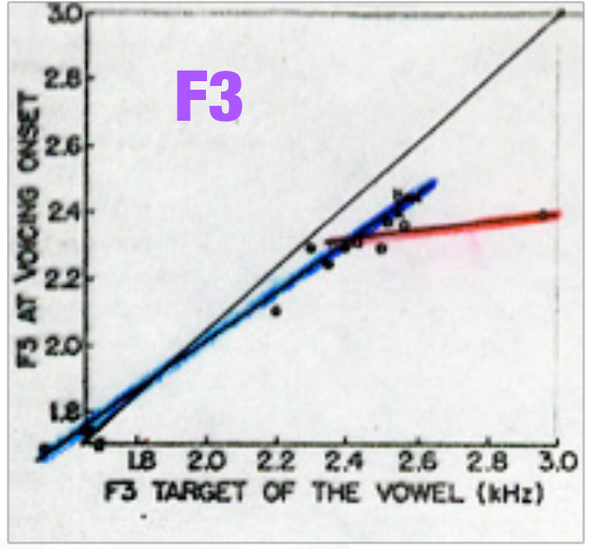
F3

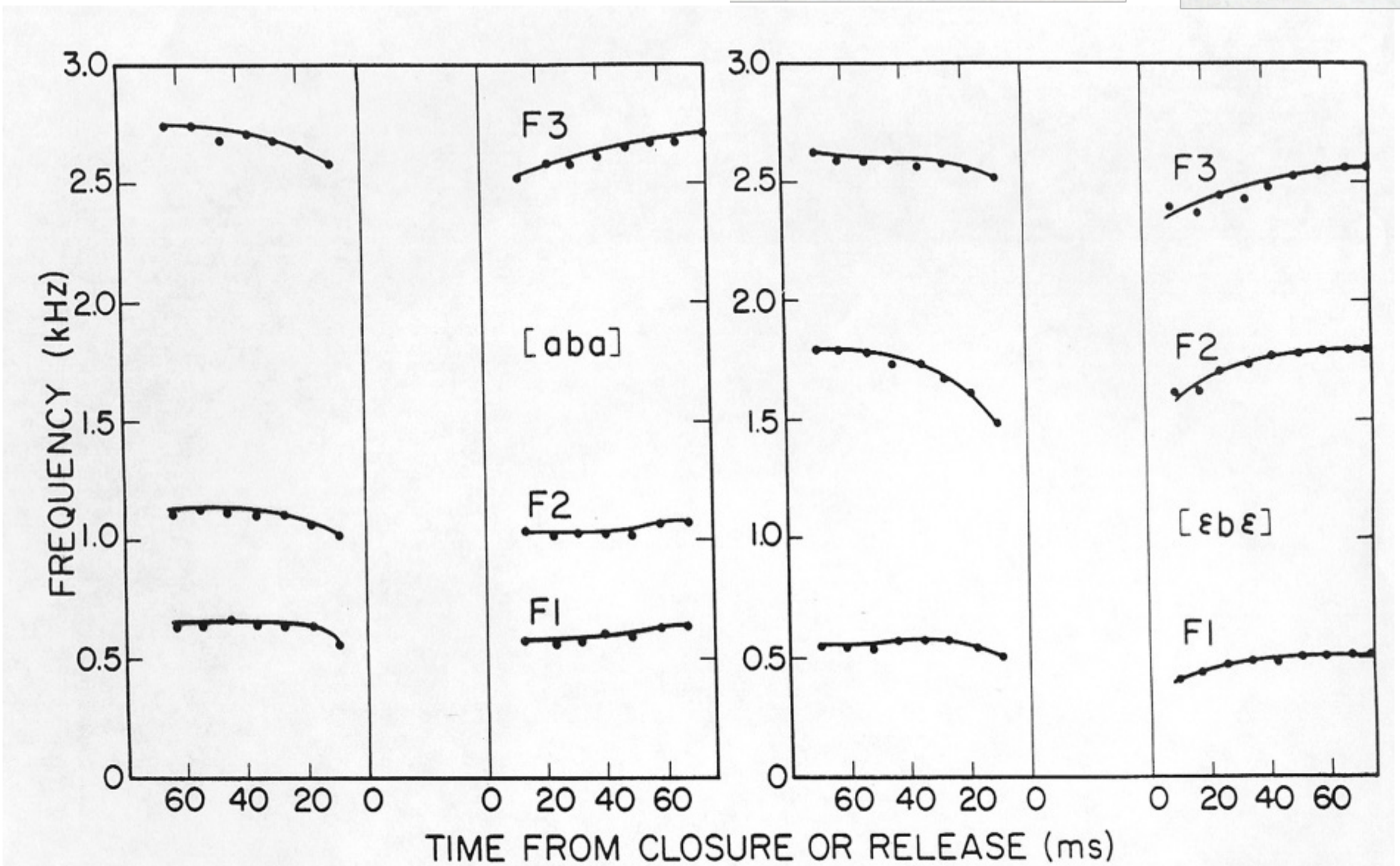


glottis lips

Labial Stops

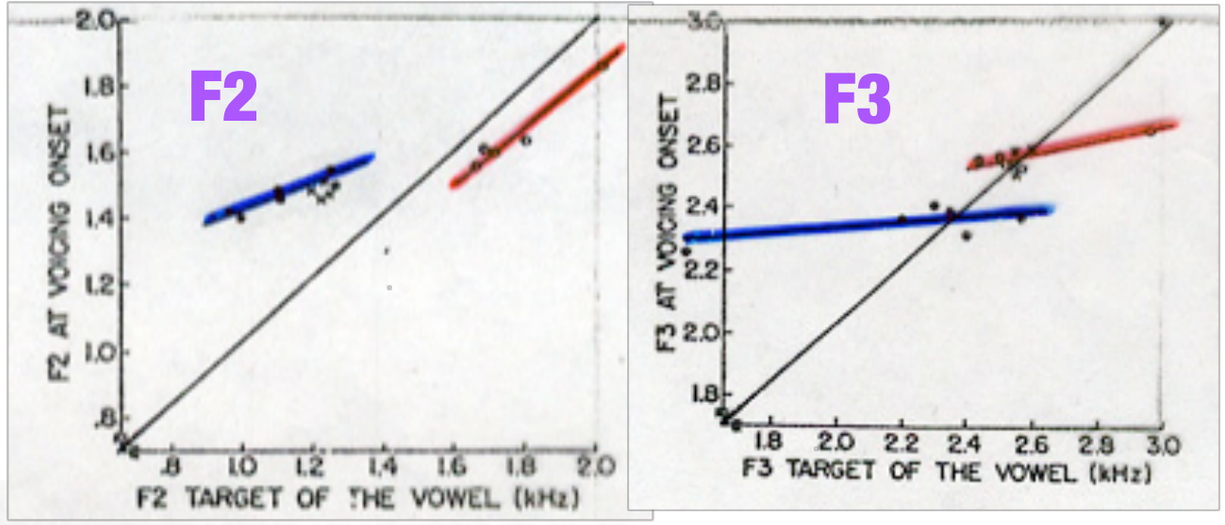


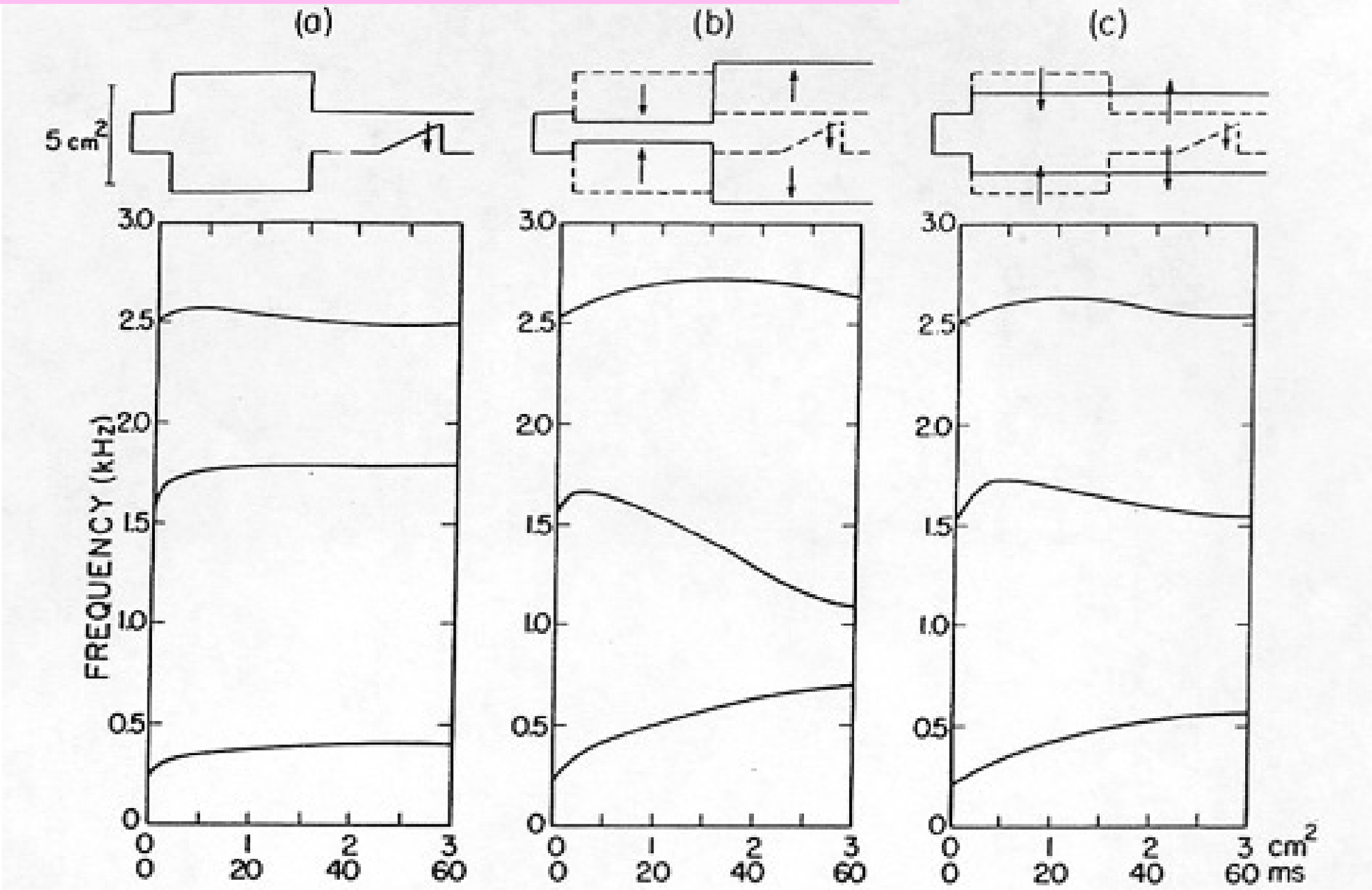




Coronal Stops

