



# THE 17TH INTERNATIONAL CONGRESS OF PHONETIC SCIENCES

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The 17th International Congress of Phonetic Sciences (ICPhS XVII)

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## Plenary lecture

### **On the acoustic and perceptual characterization of reference vowels in a cross-language perspective**

Due to the difficulty of a clear specification in the articulatory or the acoustic space, the same International Phonetic Alphabet (IPA) symbol is often used to transcribe phonetically different vowels across different languages. On the basis of the acoustic theory of speech production (Fant, 1960, Stevens, 1998), this paper aims to propose a set of focal vowels characterized by an almost complete merging of two adjacent formants: F1 and F2, F2 and F3, and F3 and F4 (sometimes F4 and F5 for some speakers). These reference vowels constitute a subset of Jones's Cardinal Vowels (CVs); they are the only vowels that can be called "quantal" in Stevens's sense. The concerned vowels are Cardinal C1 described as prepalatal ( $\uparrow F_3 F_4$ )<sup>3200Hz</sup>, Cardinal C5 [a]:  $\uparrow(F_1 F_2)$ <sup>1000Hz</sup>, Cardinal C8 [u]: ( $\downarrow F_1 \downarrow F_2$ )<sup>400Hz</sup>, Cardinal C6 and Cardinal C7 at mid-distance between C5 and C8, Cardinal C9 [y] = ( $\underline{F_2 F_3}$ )<sup>1900Hz</sup> and the non cardinal vowel Mid vowel [æ] = ( $F_2 \downarrow F_3$ )<sup>1500Hz</sup>. Formant merging creates a vowel-specific sharp concentration of spectral energy in a narrow region of the frequency scale. This acoustic result results from very specific articulatory configurations and entails special perceptual characteristics. This proposal draws on various models of the vowel space: Quantal Theory, Dispersion theory and Dispersion-Focalization Theory.

- The eight page paper corresponding to this conference is published on the web by the organizers of the conferences
- Available on the site ICPHS 2011

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**ON THE ACOUSTIC AND PERCEPTUAL CHARACTERIZATION OF  
REFERENCE VOWELS IN A CROSS-LANGUAGE PERSPECTIVE**

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# On the acoustic and perceptual characterization of reference vowels in a cross-language perspective



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*Sorbonne Nouvelle*  
*Paris, France*

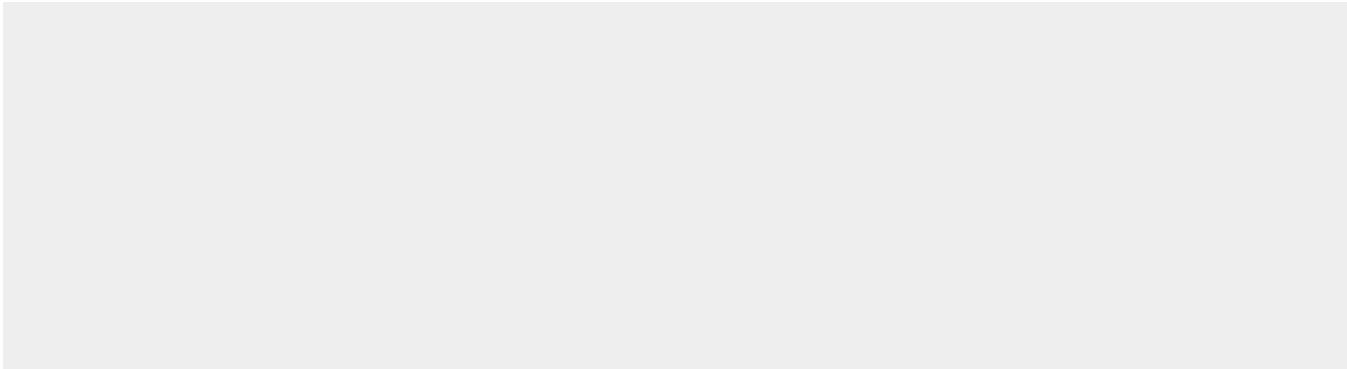


# Plan

- 1) introduction
- 2) IPA chart and cardinal vowels
- 3) Some remarks on the formants
- 4) Acoustic characteristics of some DJ's and PL's cardinal vowels
- 5) From vowels to glides to consonants and processes
- 6) Conclusions



# Introduction





# What is the purpose ?

- Revisit some of the cardinal vowels as proposed by Daniel Jones and their rendition by Peter Ladefoged, available on the web
- Search for some well-defined acoustic and perceptual criteria, if some as a complement of their articulatory description
- Using available tool such as articulatory synthesis





# Applications?

1. To characterize the vowels of a given language relatively to a set of well defined references
2. For comparison or for learning
3. To establish what types of precisely defined vocalic timbers are preferred in the languages
4. To describe fine acoustico-perceptual details for socio-phonetic and prosodic research
5. For clinical phonetics, speech pathologists and therapists
6. To make the students conscious about the non linearity between articulatory gestures, their acoustic consequences, and the resulting percept





# On the choice of an IPA symbol ?

API symbols proved to be very useful for transcribing the phonemic systems.

But

For phonetic transcription, the choice of a symbol may depend on **the transcriber**, his/her native, the languages he/her masters, the extend of his/her training in phonetic transcription, etc.

**And also**

1. The phonetic rendition of each symbol depends on the language: references needed
2. Package of articulatory maneuvers often used to achieve a particular percept and inter-articulator compensation possible : **There is no one specific invariant vocal tract configuration for creating a specific vowel auditorily quality.**
3. So articulatory definition of vowels has its own limit



As a consequence, the same symbol may be used to represent different phonetic realities and vice versa, the same reality may be described differently by two different persons.





## Traditional articulatory description: pb?

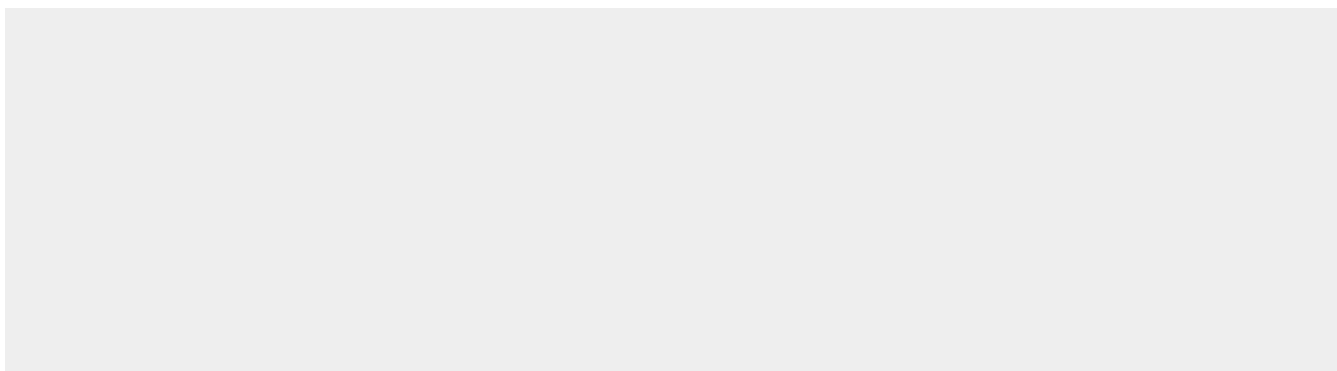
- Some unanswered questions about the two first dimensions generally used to describe the vowels:
  - high and low
  - front and back (open/close)  
(Rounding being the third)
- Traditional articulatory descriptions such as height and backness "*are not entirely satisfactory*" (Peter Ladefoged)



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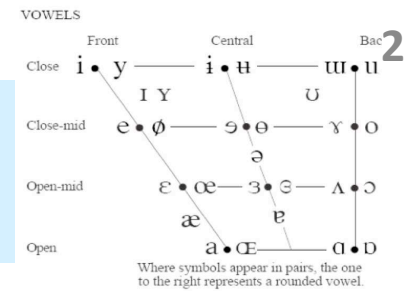


# IPA chart and the cardinal vowels





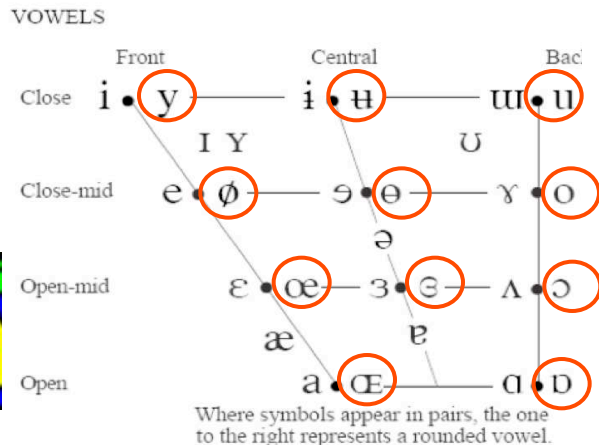
# 1) IPA chart



**For what?** to devise a system for transcribing the sounds of speech, independently of any particular language and applicable to all languages.

**When?** in 1888

**By whom?** Association Phonétique Internationale, a group of French language teachers founded by Paul Passy.



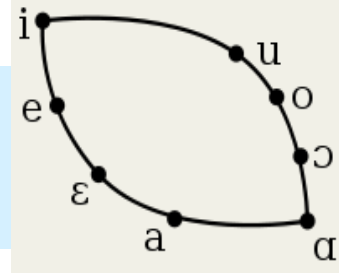
**The three articulatory dimensions in IPA:**

- 1) close-open
- 2) Front-central-back
- 3) rounding



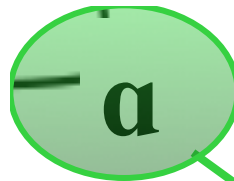
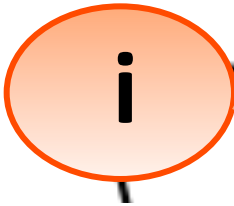


## 2) from IPA to cardinal vowels



Cardinal 1 and 5 were clearly defined in articulatory terms

- 1) ~~close-open~~ high-low
- 2) Front-central-back
- 3) rounding

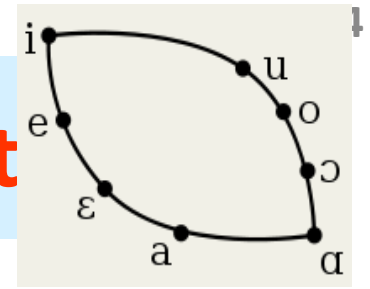


cardinal 1  
tongue as high and as front as possible  
narrow constriction, but no audible noise.

cardinal 5  
tongue as low and as back as possible



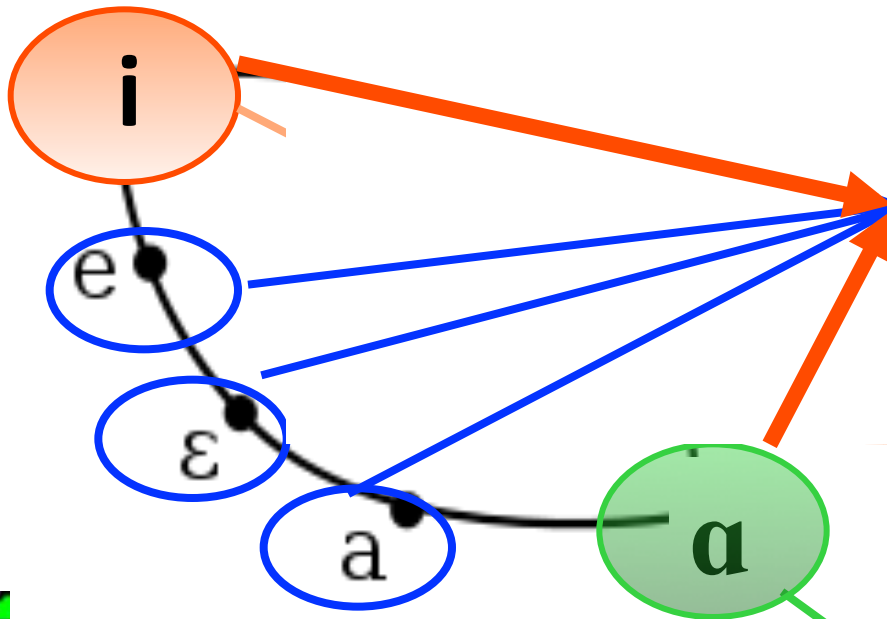
# 8 Primary Cardinal vowels: 4 front



## Articulatory (and auditory) definition



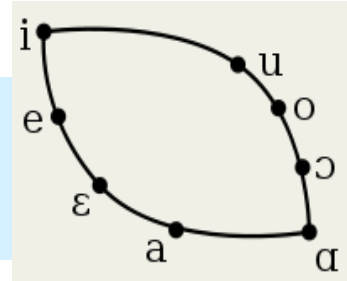
2,3, 4 derived from 1 and 5



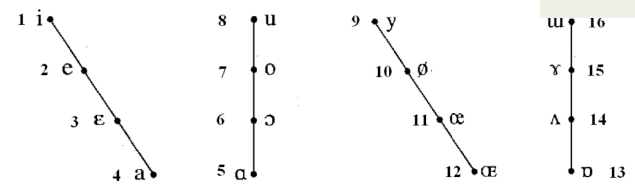
cardinal 2, 3, 4  
tongue lowered in equal steps  
supposed to be **auditorily** equidistant

cardinal 1  
tongue as high and as front as possible  
narrow constriction, but no audible noise.

cardinal 5  
tongue as high and as front as possible  
narrow constriction, but no audible noise.



# 8 Primary Cardinal vowels: 4 back



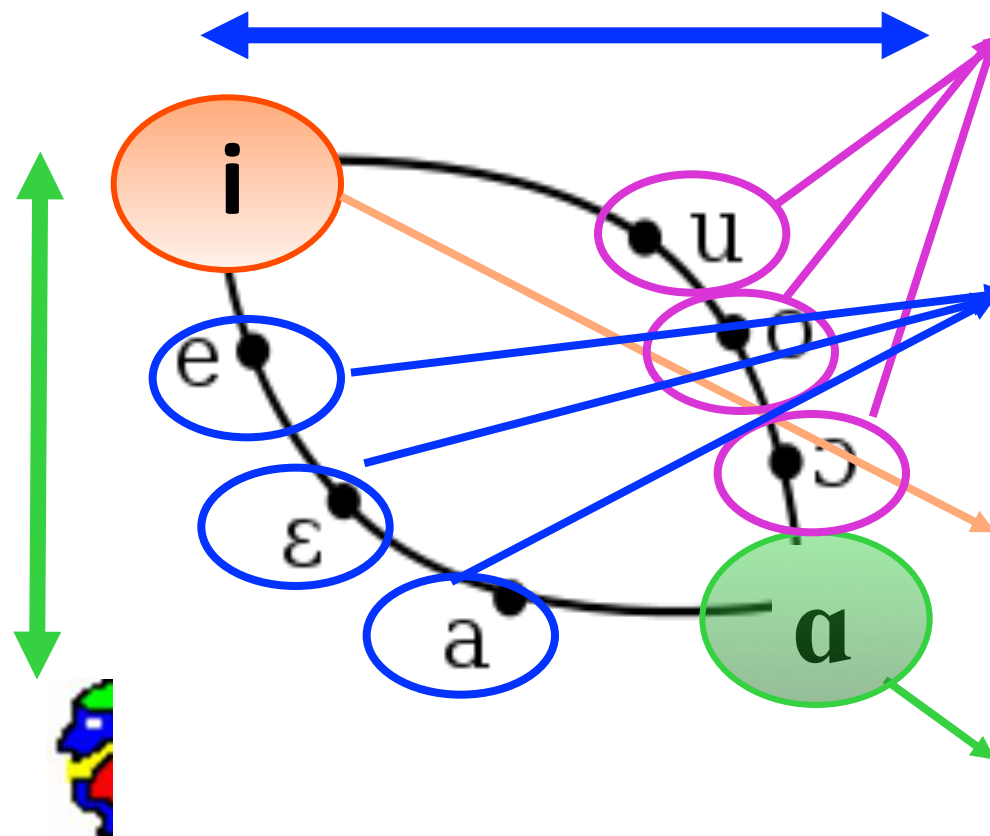
## Articulatory definition

**cardinal 6, 7, 8**  
Raising the tongue in a retracted position

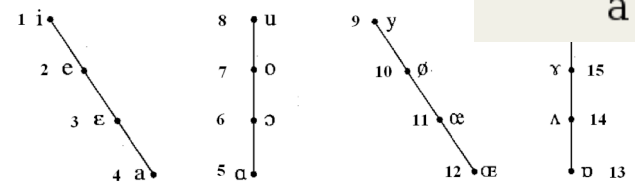
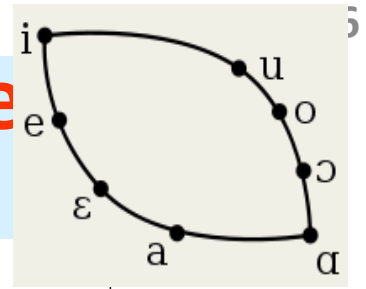
**cardinal 2, 3, 4**  
tongue lowered in equal steps  
supposed to be auditorily equidistant

**cardinal 1,**  
tongue as high and as front as possible  
narrow constriction, but no audible noise.

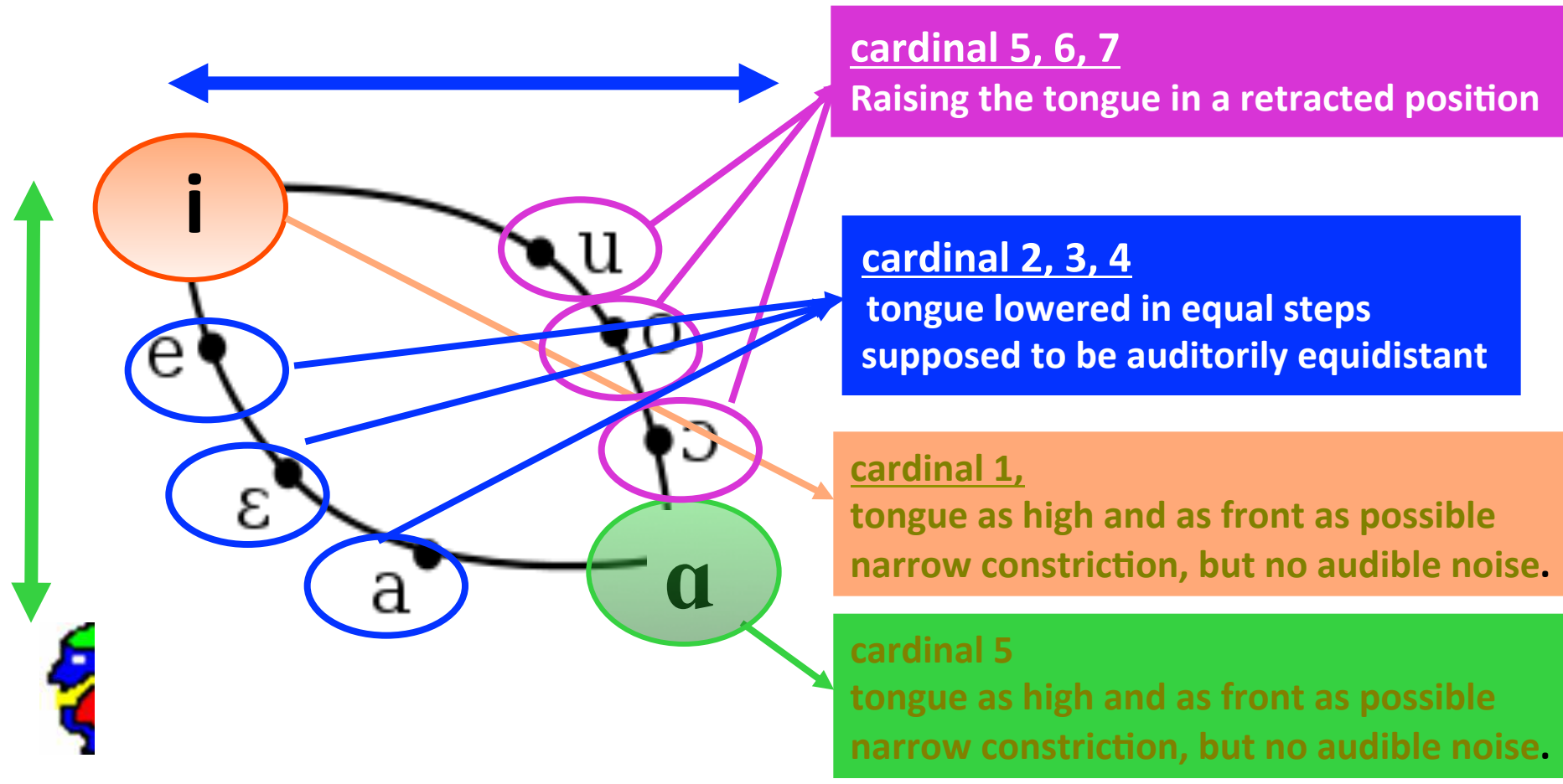
**cardinal 5**  
tongue as high and as front as possible  
narrow constriction, but no audible noise.