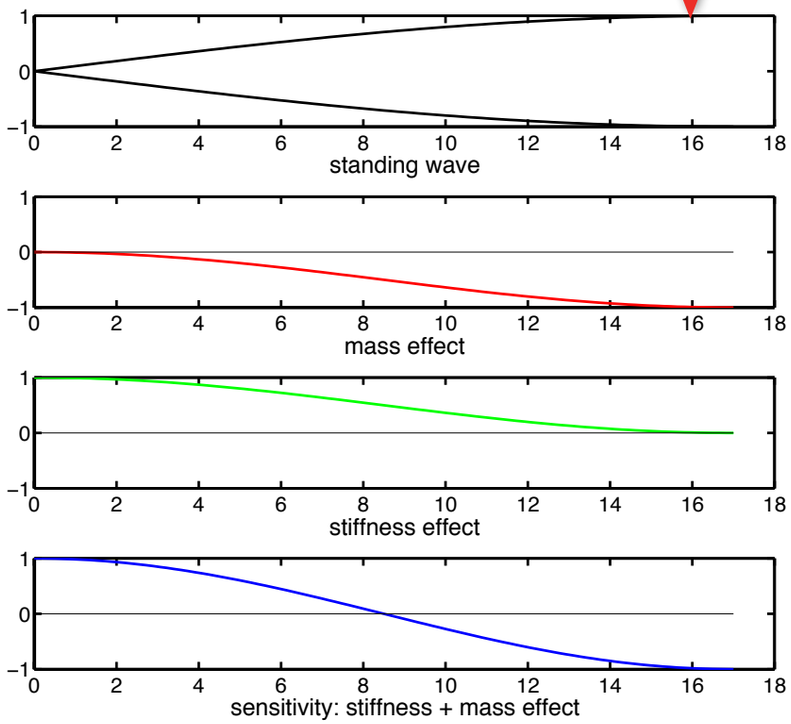
- Location not that different from labials, so sensitivity considerations are similar.
- BUT Entire tongue body must be advanced,
- Overall shape of tube similar to front V





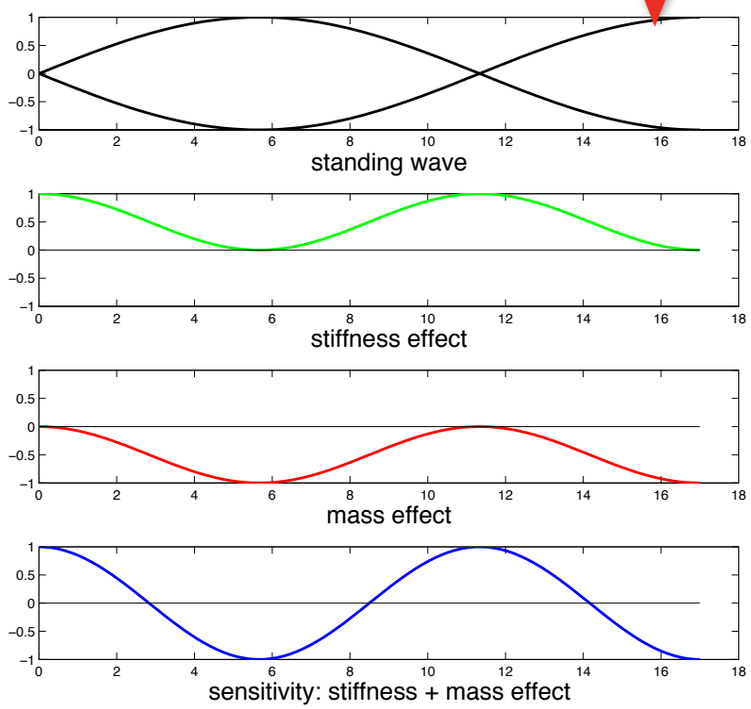
Sensitivity Functions Coronal

F1



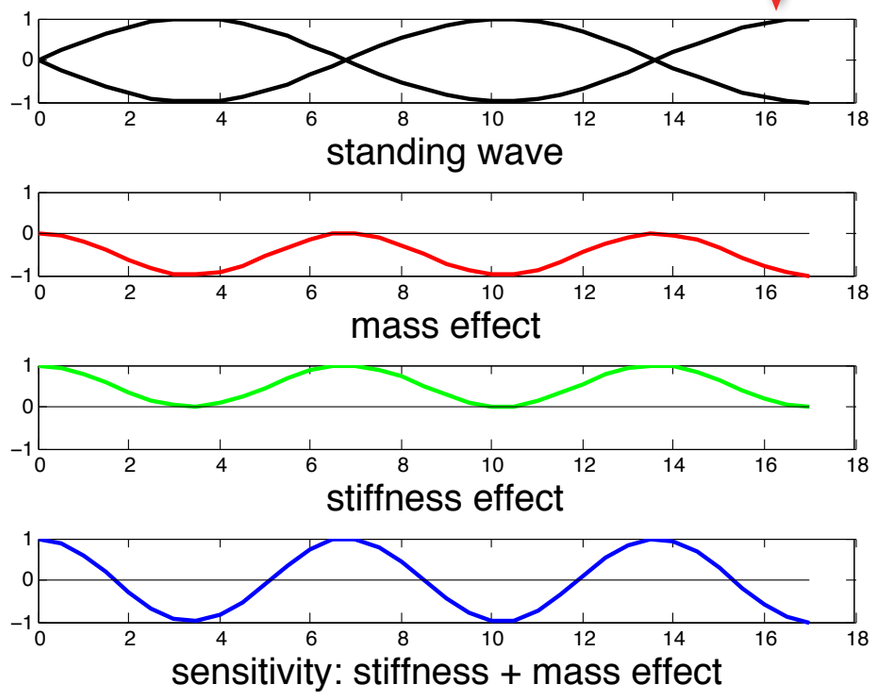
glottis lips

F2



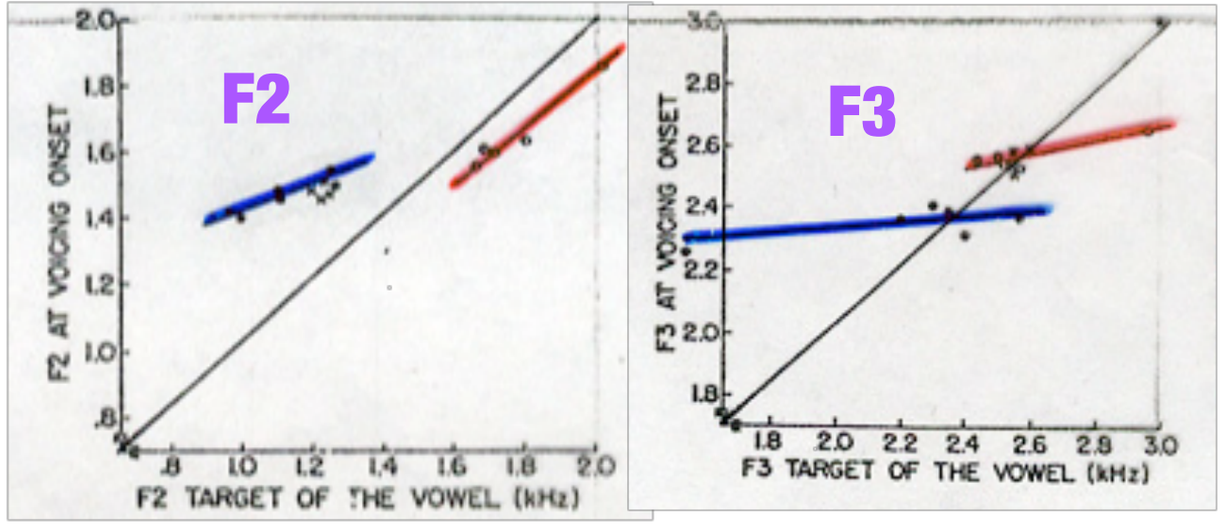
glottis lips

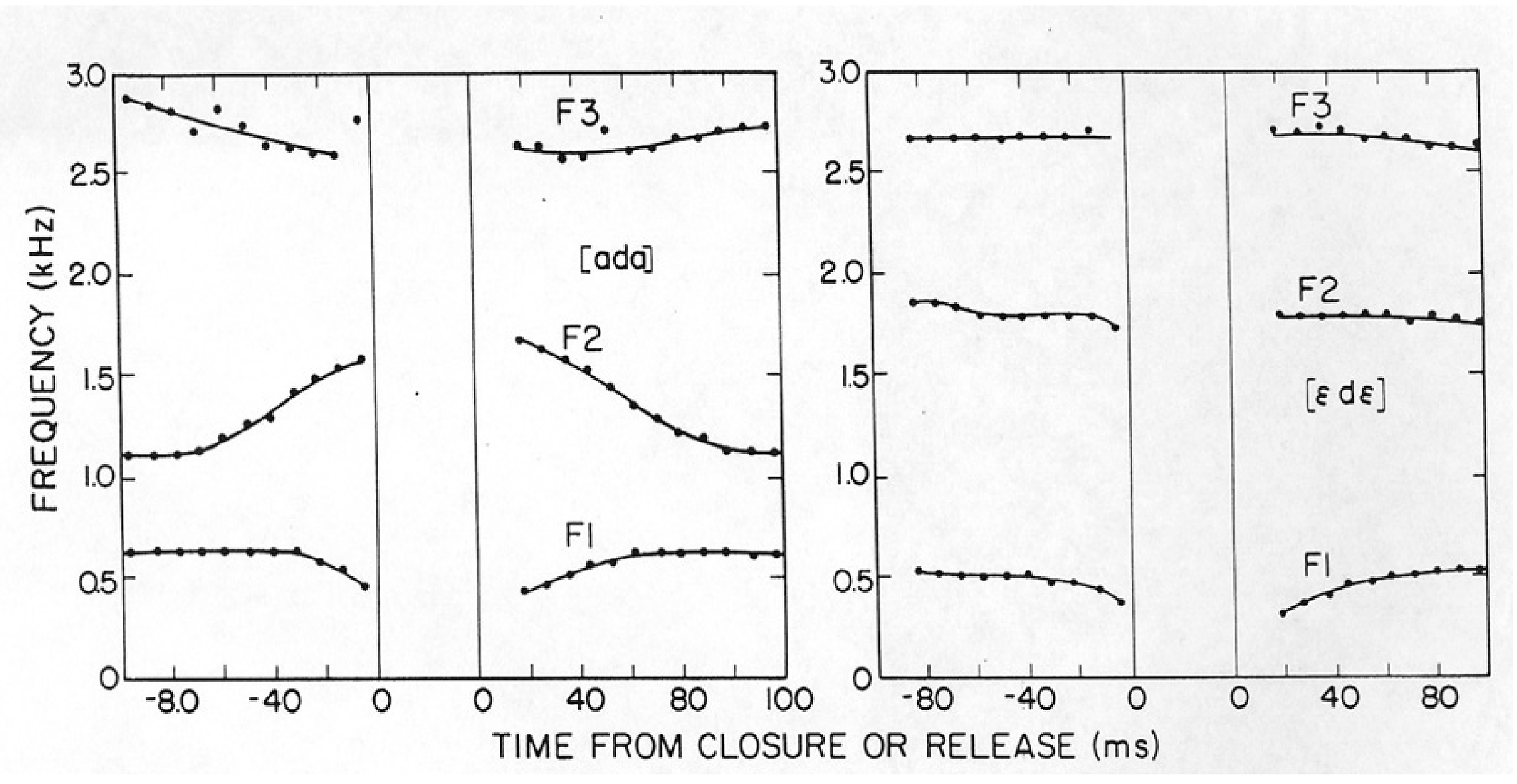
F3

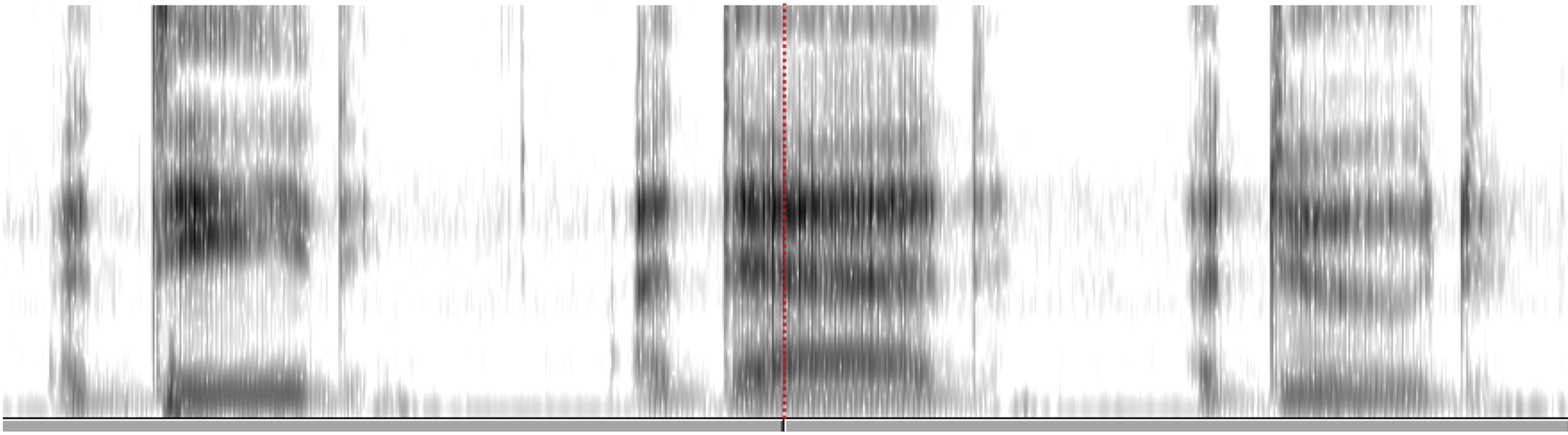


glottis lips

Coronal Stops







“a deed"

“a dad"

“a dude"

Tongue Body fronting for /d/

- TBx must be advanced for /d/.
- TB is part of synergy for coronal constriction