# So 8 Primary Cardinal vowels derive from CV 1 and CV5



## Articulatory definition

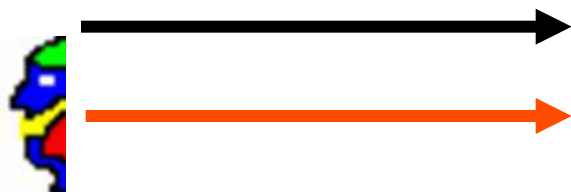
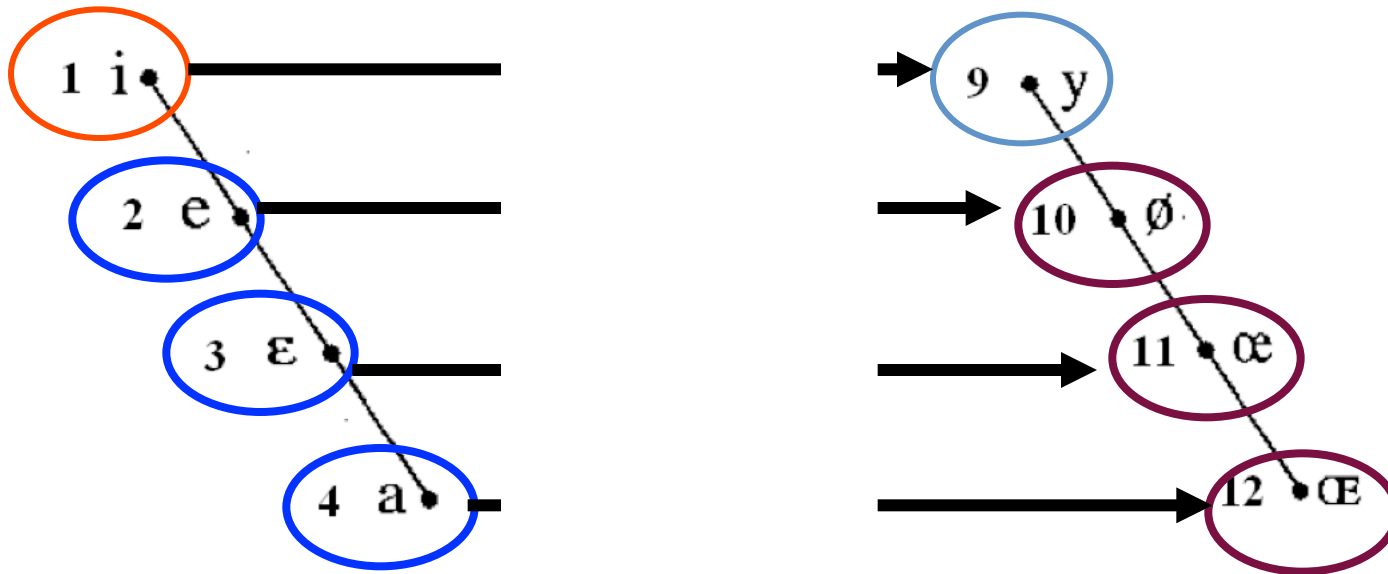






# 8 secondary Cardinal vowels derived from the primary by rounding: the front ones

**Front Primary + rounding = secondary**

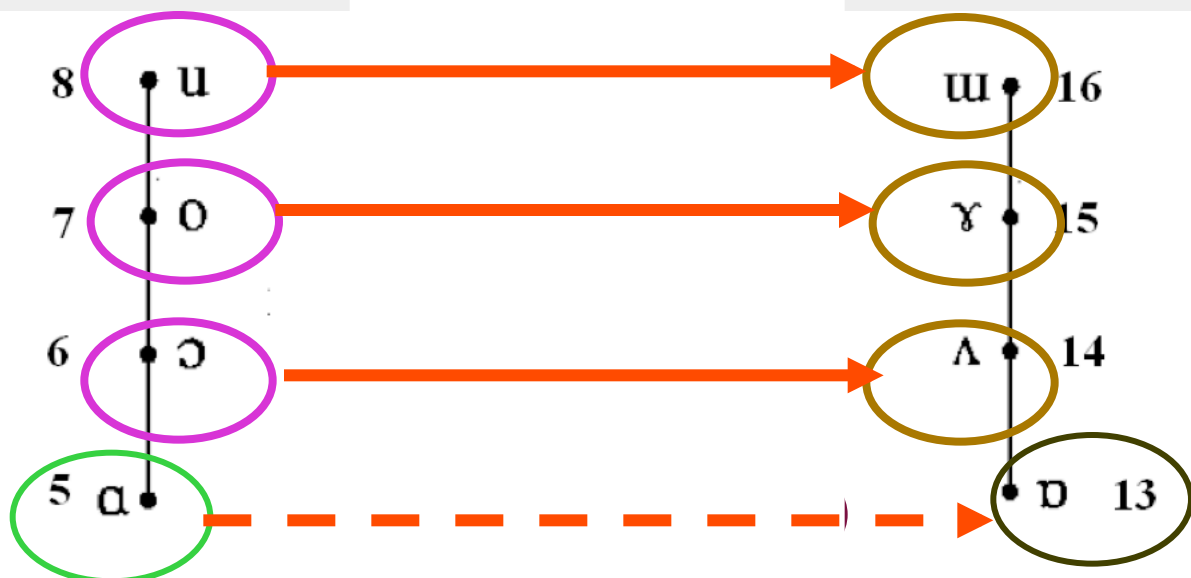


Spread > round  
Round > spread



# 8 secondary Cardinal vowels derived from the primary by rounding: the back ones

Back primary+ reverse rounding = secondary



spread > round  
 Round > spread

as possible  
 narrow constriction, but no audible noise.  
 cardinal 5  
 as high and as front as possible  
 narrow constriction, but no audible noise.



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- 6) Conclusions

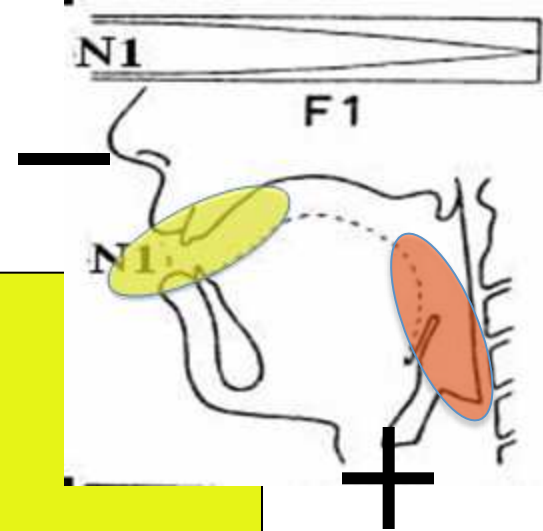


### 3) Some remarks on the formant frequencies

Formant frequencies as acoustic correlates of the oral vowels : close to perfection ...

But their articulatory correlates are not clear cut ...





**F1**

F1 = a very good acoustic parameter of the vowel quality !

(but manipulation of F1 a little less straightforward than generally assumed,

Since it is different for palatal and velopharyngeal vowels)



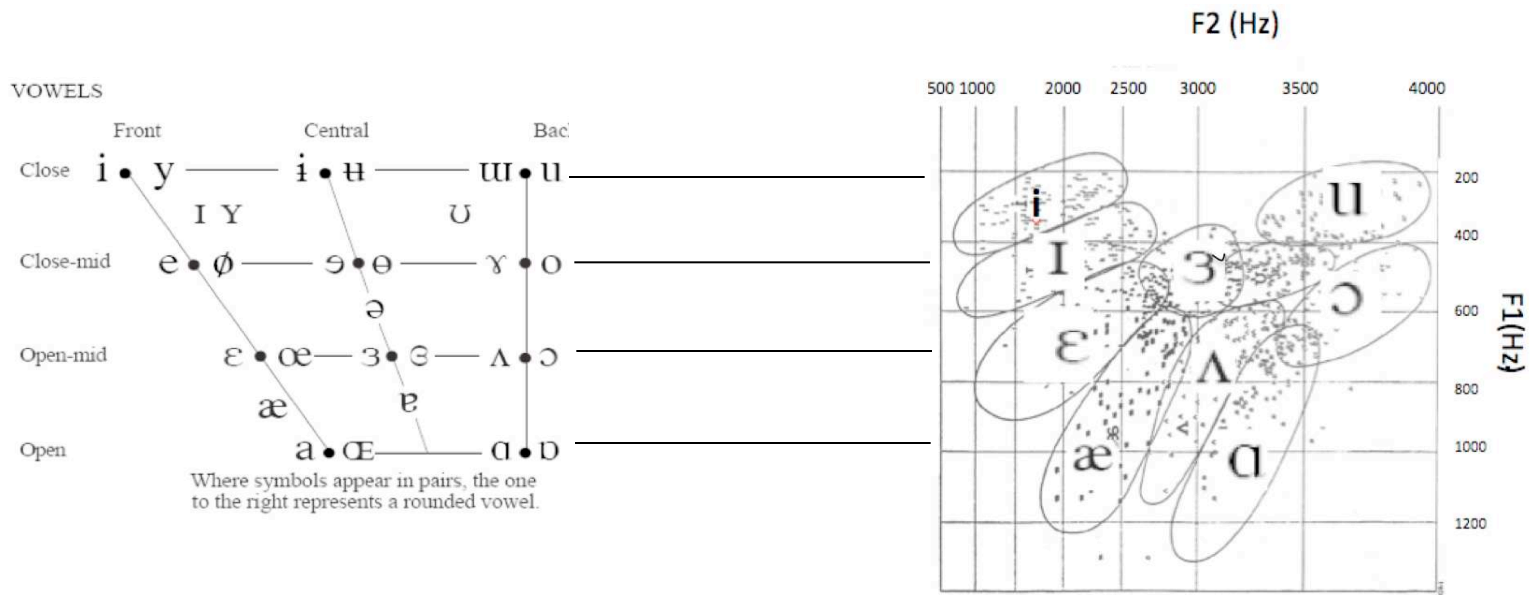


# F1 frequency adequately represents the dimension high-low

High or low (close-open)

But not a good correspondence between tongue height and high/low

**Phoneticians are in fact describing an acoustic quality (F1) rather than the actual height of the tongue (Peter Ladefoged).**

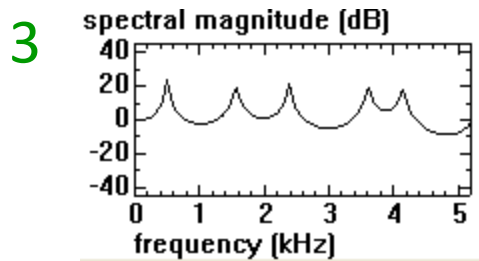
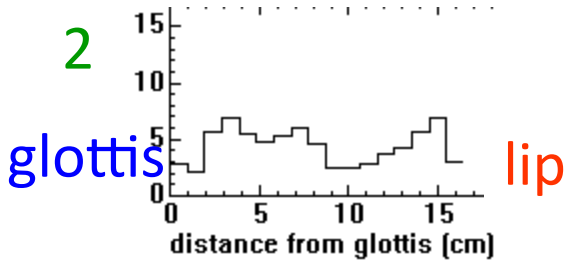


- F1 is influenced
  - by the position of the constriction,
  - by the size of the constriction
  - and lip configuration
- not uniquely by tongue height as it was still believed at Jones' s time.
- Let us demonstrate the articulatory correlates of F1



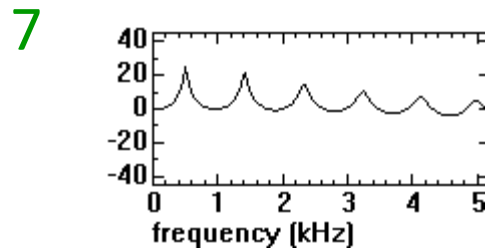
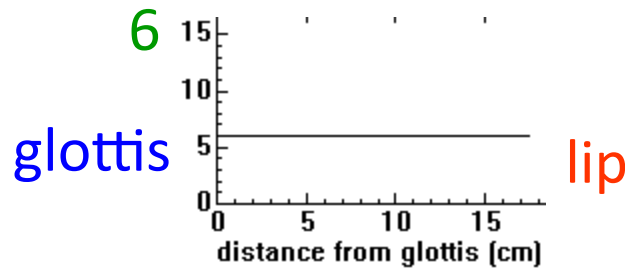


modélisation



5

	Frq(Hz)	Bw(Hz)	A(dB)
F1	495	33	24
F2	1579	72	19
F3	2383	48	22
F4	3621	72	19
F5	4148	66	18

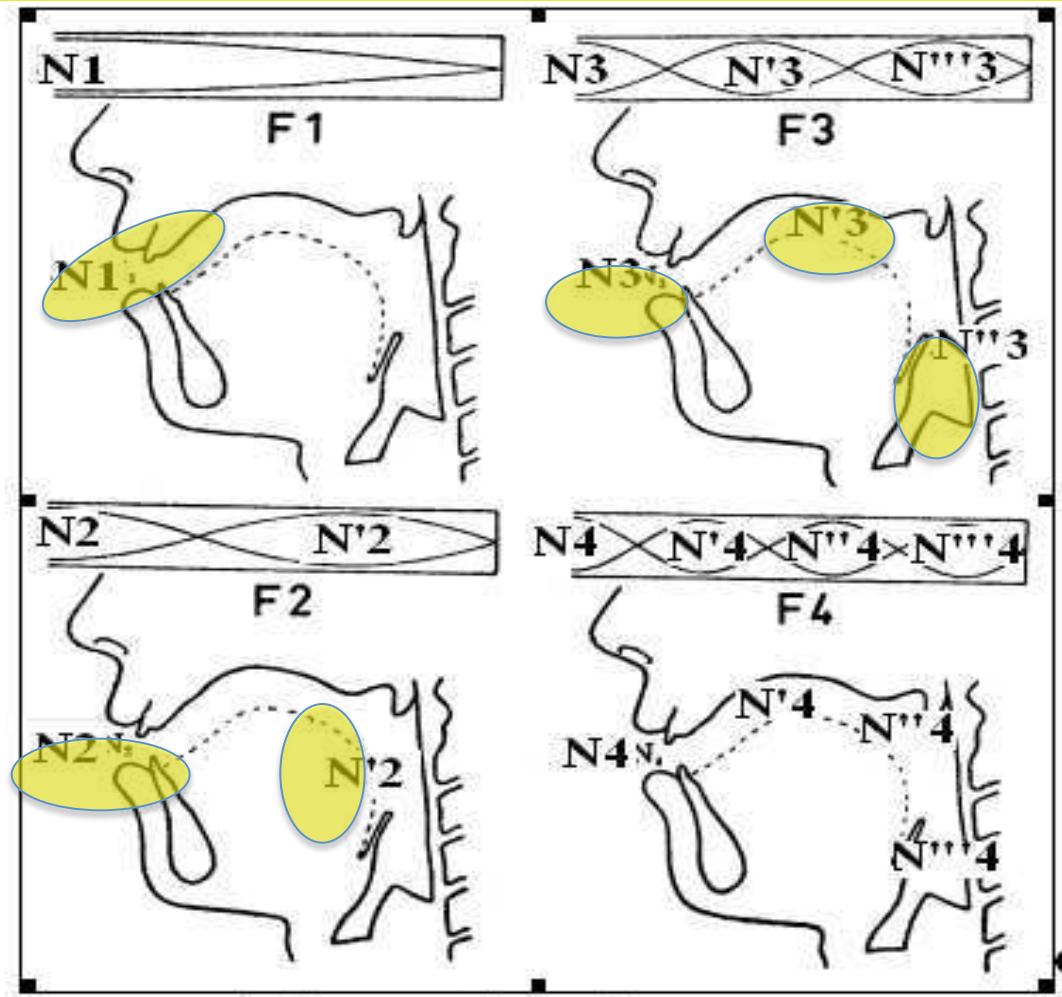


9

	Frq(Hz)	Bw(Hz)	A(dB)
F1	495	33	25
F2	1424	50	22
F3	2321	100	15
F4	3250	155	10
F5	4117	190	7
F6	4983	190	5

- 1: Neutral VT
- 2: Area function
- 4: Simple tube
- 3,7: Acoustics
- 4,8: Sounds
- 5,9: formants