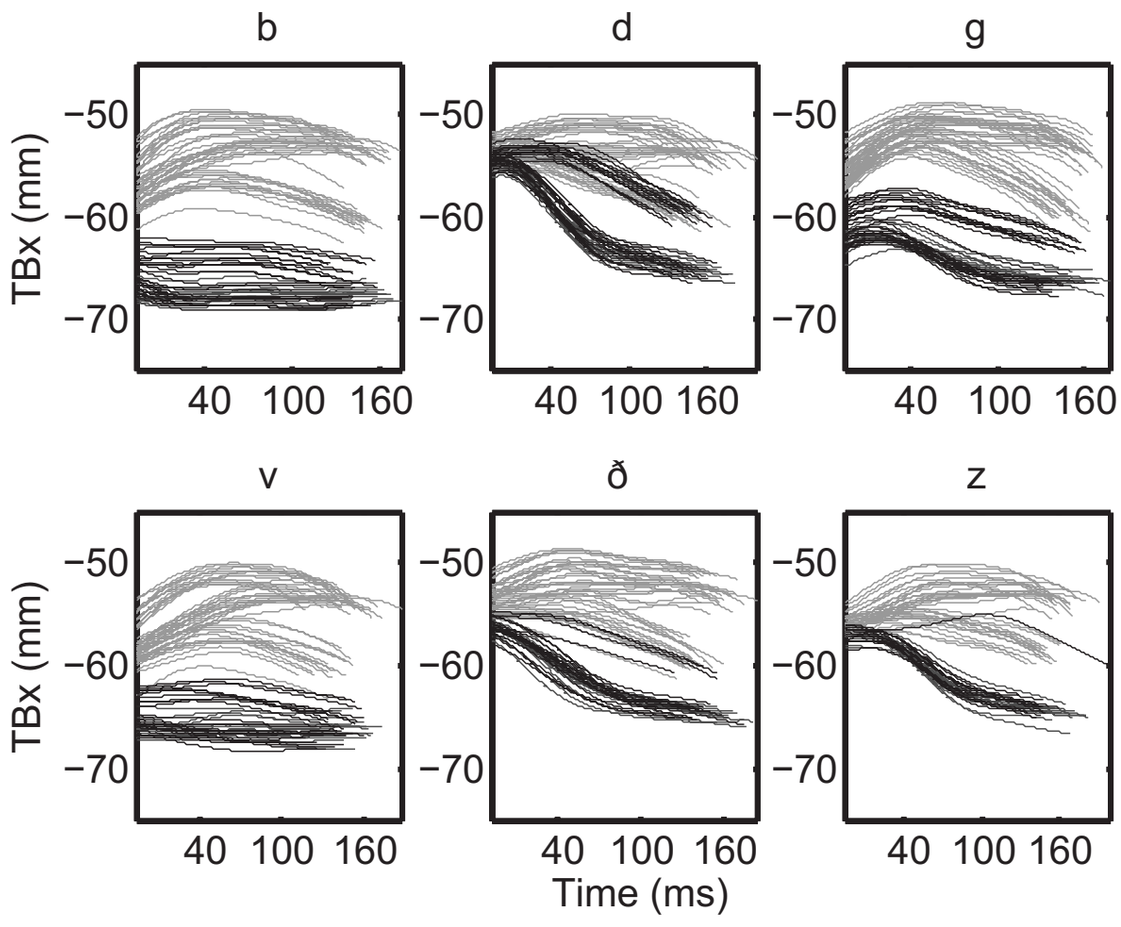


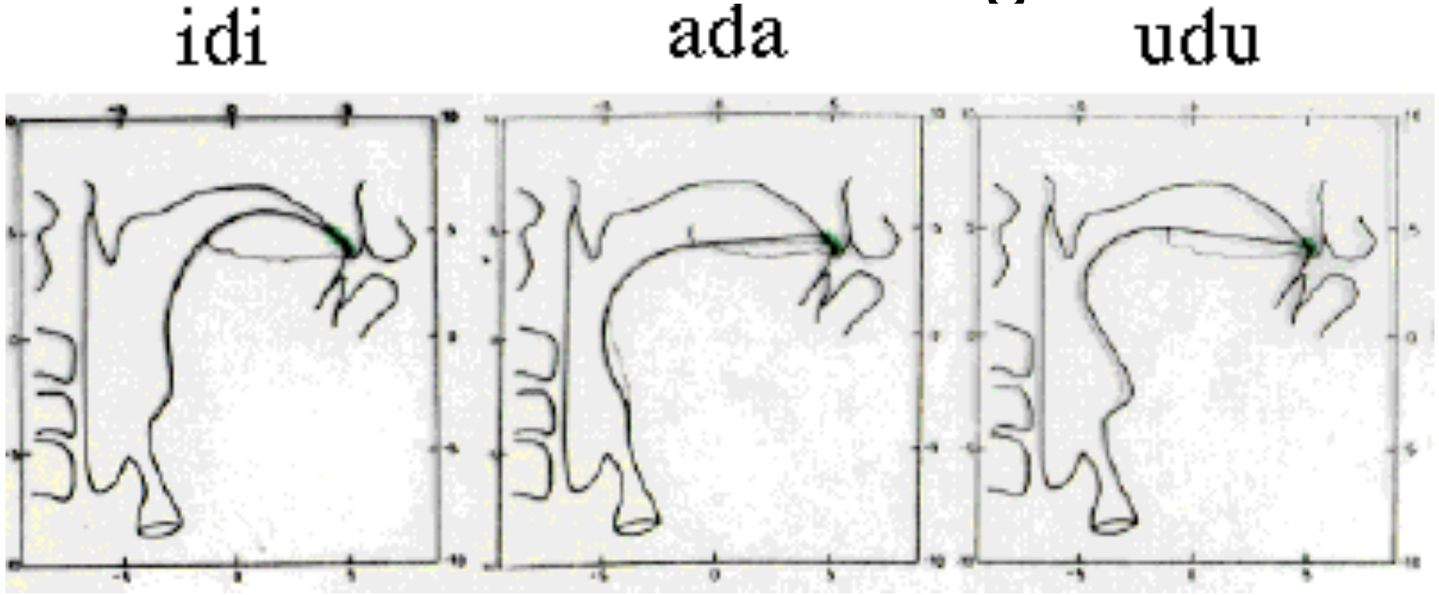
FIG. 4. Trajectories of TBx for consonants from EMMA data: For all consonants, the first articulatory sample in the time series corresponds to the acoustic frame in which the formant transition for the consonant begins. Trajectories in black are for the back vowel context, and trajectories in gray are for front vowel context. Frontness increases vertically.