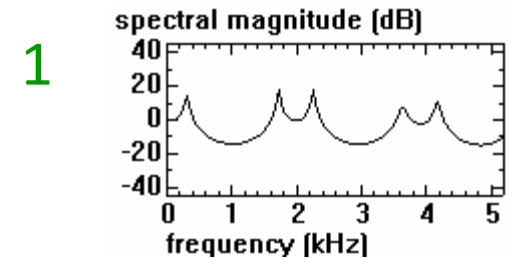
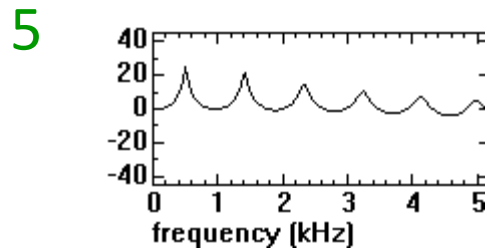
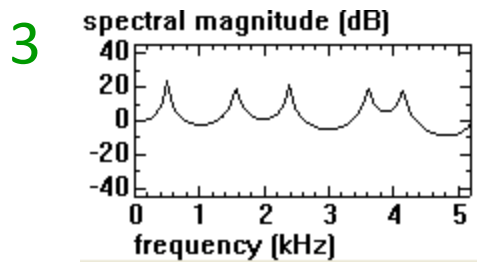
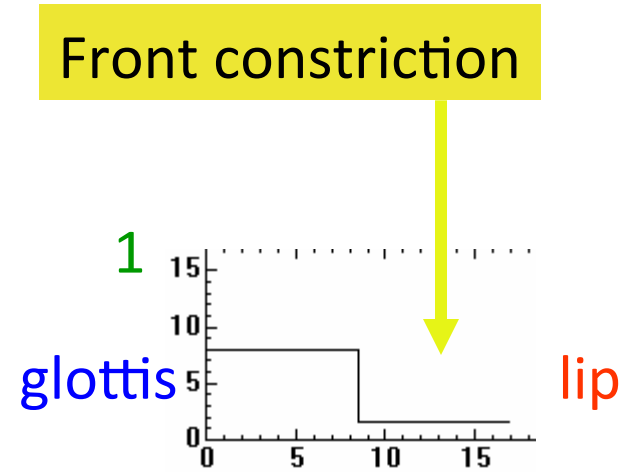
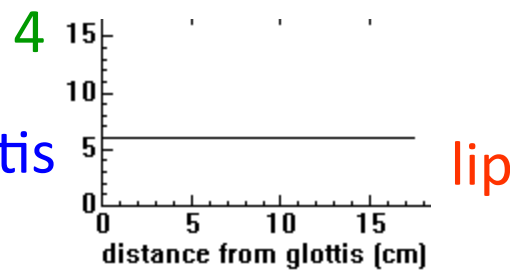
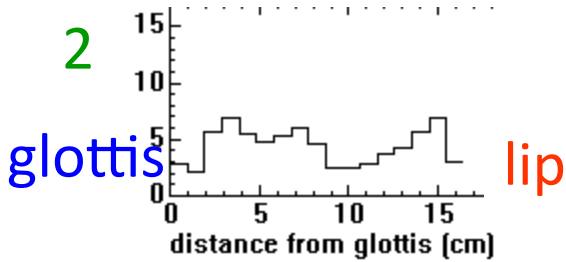
## Locations of constriction to lower each formant



Front constriction : F1 lowers  
 Back constriction: F1 raises



# Front constriction : F1 lowers from 495 to 310 Hz

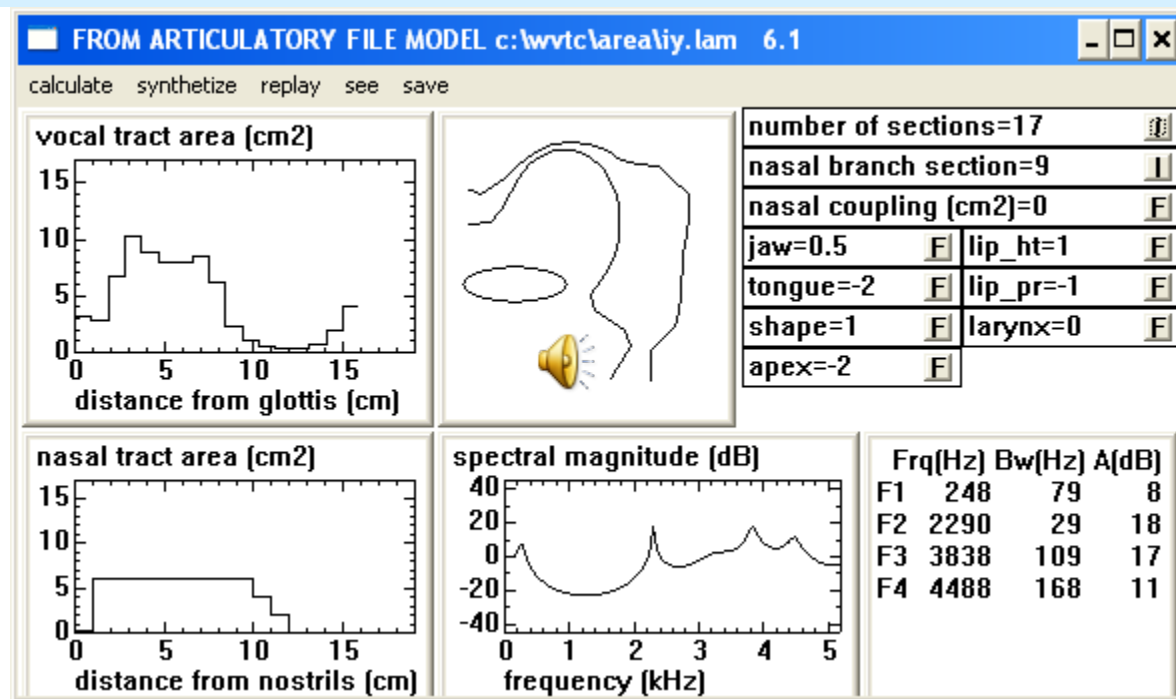


	Frq(Hz)	Bw(Hz)	A(dB)
F1	495	33	24
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	Frq(Hz)	Bw(Hz)	A(dB)
F1	495	33	25
F2	1424	50	22
F3	2321	100	15
F4	3250	155	10
F5	4117	190	7
F6	4983	190	5

	Frq(Hz)	Bw(Hz)	A(dB)
F1	310	57	14
F2	1733	37	18
F3	2260	37	18
F4	3652	115	7
F5	4179	65	11

# Example: manipulation of F1 for palatal vowels



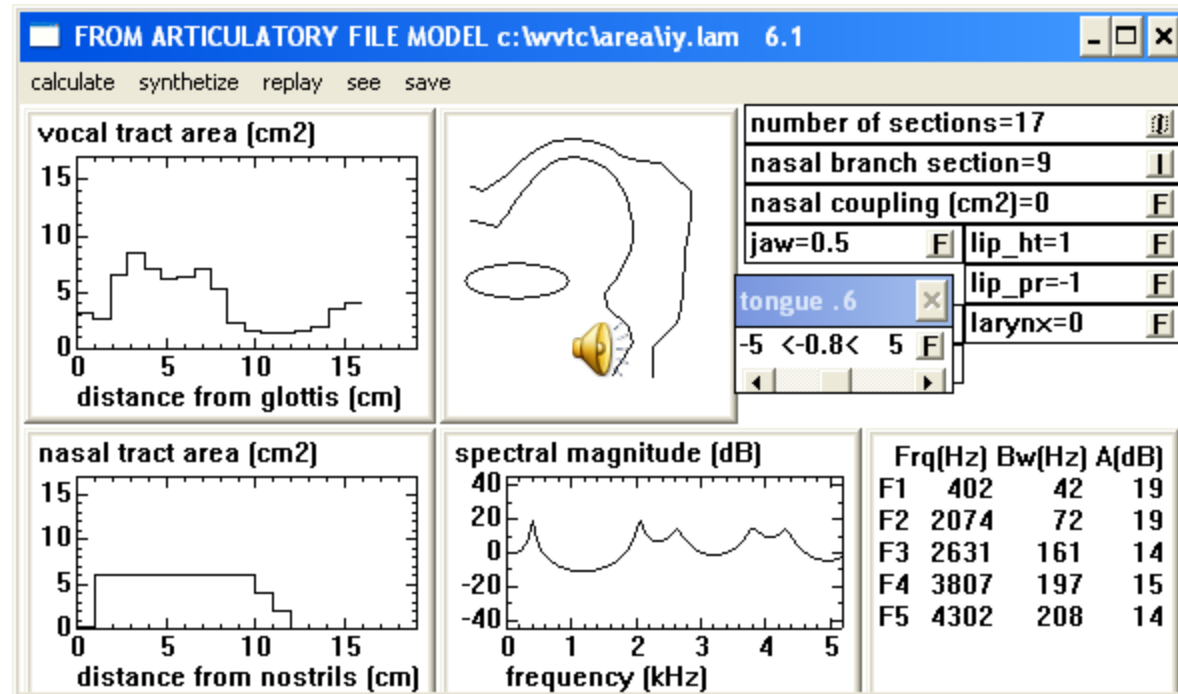
Front constriction : F1 lowers

Less tight constriction : F1 raises

Less tight constriction  
Higher F1

Front constriction  
Plus manipulation  
Of the tightness

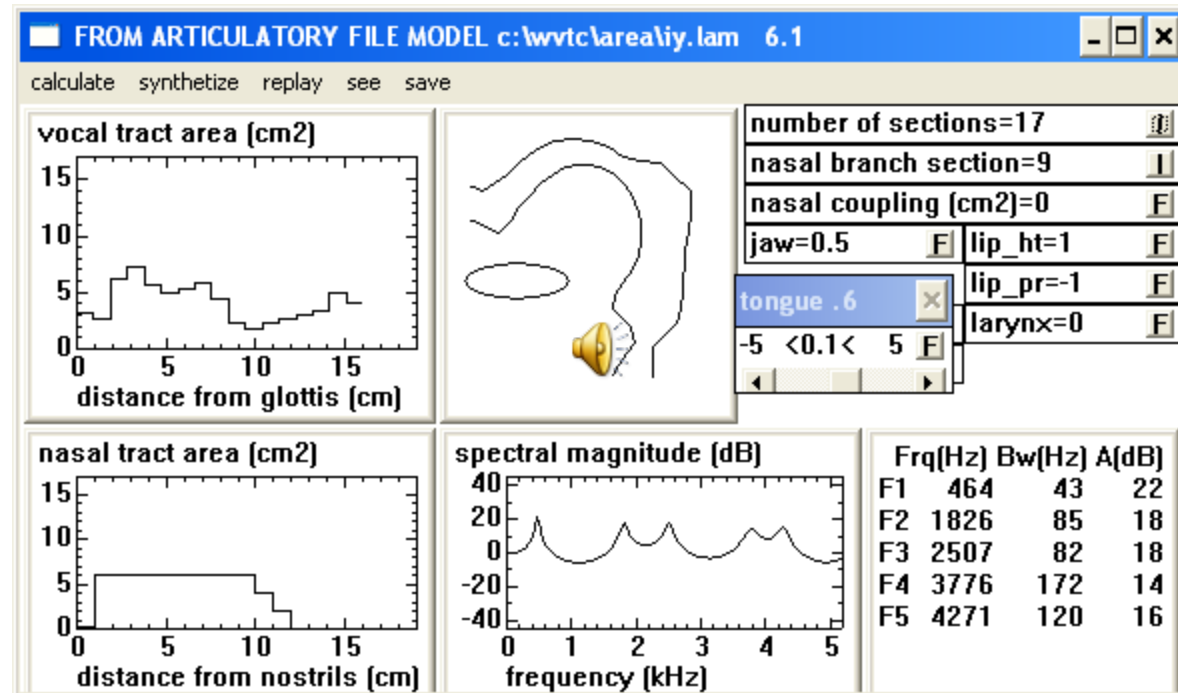




Less tight constriction  
> Higher F1

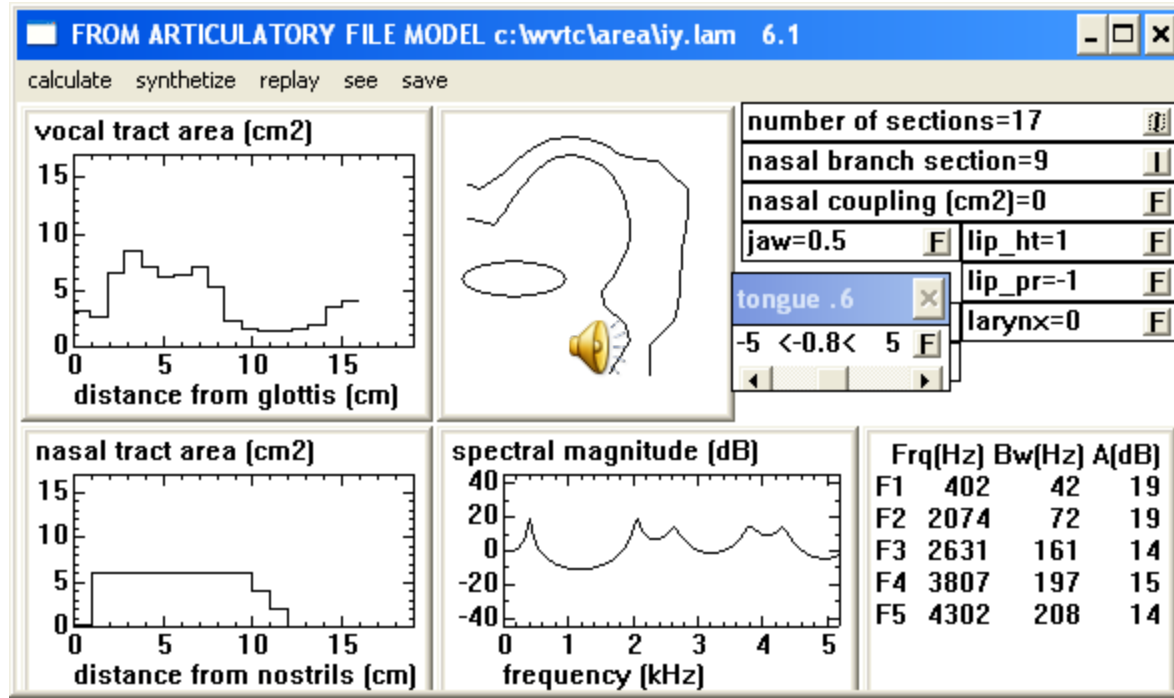
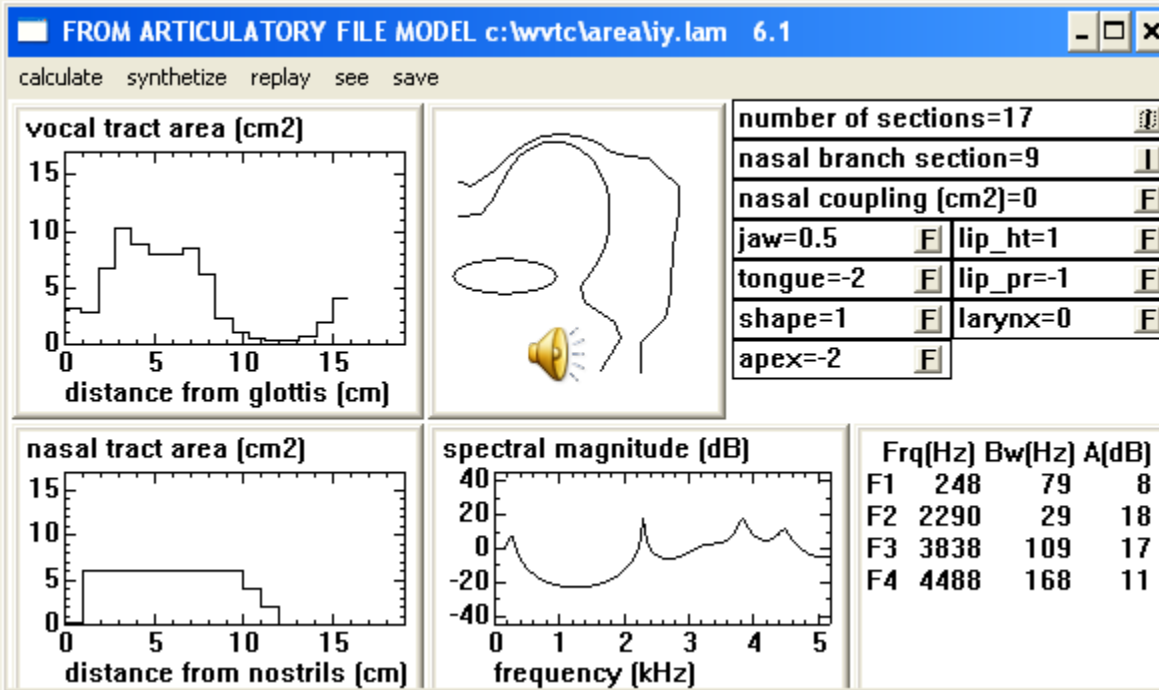
Front constriction



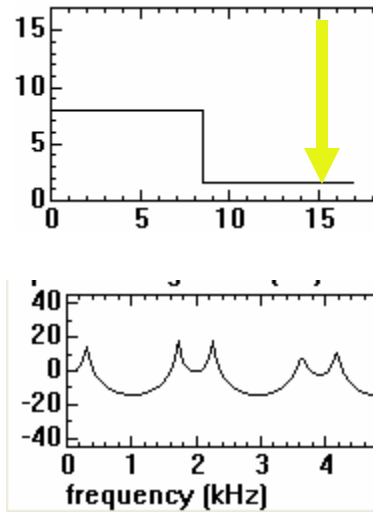


Less tight constriction  
> Higher F1





# Front constriction



## Front constriction

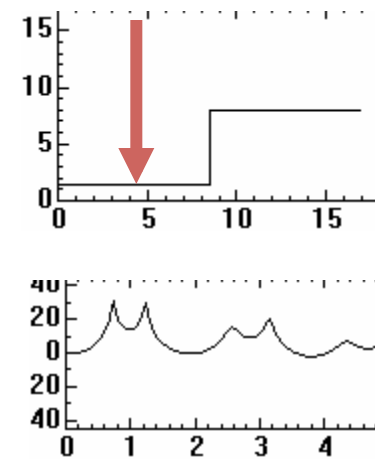
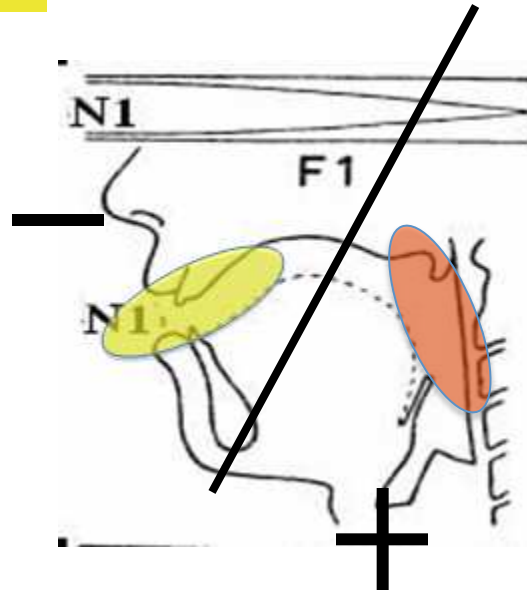
➤ **Low F1**