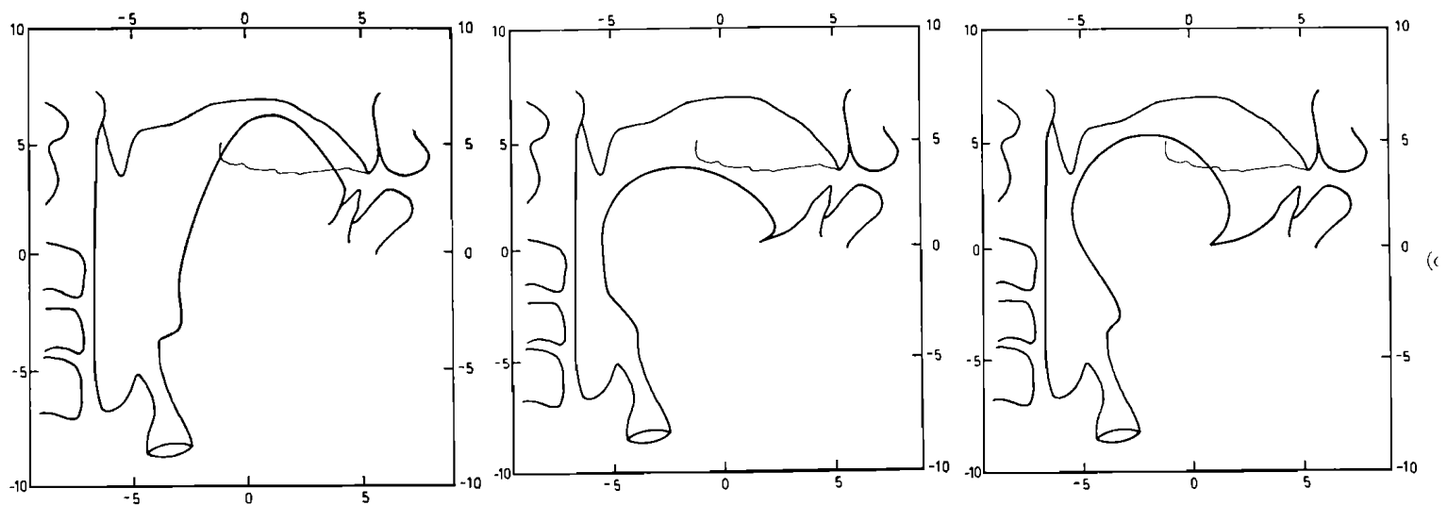
f

Coproduction during /d/

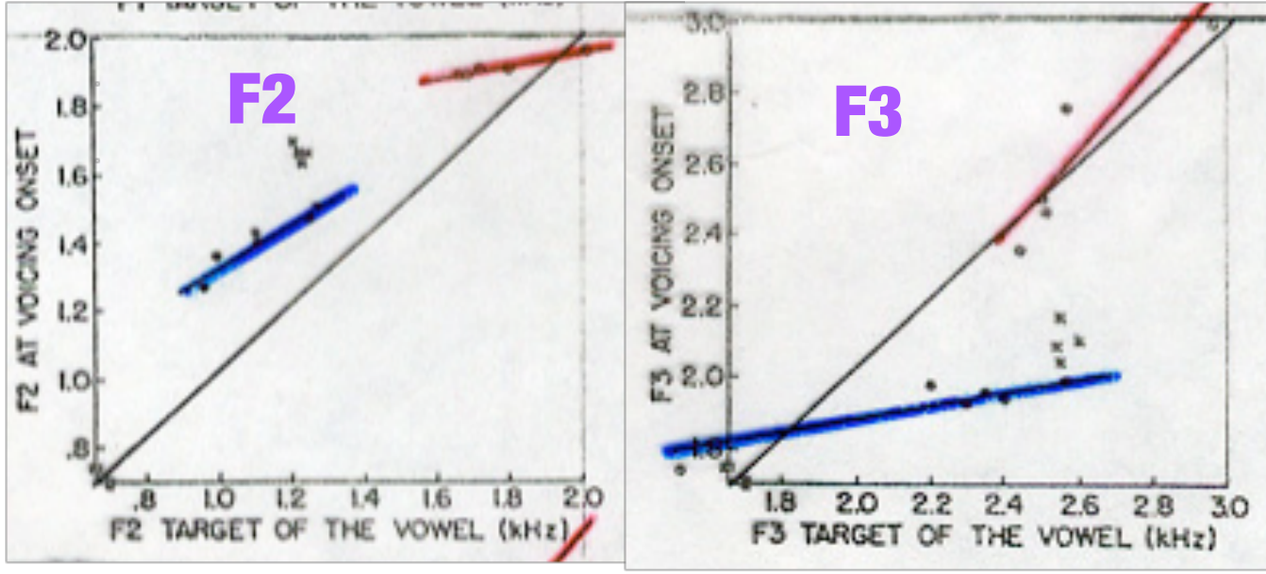
- There are tongue-shape differences for /d/ in different contexts due to coproduction (which also effects the formants, particularly higher formants).

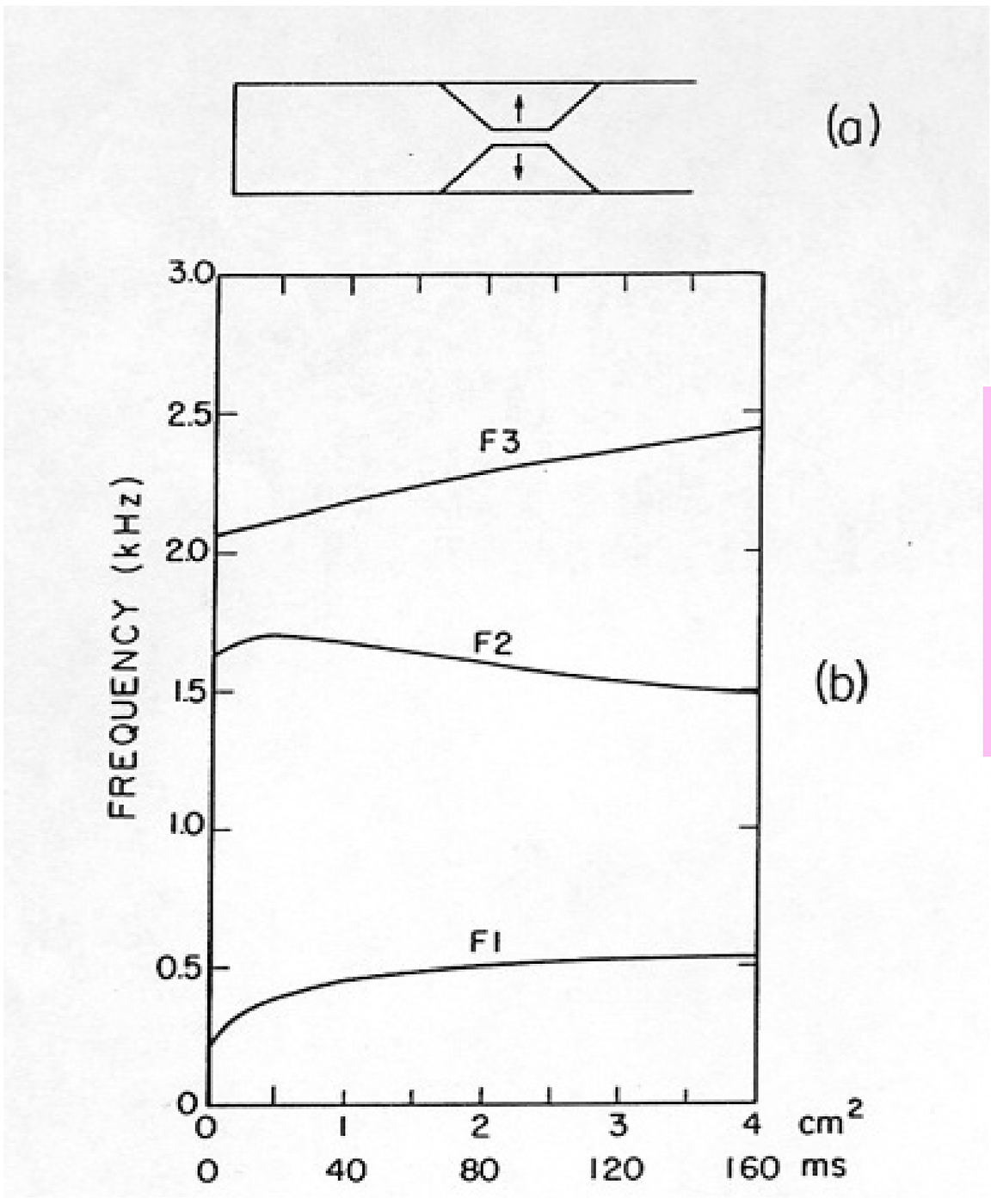
- But TB is more advanced during /d/ than during back V.