Less tight constriction

> **Higher F1**



# Back constriction



## Back constriction

➤ **High F1**

➤ **Fronting of the constriction**  
**Plus rounding**

➤ **lower F1**

But different gestures to manipulate F1 for back vowels



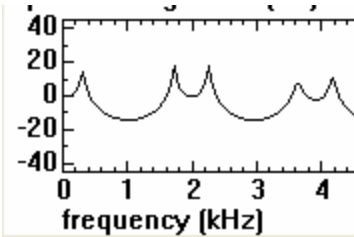
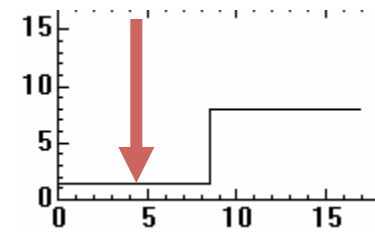
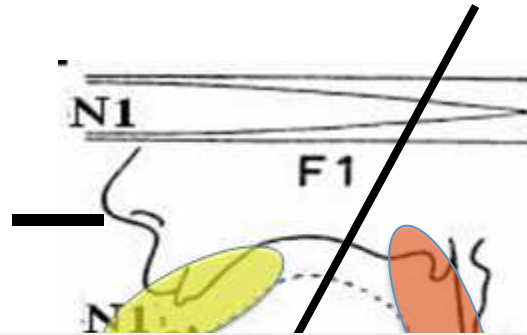
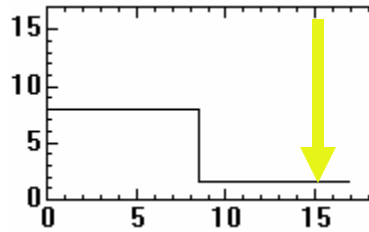
So

The size of the constriction (well related to the height of the tongue) in the case of the palatal vowels

But

fronting of the constriction and rounding in the case of back vowels (as much less known)

Important to understand the effect of the context



FROM ARTICULATORY FILE MODEL c:\wvvc\area\uw.lam 9.1

calculate synthesize replay see save

**vocal tract area (cm<sup>2</sup>)**

distance from glottis (cm)

number of sections=17	I
nasal branch section=9	I
nasal coupling (cm <sup>2</sup> )=0	F
jaw=0.5	F
lip_ht=-1	F
tongue=3.6	F
lip_pr=1.5	F
shape=1.5	F
larynx=0	F
apex=-2	F

**nasal tract area (cm<sup>2</sup>)**

distance from nostrils (cm)

**spectral magnitude (dB)**

frequency (kHz)

Frq(Hz)	Bw(Hz)	A(dB)	
F1	279	99	7
F2	681	42	7
F3	2198	26	-6
F4	3652	17	3
F5	4086	46	-3

Front constriction

➤ Low F1

Less tight con

> Higher F1

Plus rounding

➤ lower F1

restriction

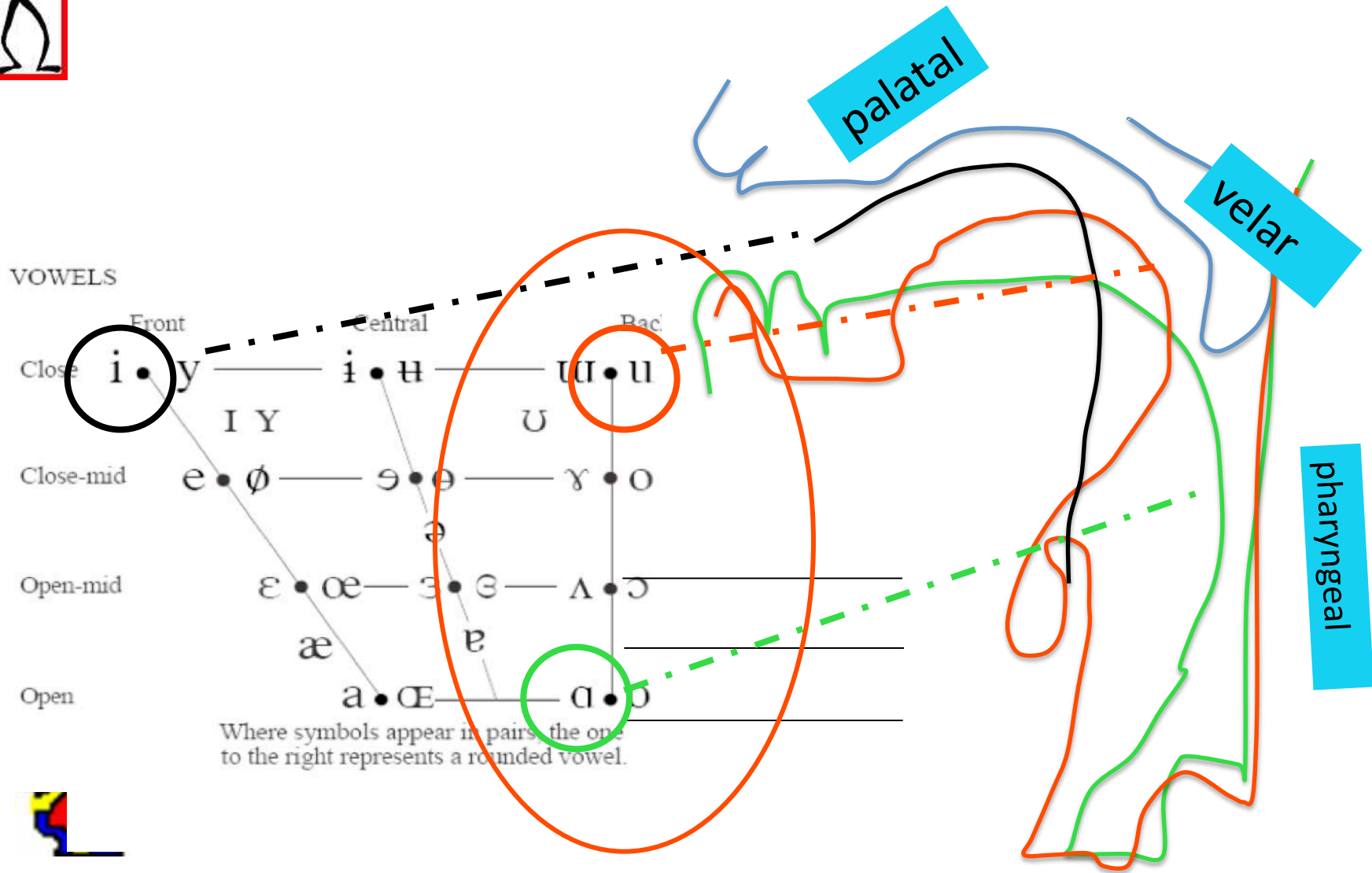


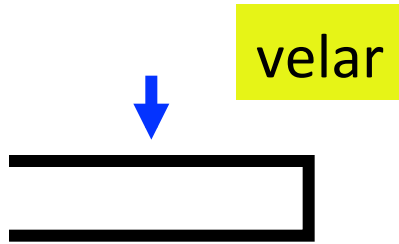
# F2

A good formant  
not sufficient with F1  
to represent the auditorily quality of  
the non back vowels  
F1/F2 representation not adequate  
for our purpose

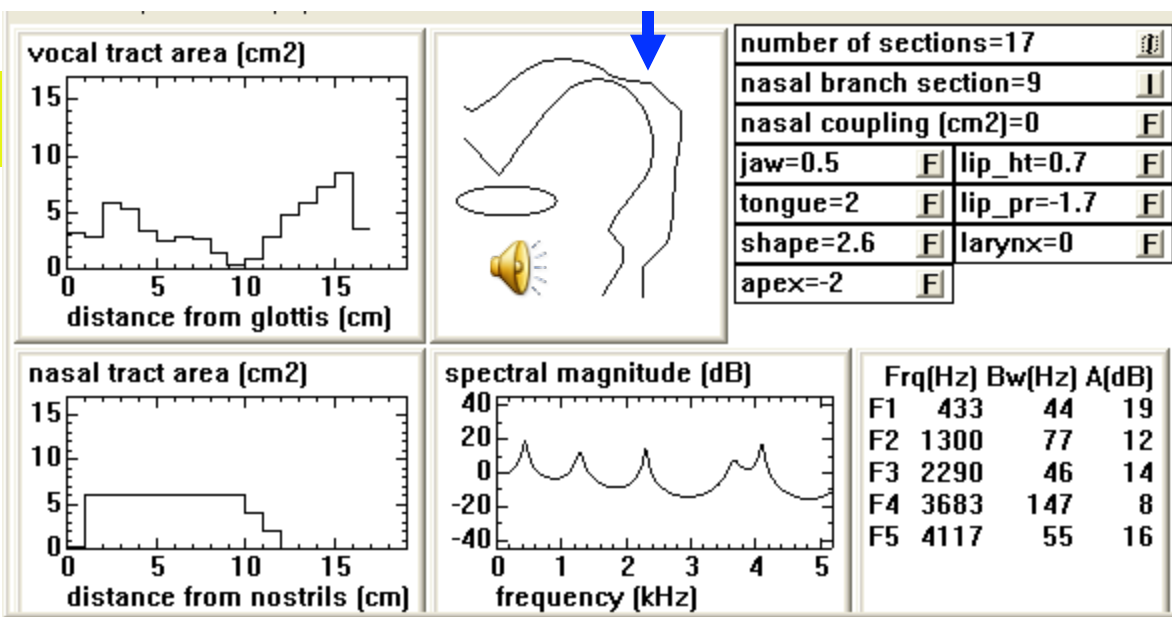
traditionnally associated with the front-back position of the tongue  
Not as simple

**Traditional front and back =  
front (palatal) mid (velar), pharyngeal (back)**



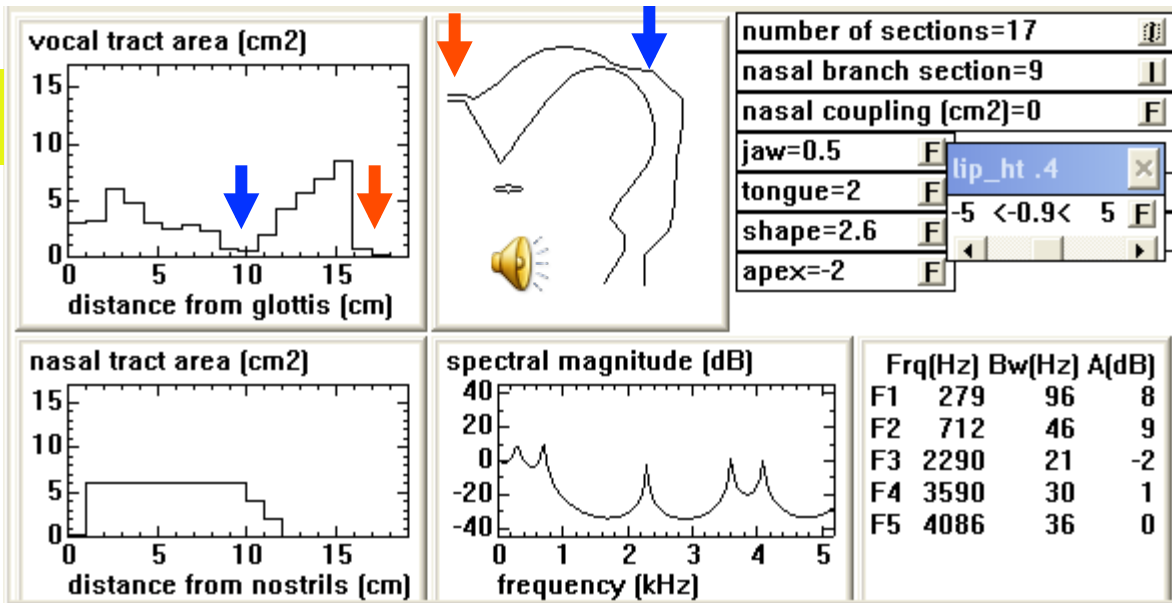
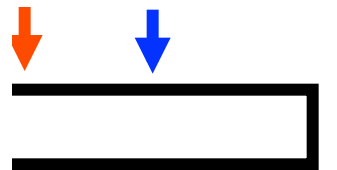


$F1 \wedge F2 \wedge F3$

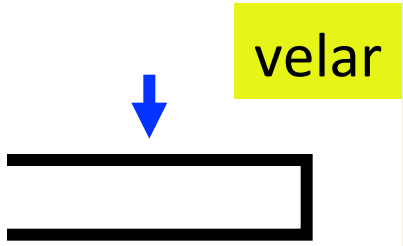


[u]

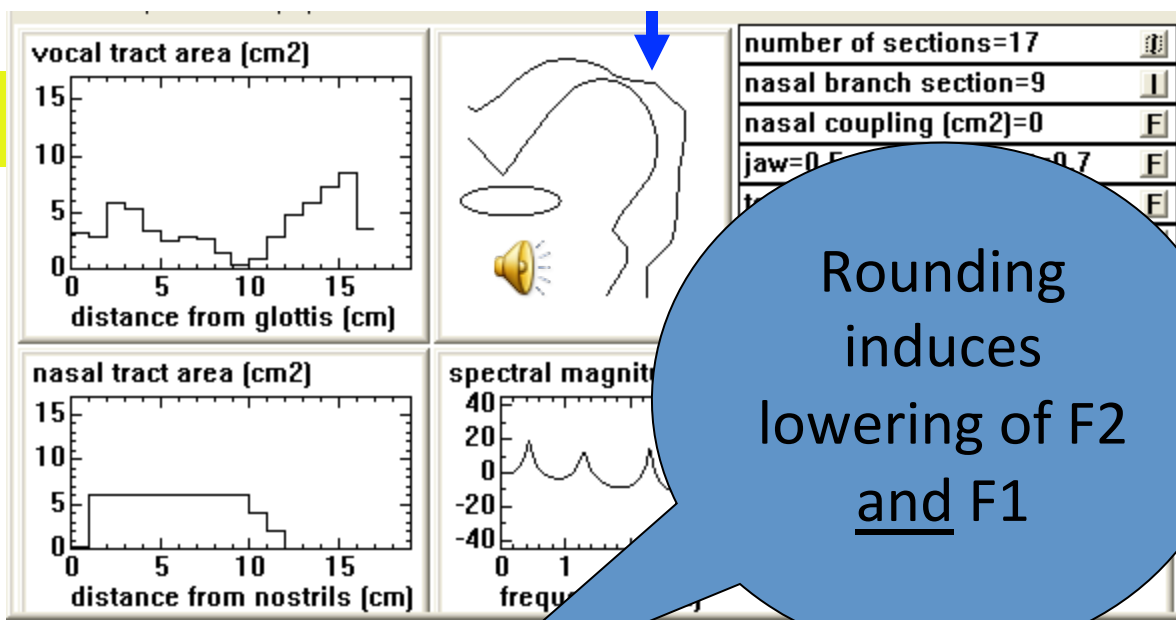
Labio-velar



Lip rounding allows to lower F2 for velar /u/



F1^F2^F3



Rounding induces lowering of F2 and F1

[u]

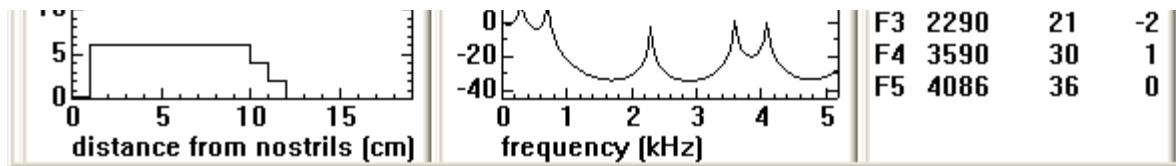
Labio-velar



To make the students conscious about the non linearity between articulatory gestures, their acoustic consequences, and the resulting percept

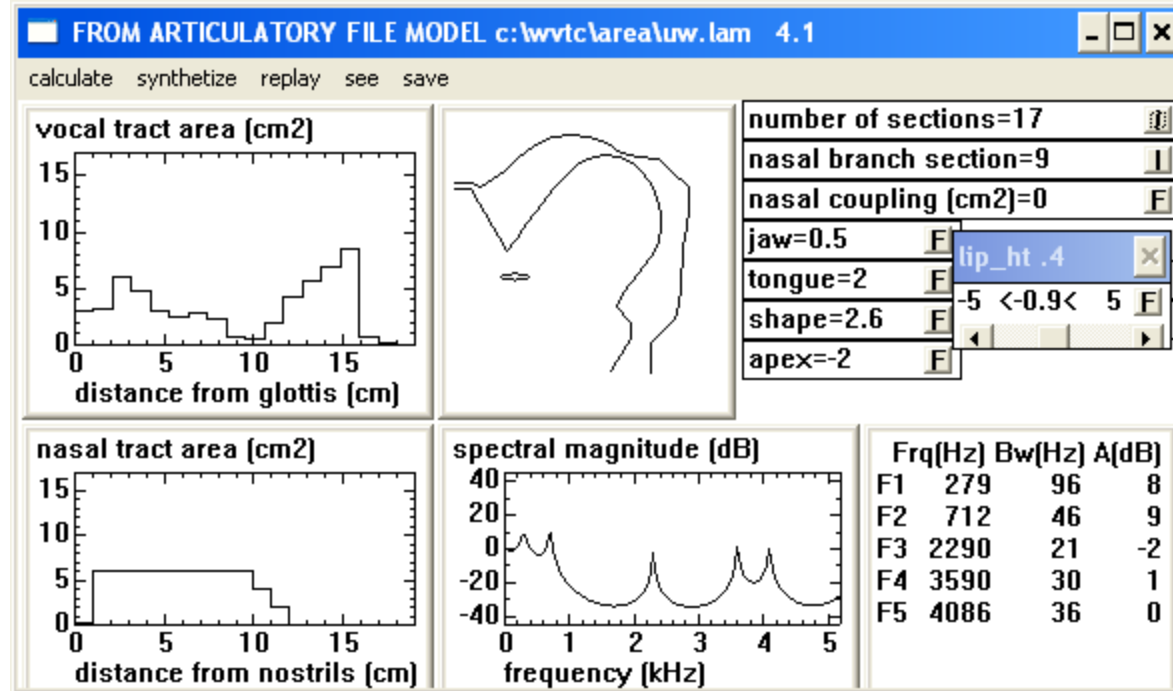


(F1F2)^F3

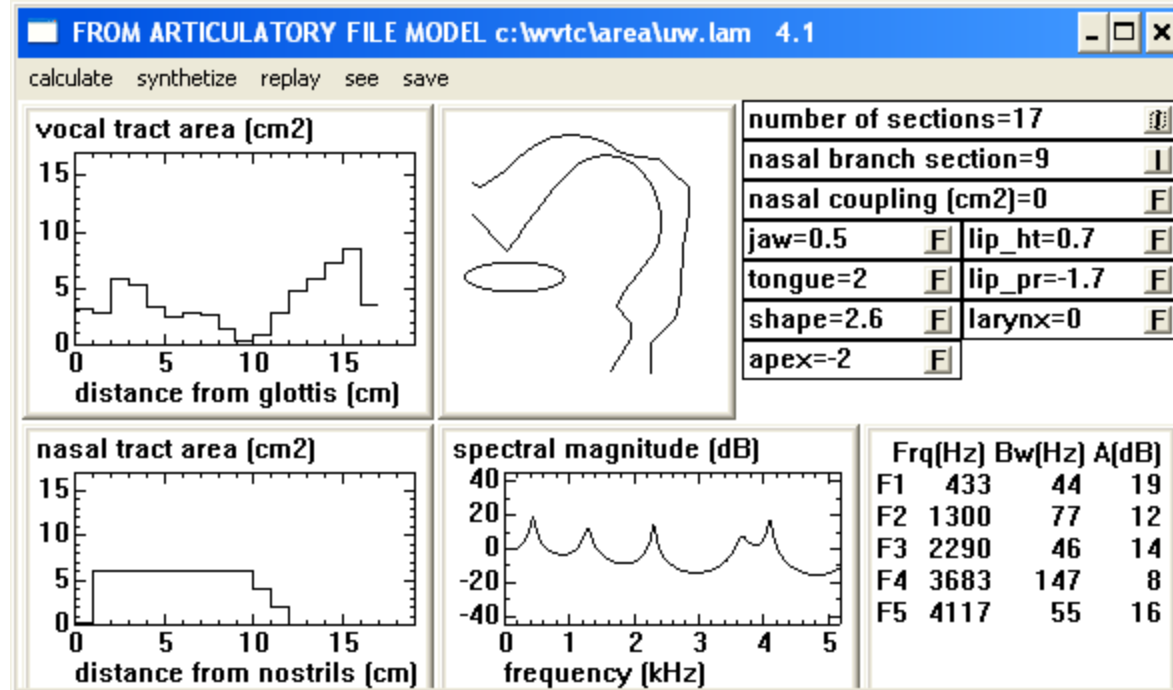


Lip rounding allows to lower F2 for /u/

round



Lip rounding allows to lower F2 for /u/

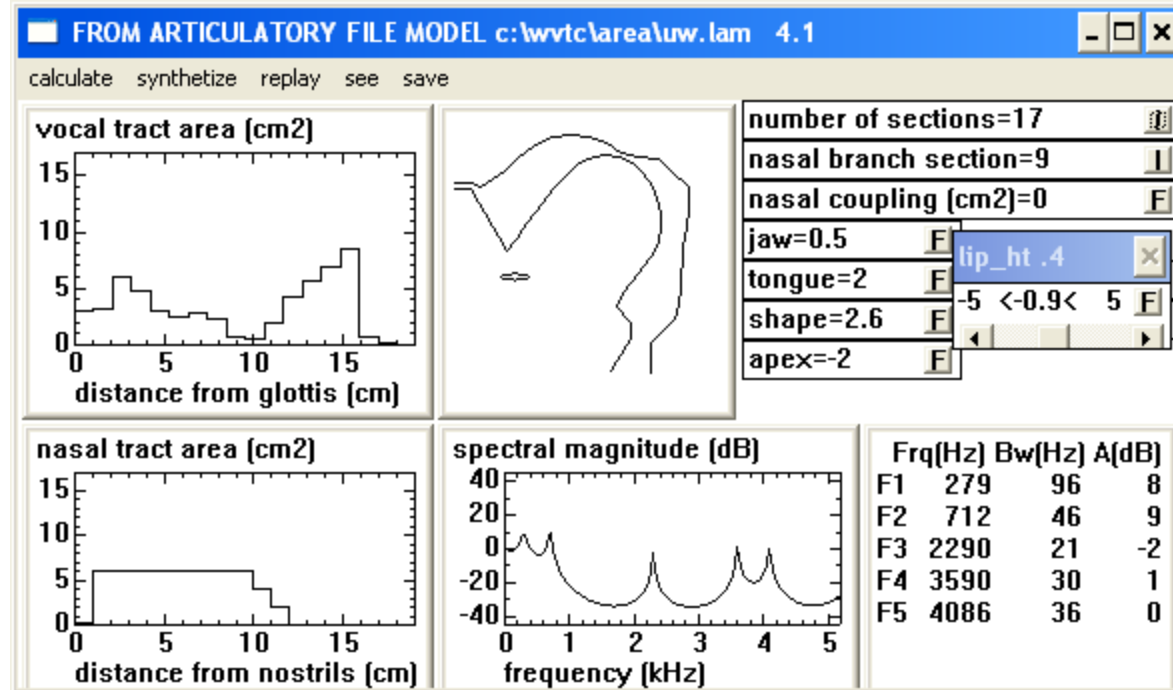


Lip rounding allows to lower F2 for /u/

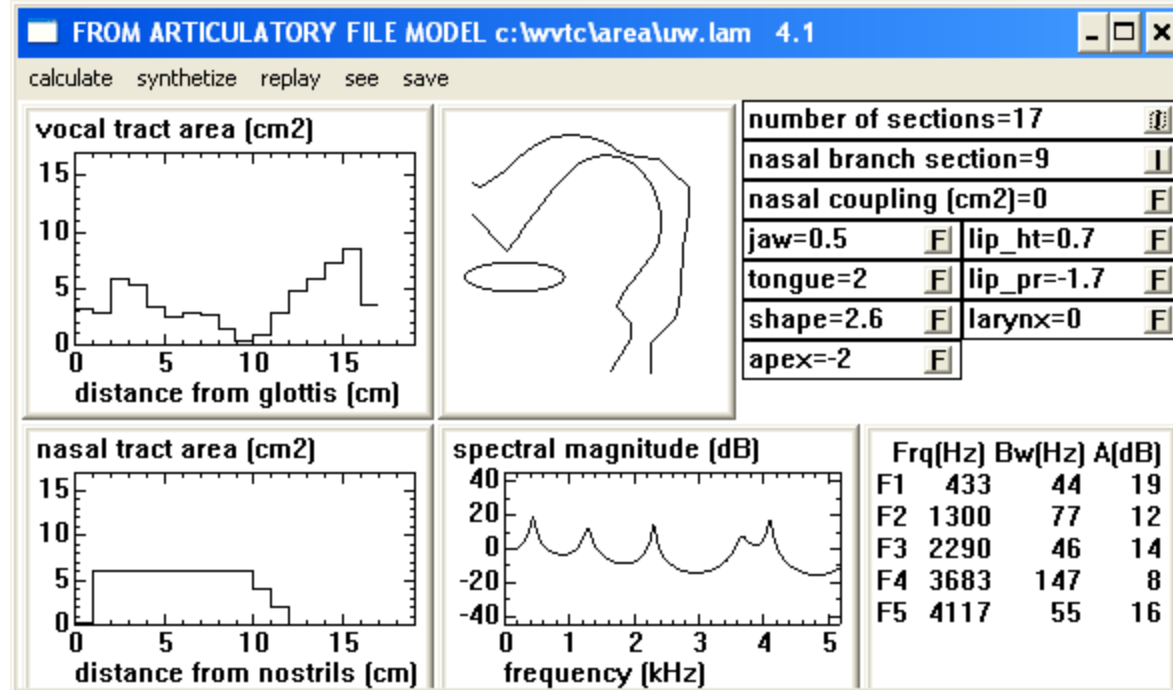
Not round



round



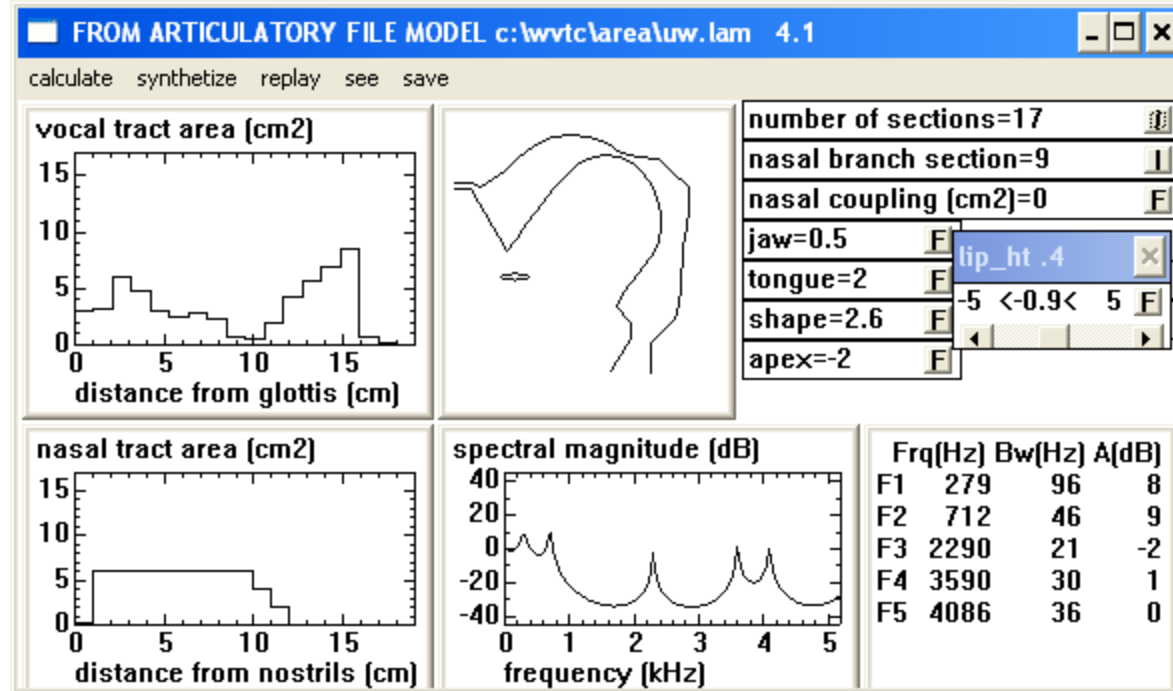
Lip rounding allows to lower F2 for /u/



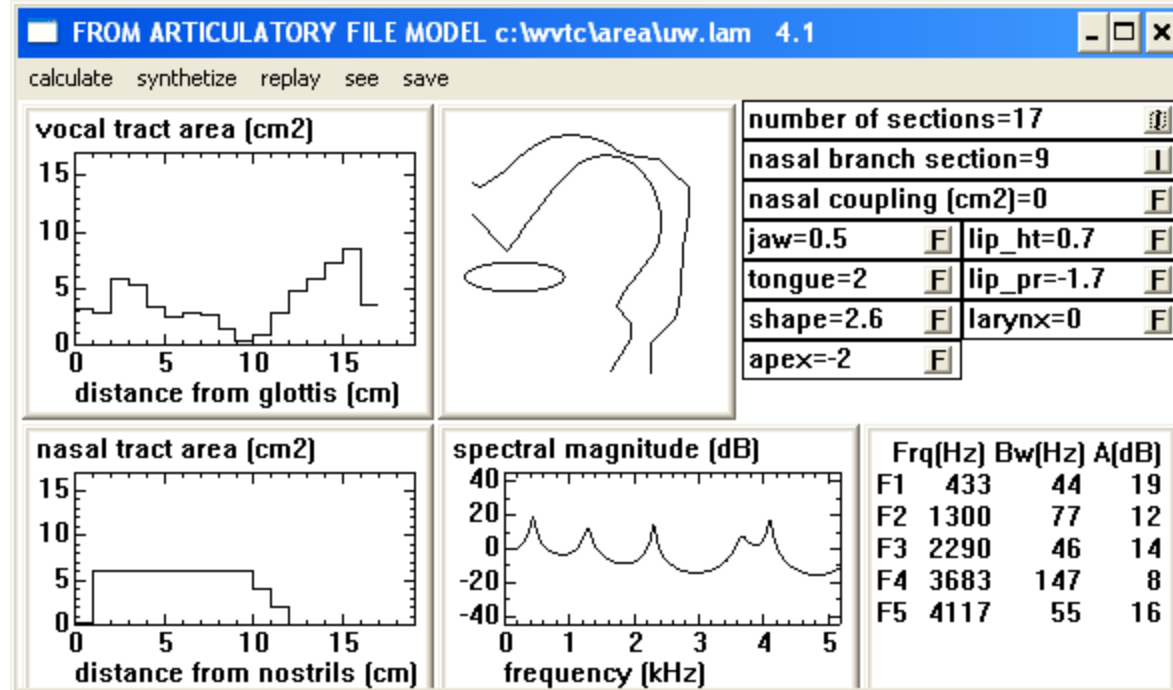
Lip rounding allows to lower F2 for /u/

Non round

round



Lip rounding allows to lower F2 for /u/



Non round



Lip rounding allows to lower F2 for /u/

- F2 is important, yes

but

there is at least one case where it has no auditory weight

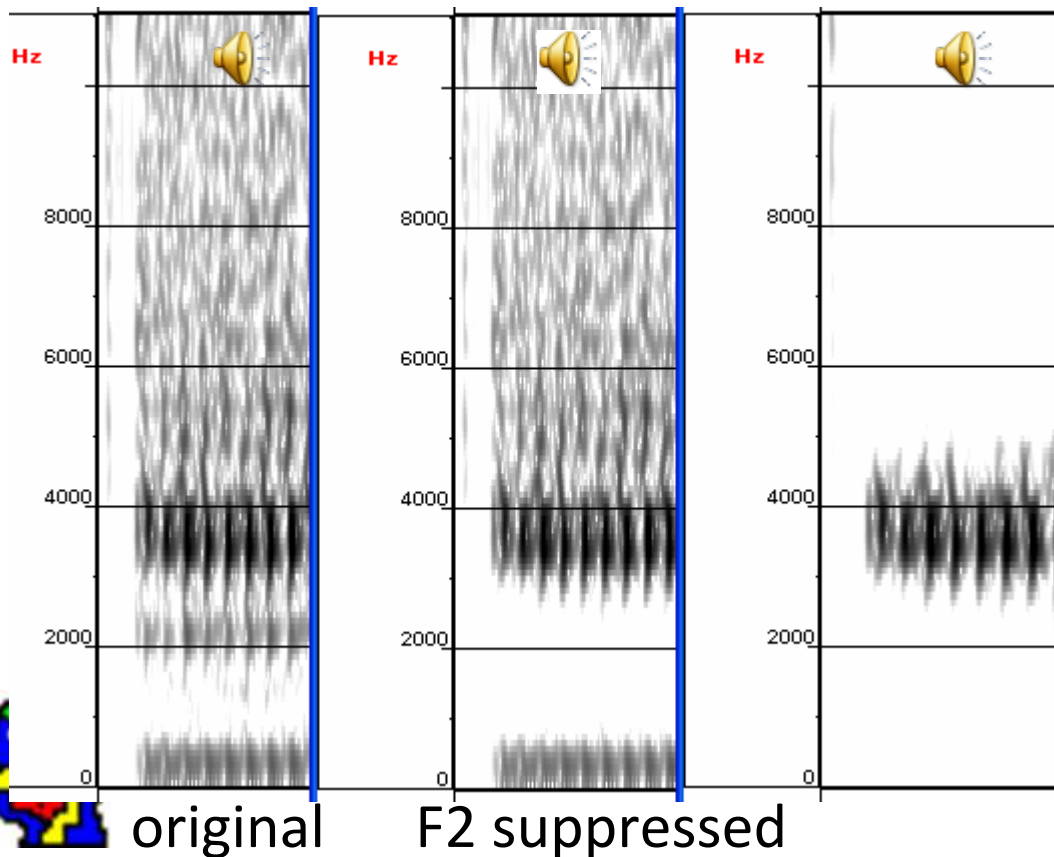
Let us see and hear the case ...