Velar Stops

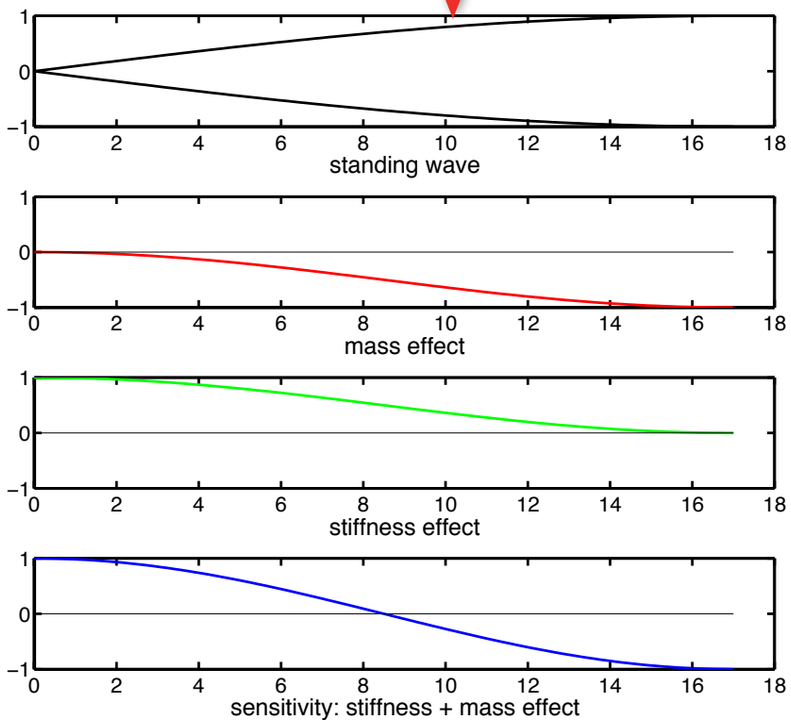




- F2 and F3 are close during constriction.