# Suppression of F2 and even F1 ...

Bruce Hayes

Cardinal /i/



(F3F4)  
F1 (F3F4)  
F1 F2 (F3F4)

F2 here  
not perceptual weight

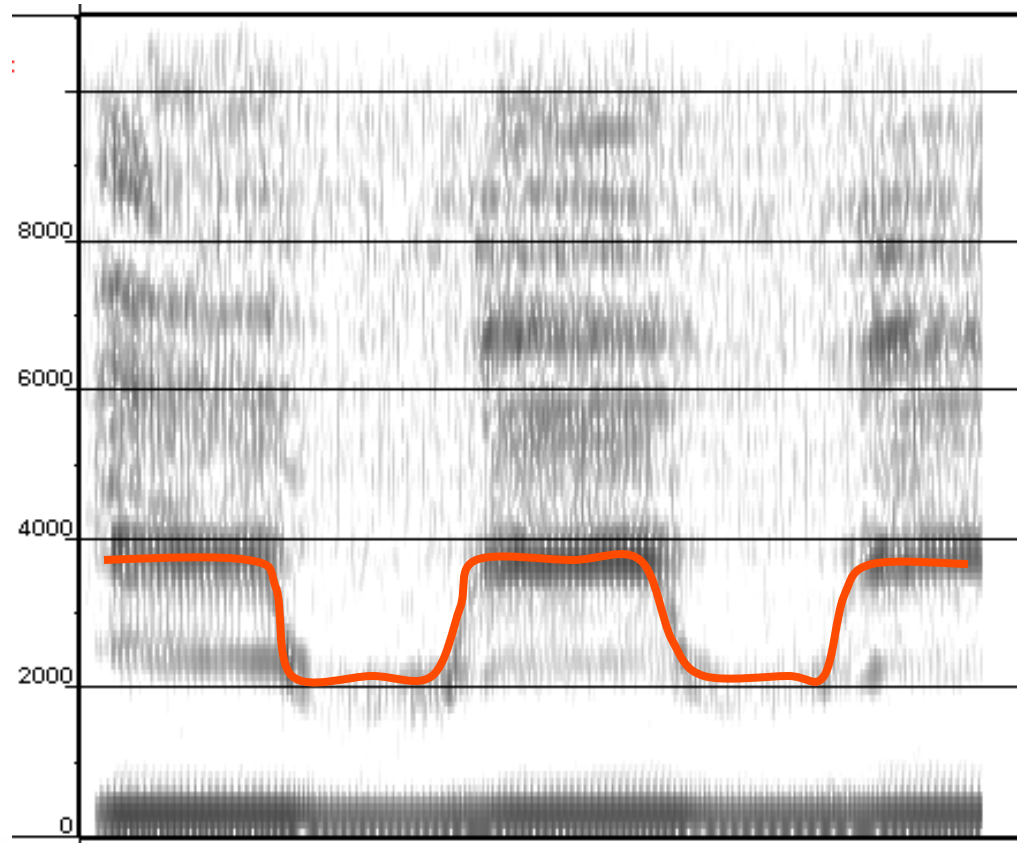
Nb: F4 is strong before  
It is regrouped with F3

# F3


- Speaker
- F2' (effective formant)



# But F3 alone carries the distinction between /i/ and /y/ (*distinctive acoustic feature*)



- Cardinal /i/
- and cardinal /y/ have a similar (very low) F1
- And close F2
- (for some speakers, similar).
- F3 plays the main (distinctive) role between
- /i/ and /y/

 (F2.F3)





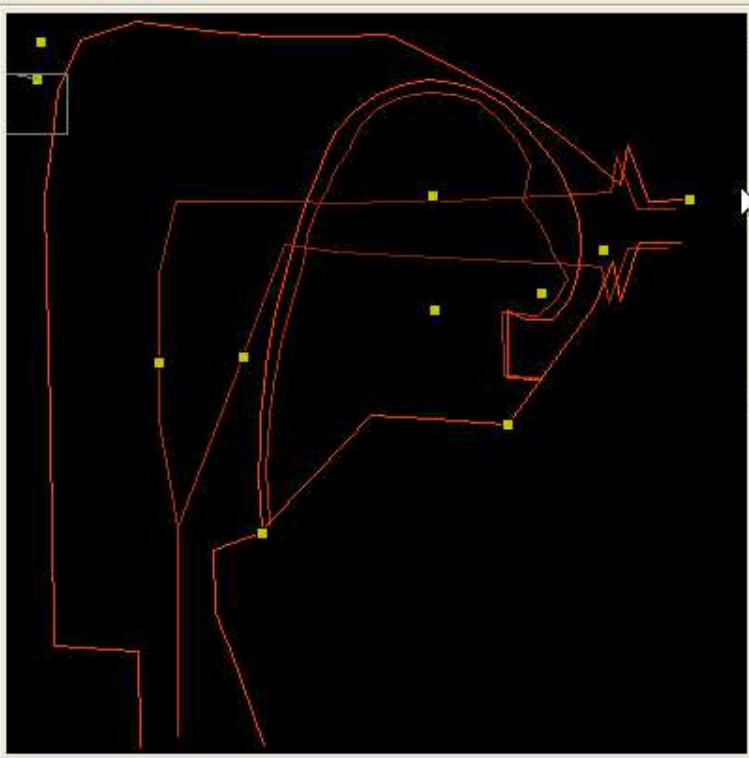
# articulatory manipulation of F3?

- Front vowels: lip configuration
- Next illustration : program Tractsyn, Peter Birkholz, from Germany, available on the web.
- Tongue fixed and in a fronted position .
- Remarks
- 1) the reinforcement of the formant amplitude when the two formants are closed together.
- 2) Two formants closed: two cavities are resonating at the same frequency.

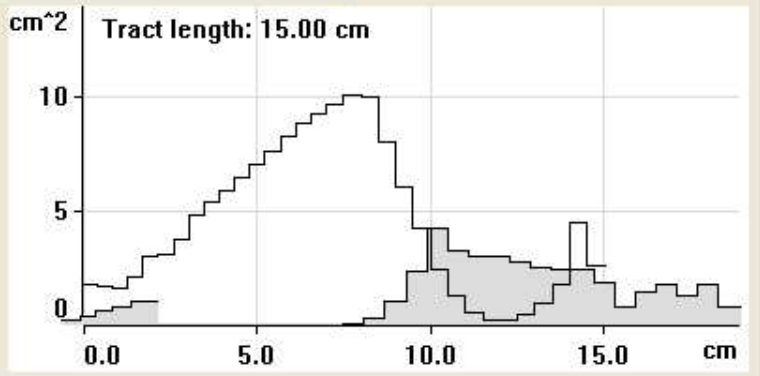
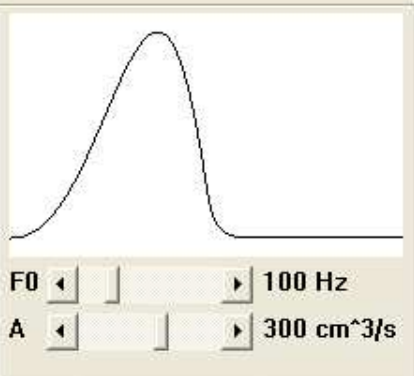
- Visualization**
- 2D
  - 3D one-sided
  - 3D two-sided

- Extras**
- Help lines
  - Control points
  - Cut area
  - Cut vectors
  - Rough center line
  - Final center line

- Test
- Spectrum
- Acoustics
- Pole-zero plan

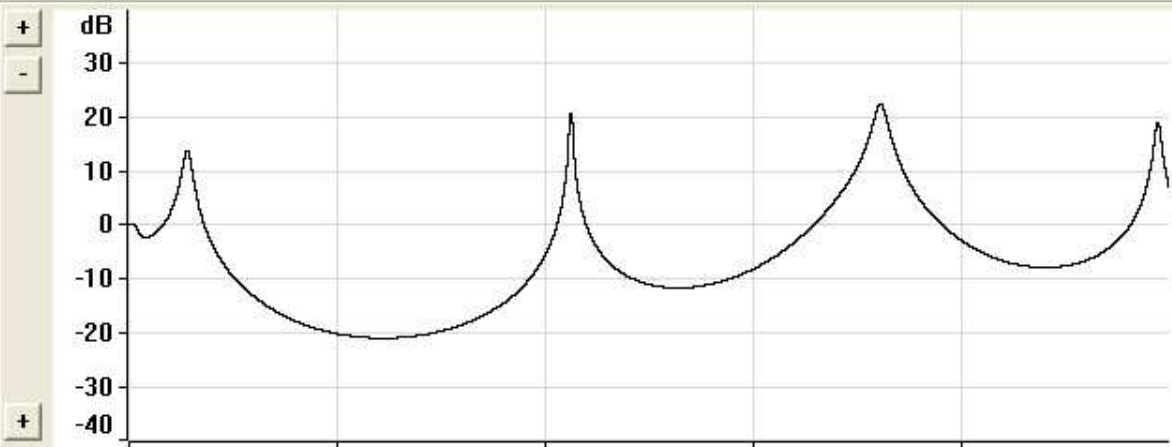


Area: 7.17 cm<sup>2</sup>  
Position: 5.10 cm



- Play all
- Play part
- Record
- Clear all tracks

- Oscil.
- Tract
- Time-sim.
- Seg. model



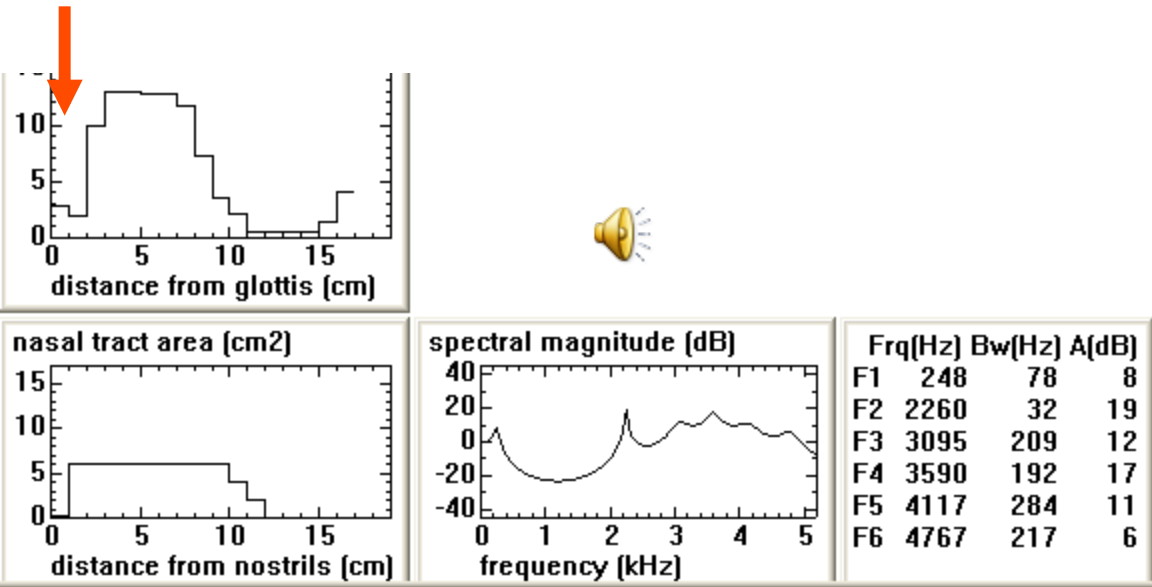
- Sec. spec.:
- 0 +
  - Primary
  - Sekundary
  - P-Z-Spec.
  - Magnitude
  - Phase

# F4

Often considered as being due to the  
laryngeal cavity  
(sometimes F5)

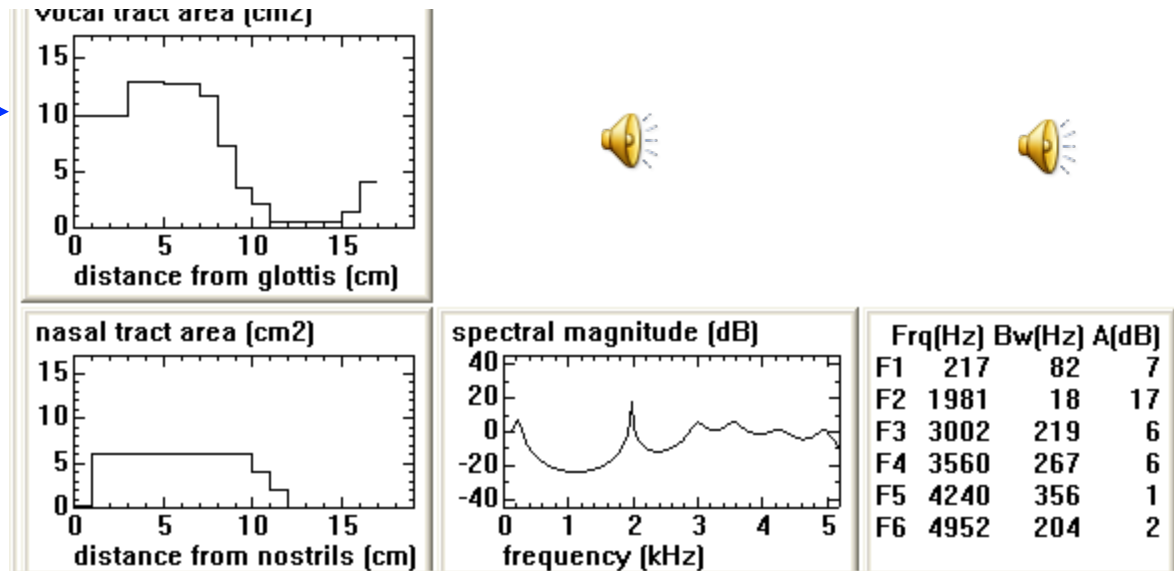


# Laryngeal cavity

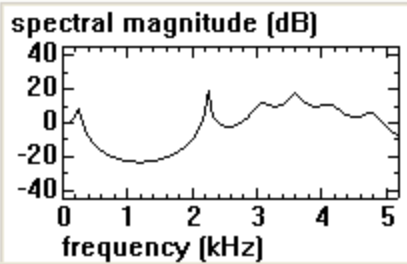
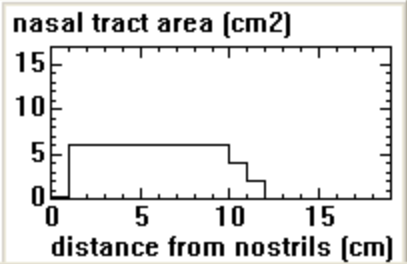
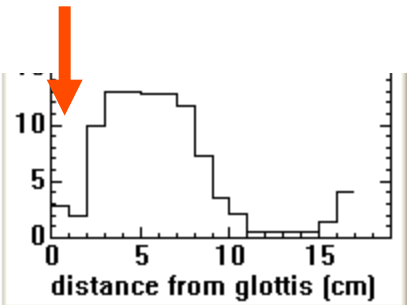


(Fant, Honda, etc.)

Suppression of the laryngeal cavity



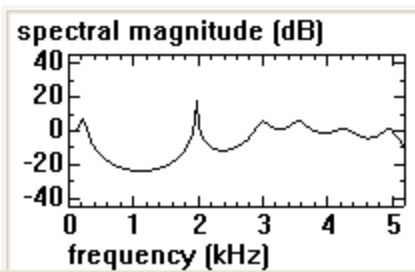
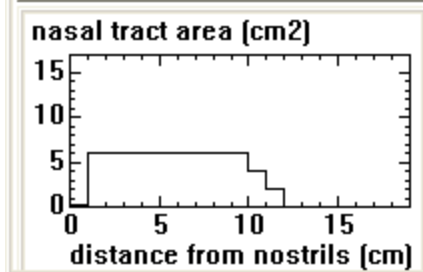
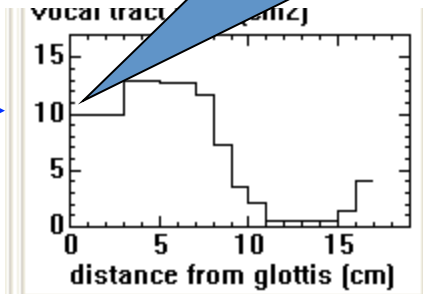
# Laryngeal cavity



Frq(Hz)	Bw(Hz)	A(dB)
F1	248	78
F2	2260	32
F3	3095	209
F4	3590	192
F5	4117	284
F6	4767	217

Suppression of the laryngeal cavity:  
sounds more dull

Suppression of the laryngeal cavity



Frq(Hz)	Bw(Hz)	A(dB)
F1	217	82
F2	1981	18
F3	3002	219
F4	3560	267
F5	4240	356
F6	4952	204



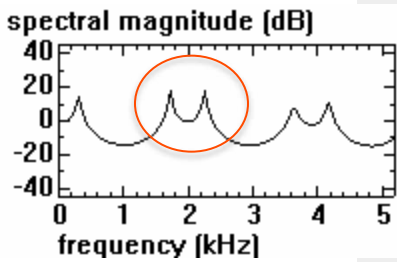
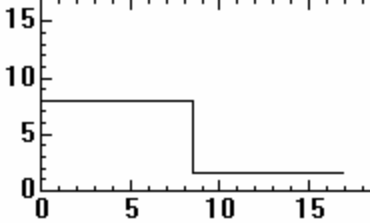
# $(F_n F_{n+1})$

Regrouping of two consecutive formants

- Reinforcement of their amplitude
  - >more perceptual weight + perceptual integration
- >masking of surrounding formants

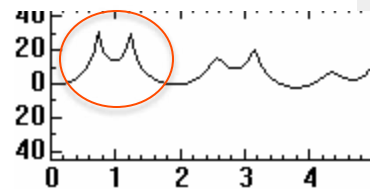
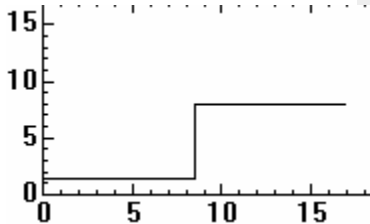


# Grouping of formants? How to do?

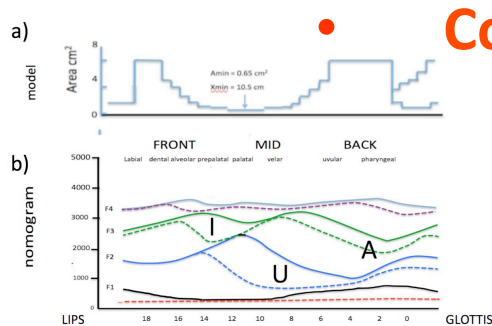


Only when there is a strong constriction along the VT to separate two cavities or when two cavities are of very different cross sections, they are acoustically decoupled and then

- when the whole VT and the lips are configured so that one resonance of one cavity is tuned to the resonance of the second cavity.
- Then the vowel is said « focal »



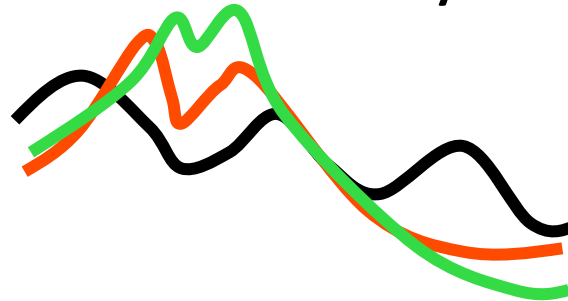
# Very special points



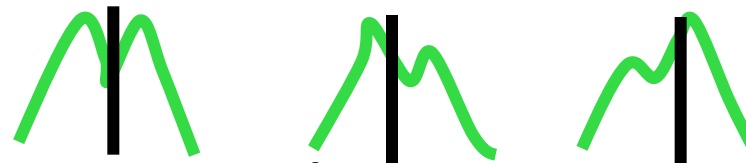
## Converging formants

create a spectral prominence

zones of stability for the formants concerned (Stevens)



increase of the two formants amplitude



perceptual integration perceived as a single peak

very sensitive to lip rounding

two cavities that resonance at the same frequencies





# Intermediate summary

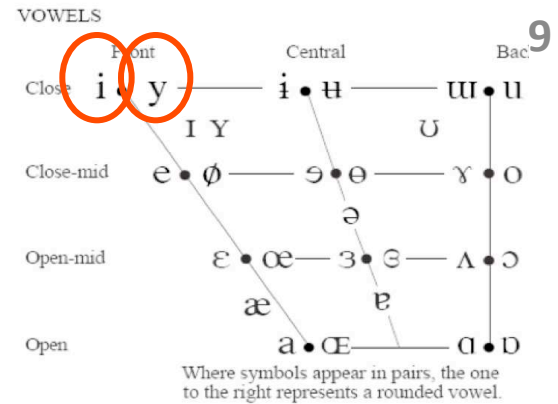
- F1 = « height »
  - place of articulation, degree of constriction and lip configuration
- F2
  - place of articulation, the degree of constriction
  - for the velar and laryngeal vowels, lip configuration
- F3
  - for the velar and palatal vowels, lip configuration
- F4
  - increases the acuteness of the /i/ timber
  - (F3F4) for the cardinal vowel /i/.



**focal vowels** very special (perceptually)

- 1) introduction
- 2) IPA chart and cardinal vowels
- 3) Some remarks on the formants
- 4) Acoustic characteristics of some DJ's and PL's cardinal vowels
- 5) From vowels to glides to consonants and processes
- 6) Conclusions





# Acoustic characteristics of some DJ's and PL's cardinal vowels

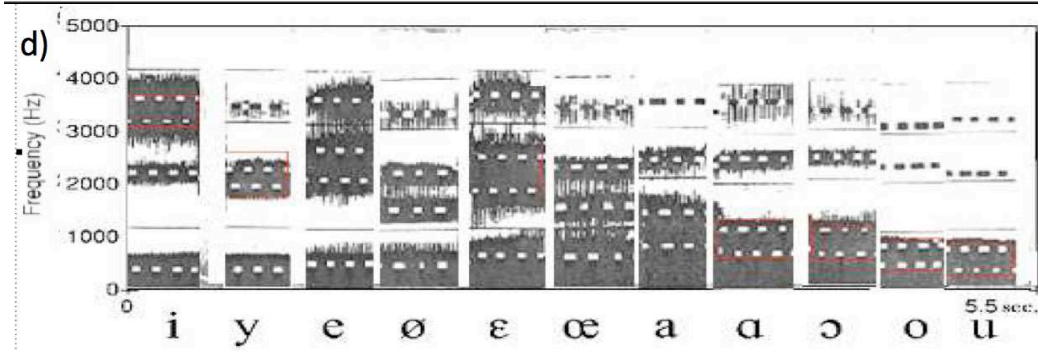
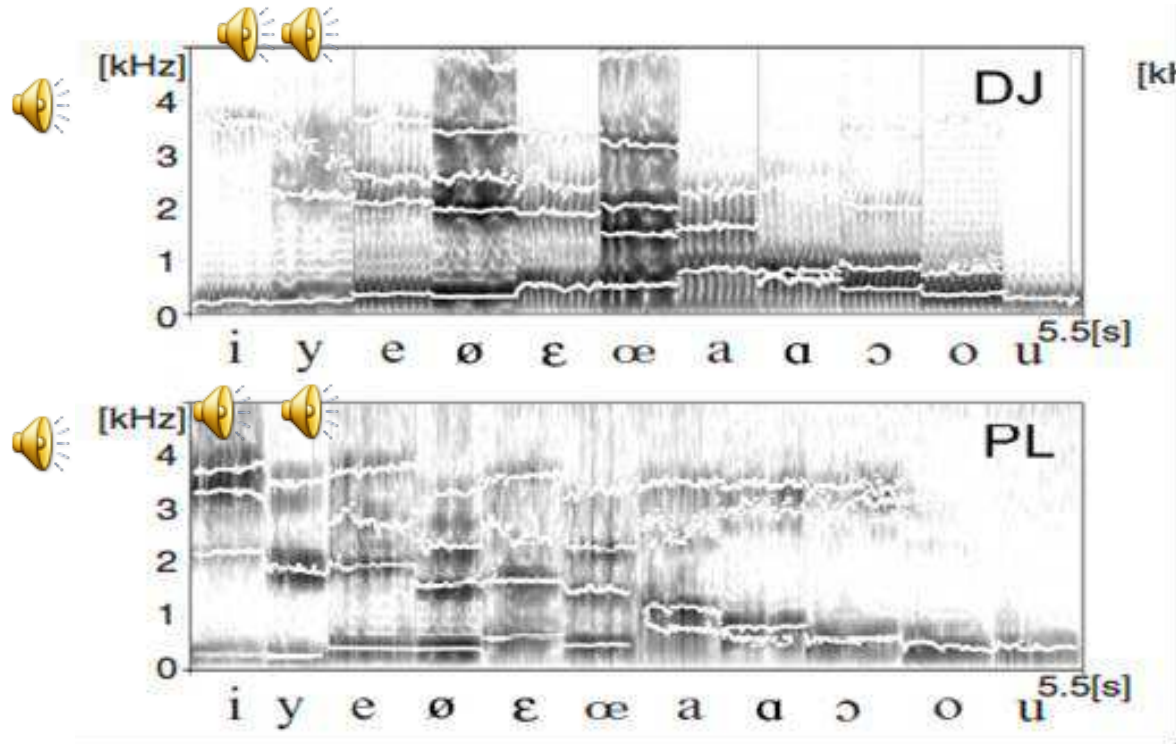
1) The cardinal vowel 1 and the cardinal vowel 9

are (F3F4) and (F2F3) **focal vowels**

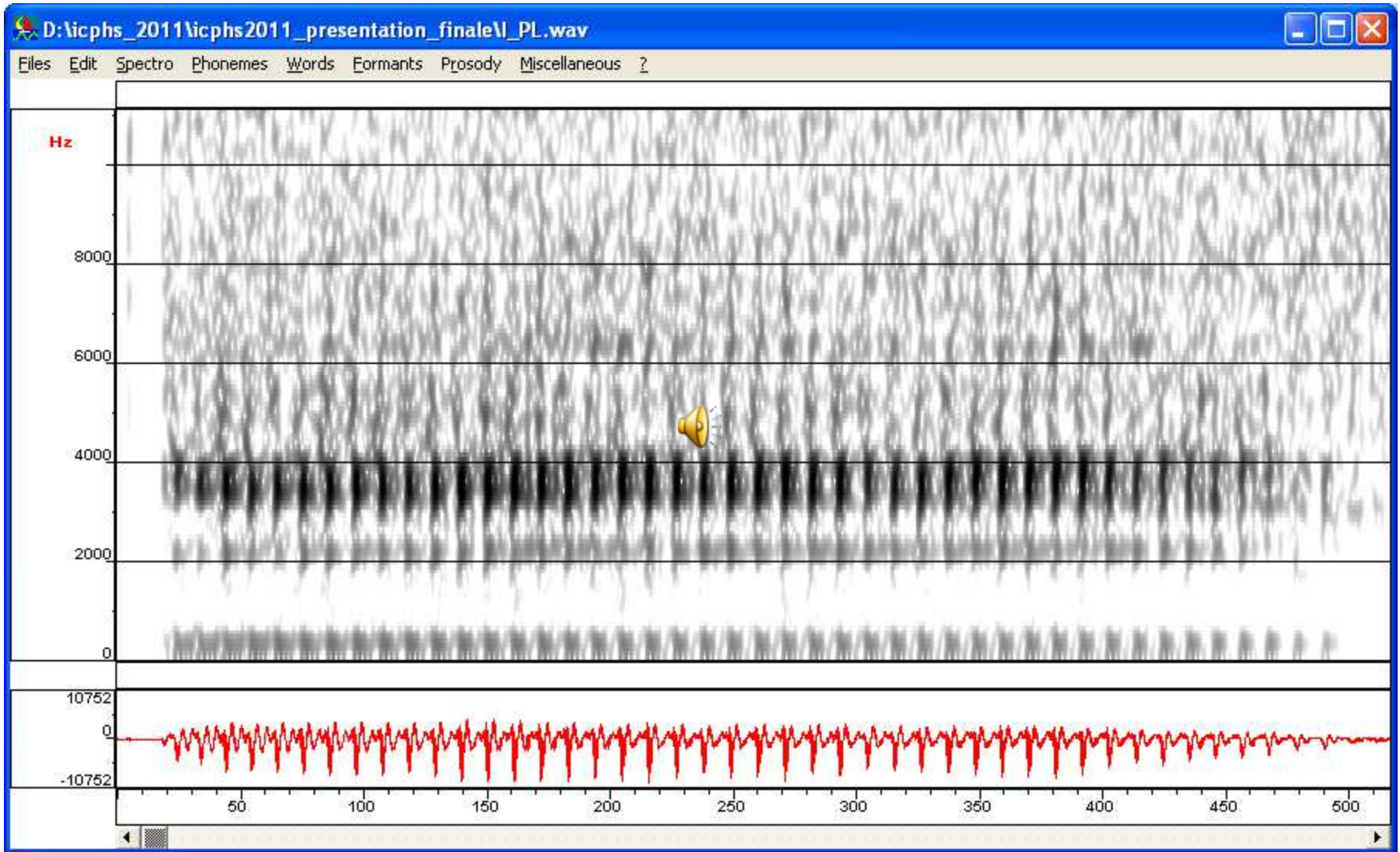




# Jones's and Ladefoged's rendition and the French vowels

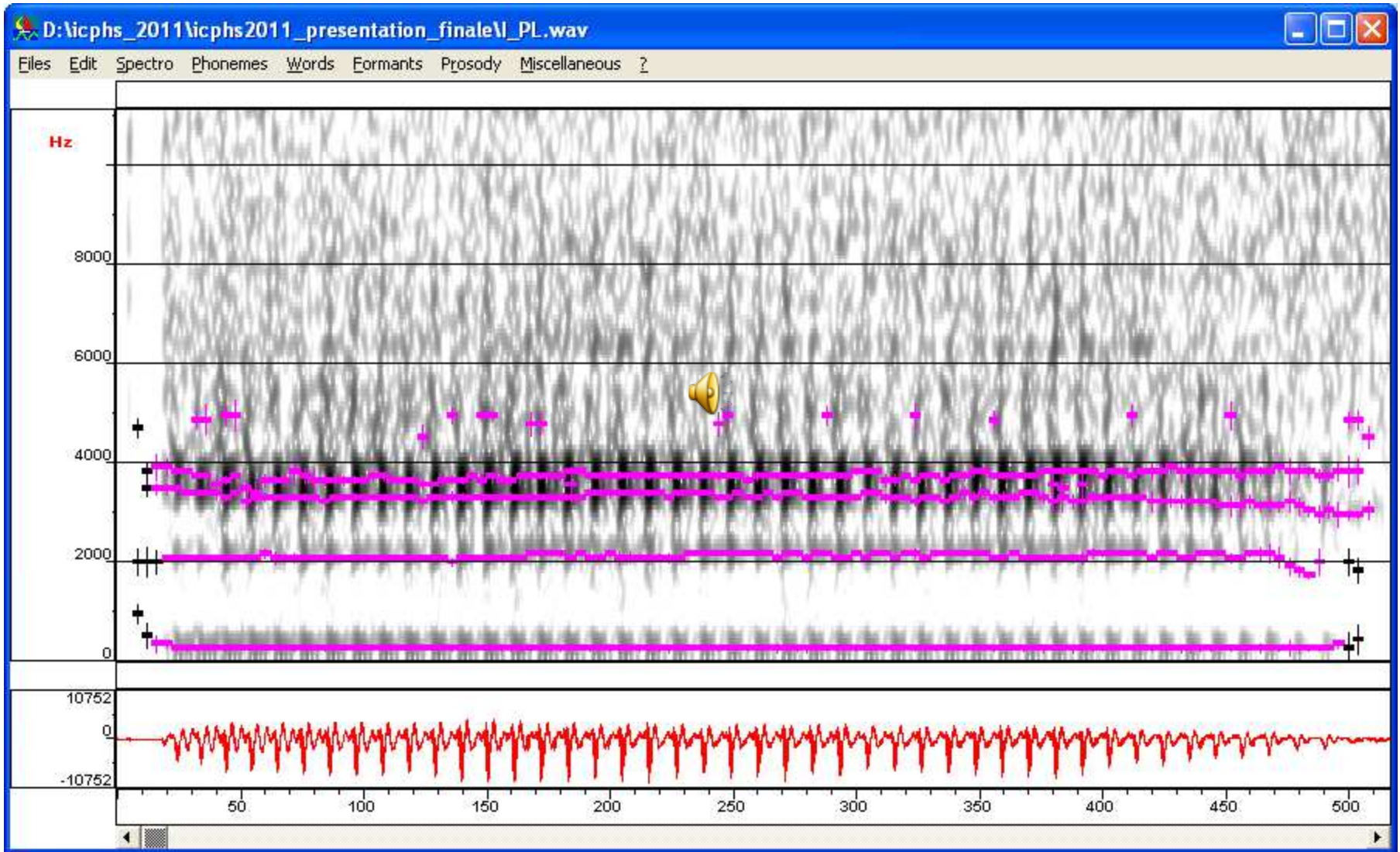


Lienard's book



Peter Ladefoged's cardinal vowel /i/ (F3F4)

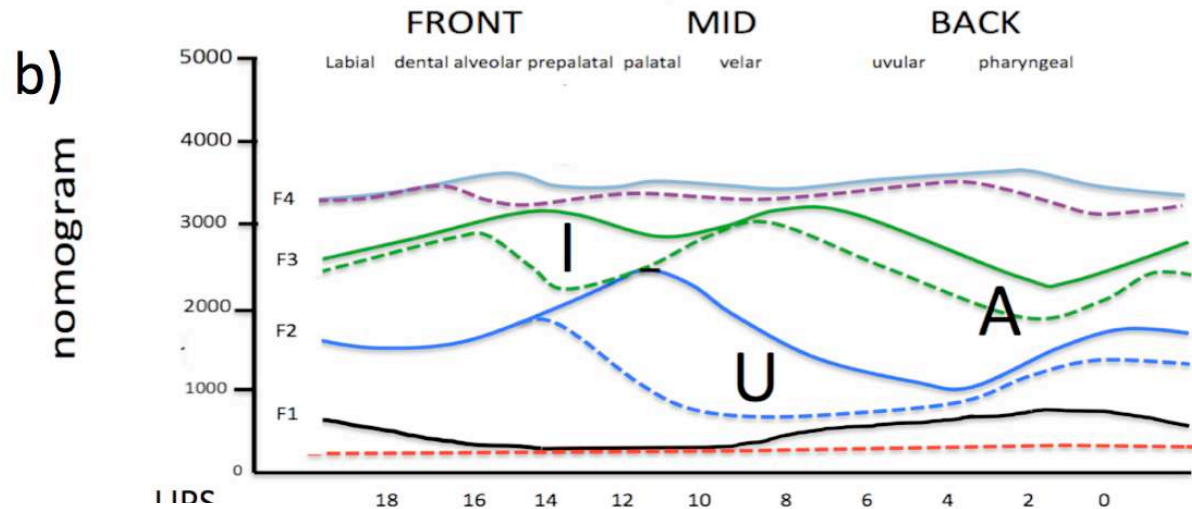
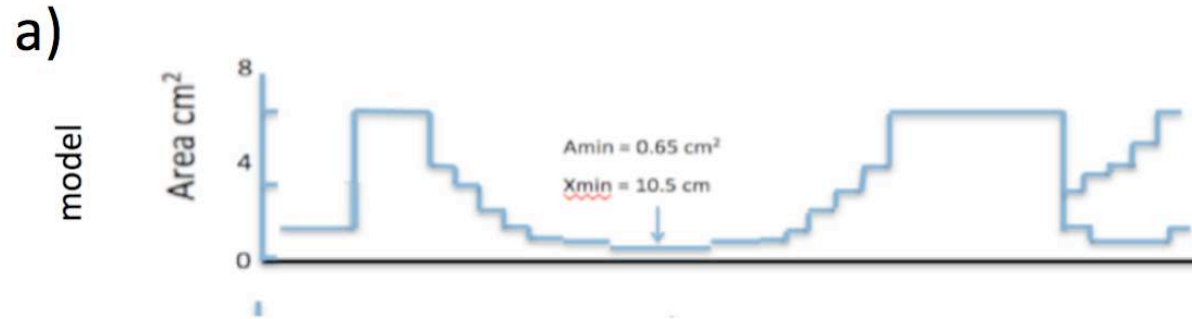




Peter Ladefoged's cardinal vowel /i/ (F3F4)

# Focal vowels from nomograms

2



lip

glottis



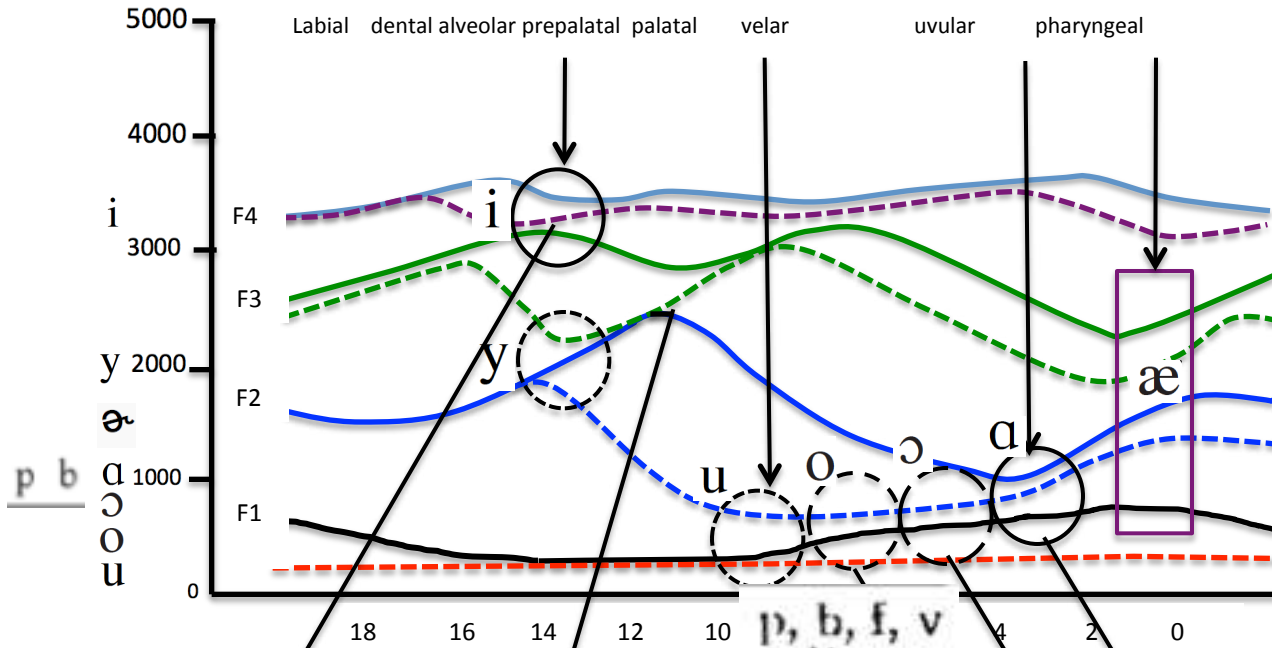
As vague region (quantal theory)