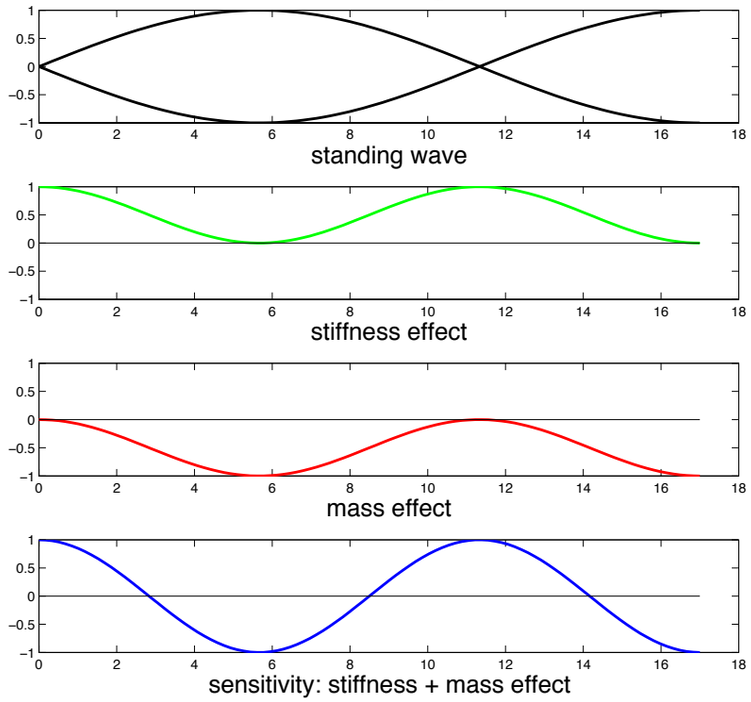
Sensitivity Functions Velar

F1



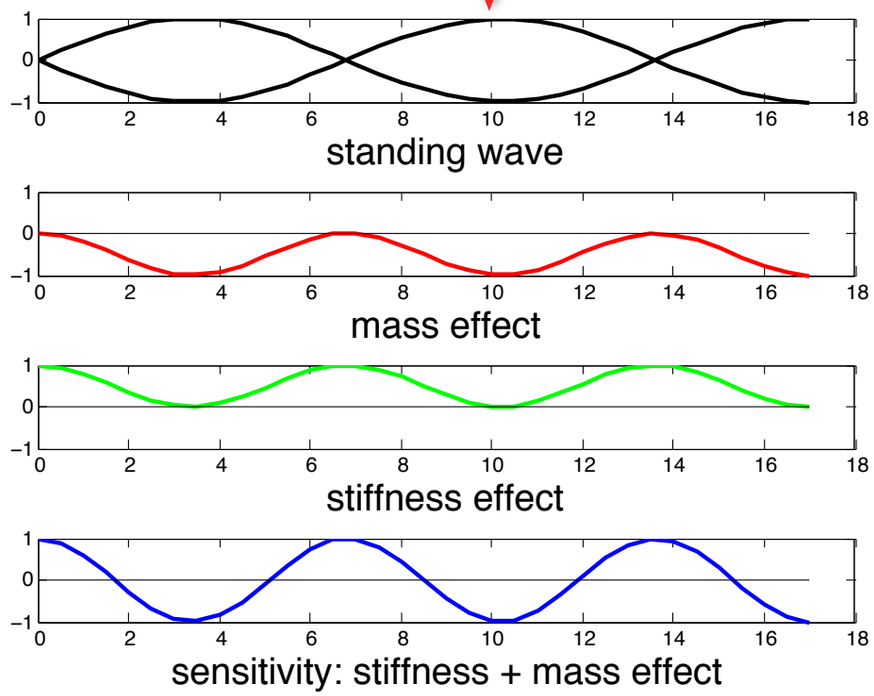
glottis lips

F2



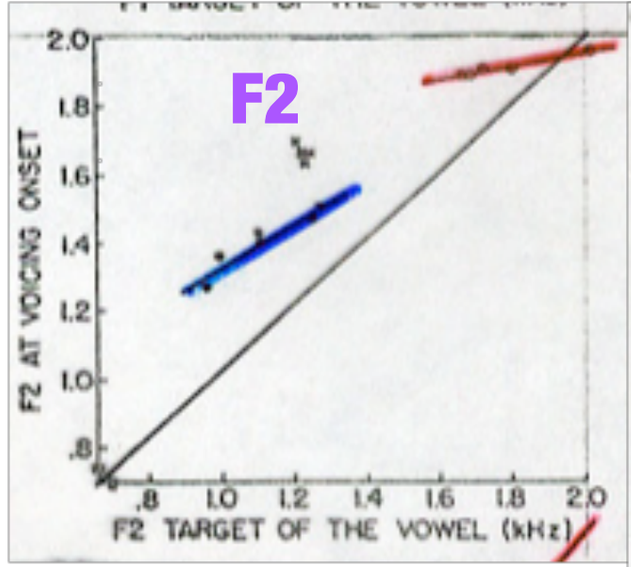
glottis lips

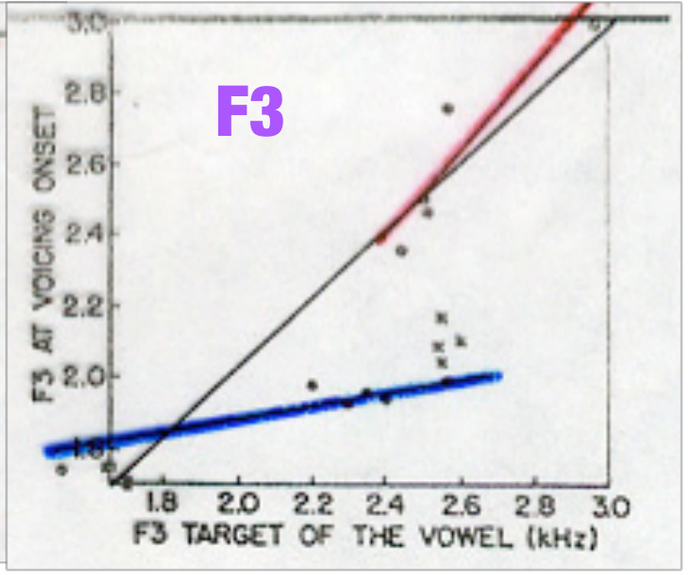
F3

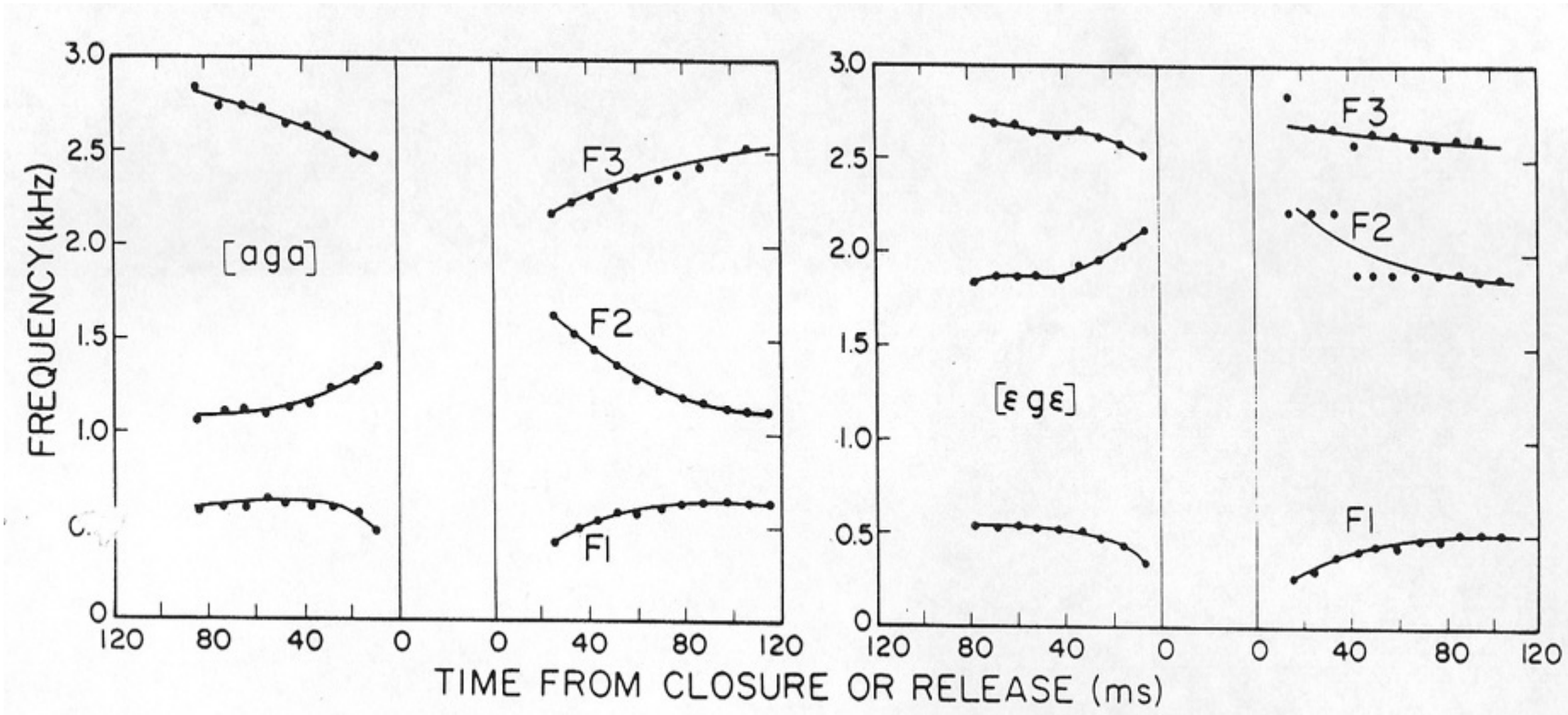


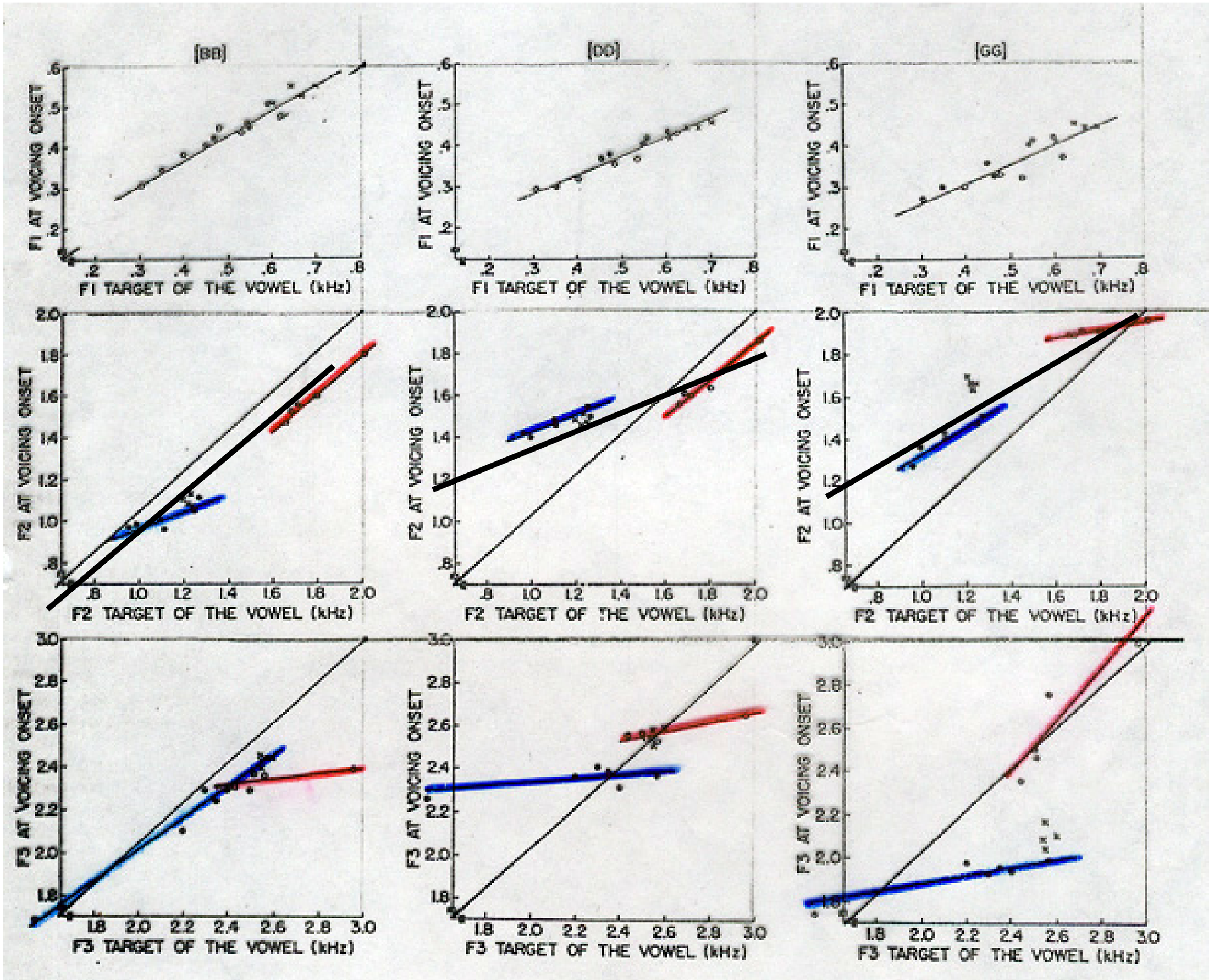
glottis lips

Velar Stops


F2
F2 AT VOICING ONSET
F2 TARGET OF THE VOWEL (kHz)
2.0
1.8
1.6
1.4
1.2
1.0
.8
.8 1.0 1.2 1.4 1.6 1.8 2.0


F3
F3 AT VOICING ONSET
F3 TARGET OF THE VOWEL (kHz)
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.8 2.0 2.2 2.4 2.6 2.8 3.0


FREQUENCY (kHz)
3.0
2.5
2.0
1.5
1.0
0.5
0
[aga]
[ɛgɛ]
F3
F2
F1
120 80 40 0 0 40 80 120
TIME FROM CLOSURE OR RELEASE (ms)


[BB]
[DD]
[GG]
F1 AT VOICING ONSET
F1 TARGET OF THE VOWEL (kHz)
F2 AT VOICING ONSET
F2 TARGET OF THE VOWEL (kHz)
F3 AT VOICING ONSET
F3 TARGET OF THE VOWEL (kHz)

Locus Equations for F2

- Place of articulation for stops can be distinguished by the slopes and intercepts of the regression equation between
  - F2 at vowel center
  - F2 at the onset of the CV transition.
    - SLOPES: Labial > Dorsal > Coronal
    - INTERCEPTS: Labial < Dorsal < Coronal

Sussman, H. M., McCaffrey, H. A., and Mathews, S. A. (**1991**). "An investigation of locus equations as a source of relational invariance for stop place categorization," J. Acoust. Soc. Am. **90**, 1309–1325.

Locus equations are an acoustic expression of articulator synergy

Khalil Iskarous,[a)] Carol A. Fowler, and D. H. Whalen

- F2 is influenced by horizontal position of TB.
- slope (b) of regression equation is mathematically equivalent to:

$$b = \rho \frac{\sigma_{F2C}}{\sigma_{F2V}}$$

- ρ = correlation coefficient
- σ_{F2C} = variance of F2 at transition onset
- σ_{F2V} = variance of F2 at vowel center
- $\sigma_{F2C}/\sigma_{F2V}$ = measure of coarticulation resistance (Recasens)

TB Coarticulation Resistance

- If TB coarticulation is the source of the Locus Equations, measurement of TBx at the two points should show the same regression equation characteristics.

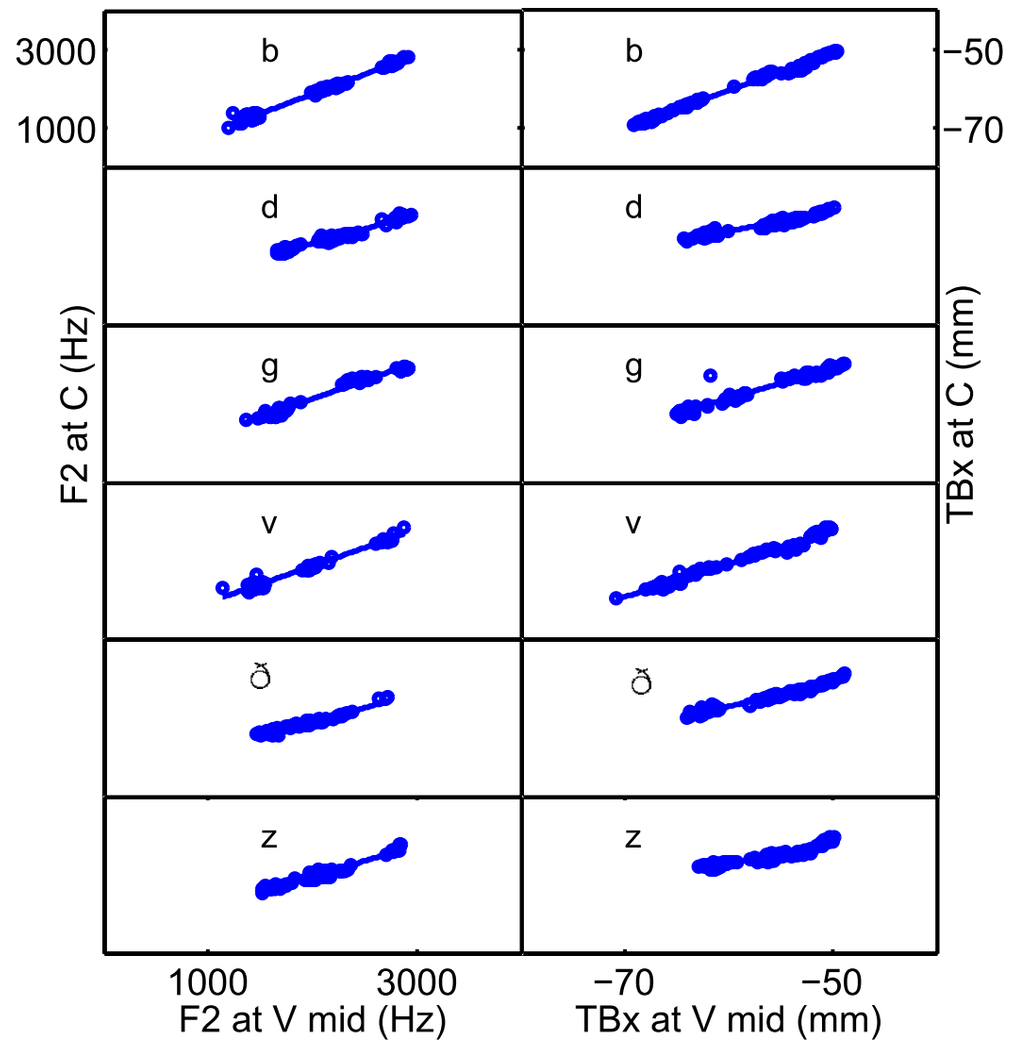


FIG. 1. (Color online) Linear functions relating the horizontal position of the tongue back (TBx) at the consonant release (dependent variable) to TBx at the middle of the vowel (right) and F2 at the consonant release to F2 at the middle of the vowel (left) for each of the consonants examines. Each line fits 90 tokens from six vowels for the EMMA subject.

Results

TABLE II. Linear parameters for EMMA data.

	F2			TBx		
Segment	Slope	Intercept	r^2	Slope	Intercept	r^2
b	1.004	−141.86	0.9886	0.954	−3.225	0.993
d	0.738	583.883	0.9645	0.491	−26.74	0.948
g	0.934	251.699	0.9778	0.767	−12.571	0.960
v	0.931	1.203	0.9737	0.842	−10.226	0.980
ð	0.689	525.369	0.9502	0.615	−20.220	0.966
z	0.799	354.96	0.9575	0.503	−26.938	0.881
Correlations:		Slope, 0.873			Intercept, −0.892	

Synergy Analysis of Locus

- Labials: TBx does not contribute to constriction
- Velars: TBx contributes to constriction for front, but not back velars
- Coronals: TBx contributes substantially to constriction.