FRONT

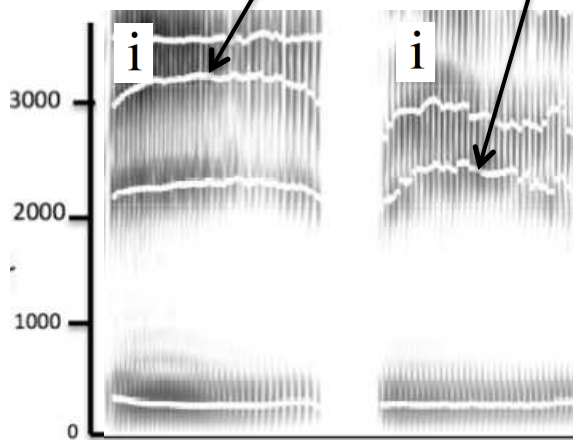
MID

BACK

Labial dental alveolar prepalatal palatal velar uvular pharyngeal

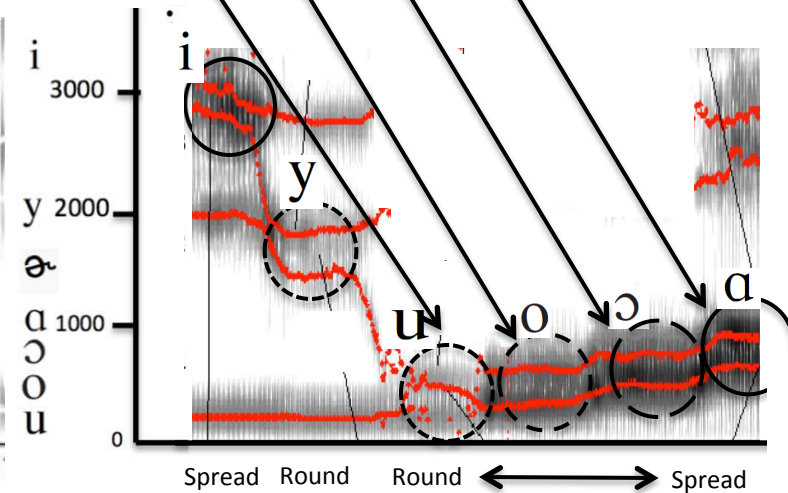


Prepalatal (sharp, F3max) and Palatal (dull, F2max) /i/s

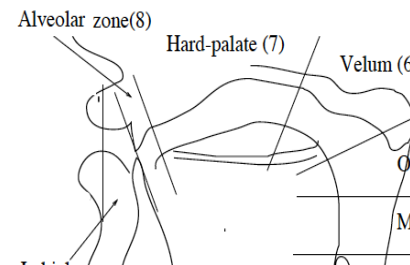


Prepalatal

Palatal



As well defined region



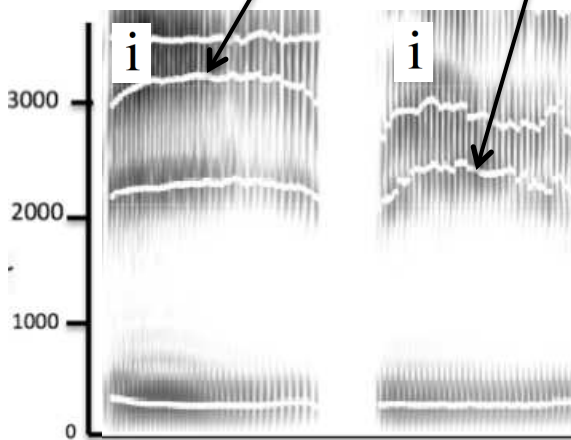
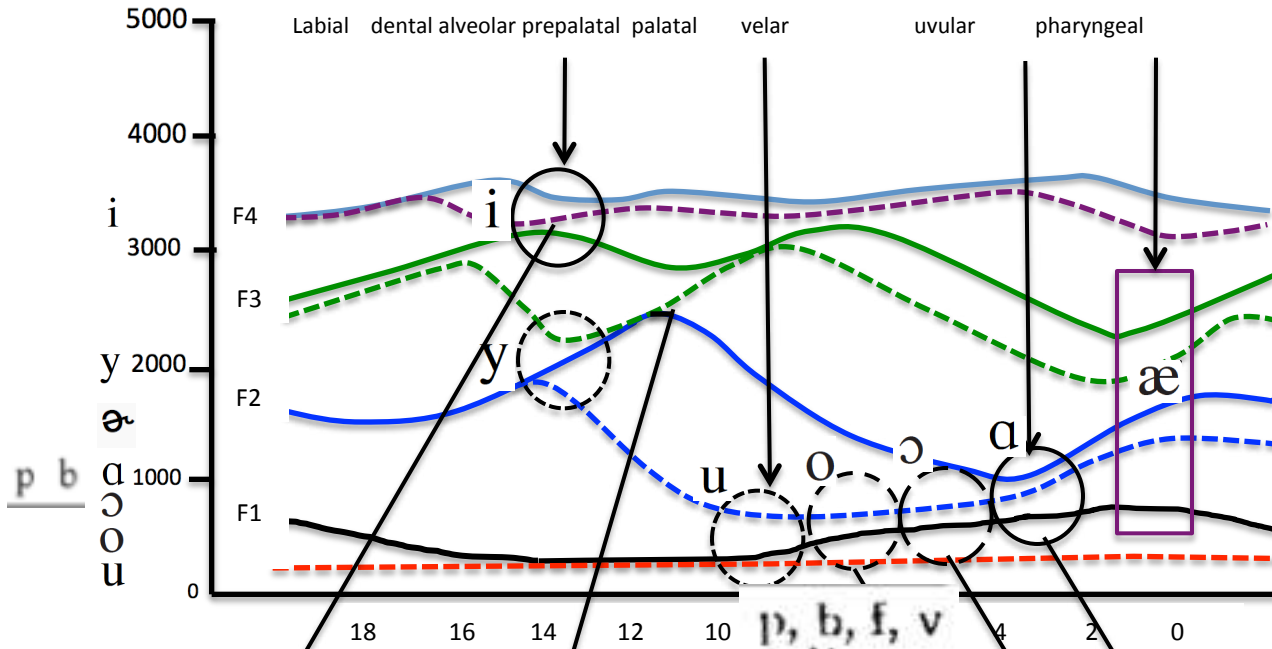


FRONT

MID

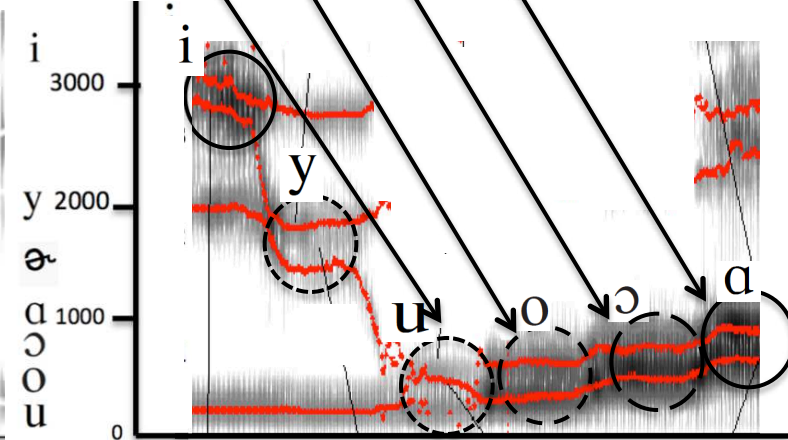
BACK

Labial dental alveolar prepalatal palatal velar uvular pharyngeal



Am.E. /i:/

Br.E. /i:/



Spread Round Round ← → Spread



BH

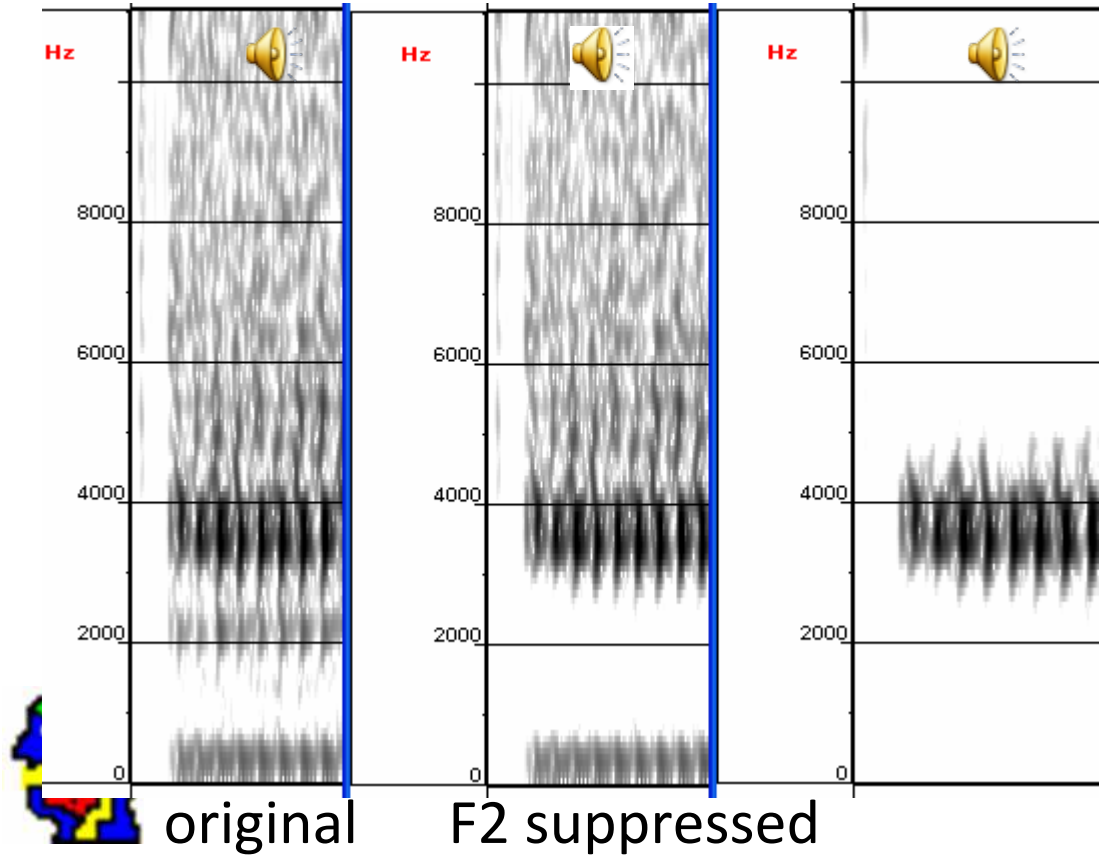
PL

Alveolar zone(8)

Hard-palate (7)

Velum (6)

# The (↑F3F4) vowel



## Comparison 8 languages

/i/

French /i/: the shorter distance between F3 and F4

To create a strong concentration of energy in the high frequencies

	F1	F2	F3	F4	F4 – F3
German	319 (70)	1991 (222)	2610 (239)	3621 (248)	1012 (269)
English	352 (61)	2044 (186)	2503 (199)	3442 (225)	939 (244)
Arabic	398 (130)	2102 (169)	2678 (141)	3364 (295)	686 (258)
Spanish	375 (57)	2126 (155)	2784 (149)	3634 (126)	851 (226)
<b>French</b>	<b>302 (87)</b>	<b>2024 (158)</b>	<b>2848 (228)</b>	<b>3494 (258)</b>	<b>646 (230)</b>
Italian	347 (61)	2065 (231)	2693 (236)	3589 (400)	895 (301)
Mandarin	360 (109)	2132 (358)	2836 (290)	3644 (265)	809 (304)
Portuguese	344 (67)	1906 (185)	2503 (277)	3576 (277)	1075 (329)



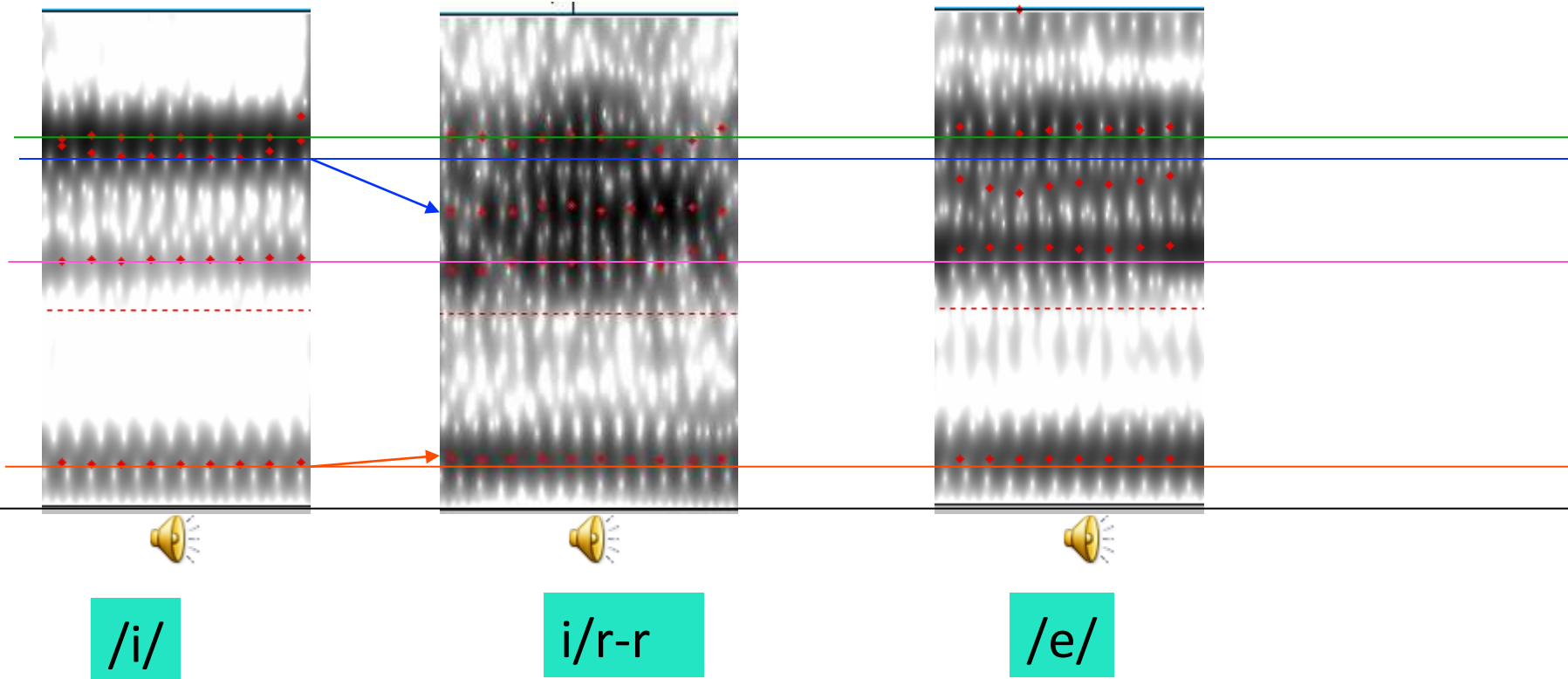


# Is ( $\uparrow$ F3F4) vowel more stable?

- Yes and no
- No: F3 depends in the length of the front cavity, so it is sensitive to tongue backing and lip rounding,
- Yes: F1 and F2 are stable (quantal theory)
- But acoustically sharper, auditory sharpness seems more important than articulatory stability



# 1) F3 sensibility to tongue backing



Extracted /i/ portion in “rire” (laugh) is heard as /e/



F3, due to the front cavity, is very sensitive to the length of the front cavity, so to the front-back position



## Is ( $\uparrow$ F3F4) vowel more stable?

- Yes and no
- F3 depends in the length of the front cavity, so it is sensitive to tongue backing and lip rounding.



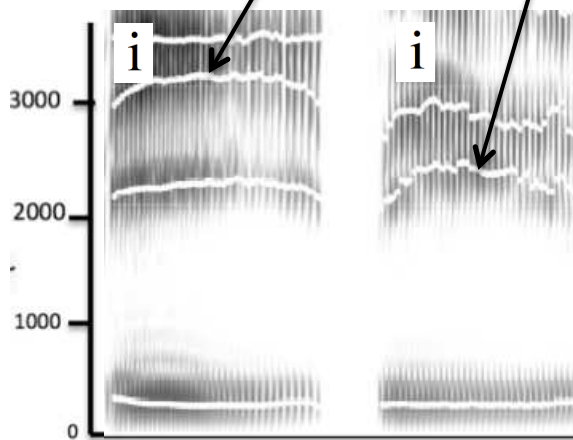
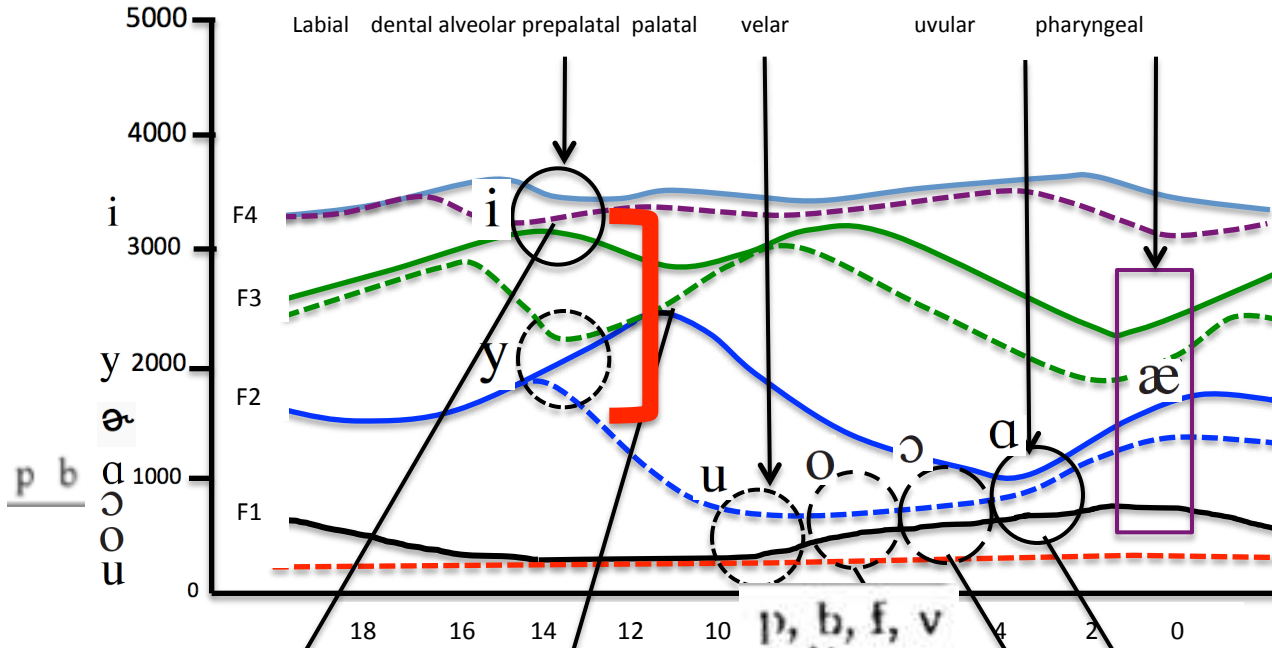
- The language exploits the extreme sensitivity to front cavity length... for the creation of cardinal /y/



FRONT

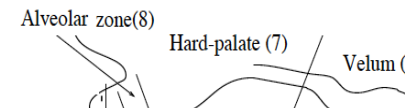
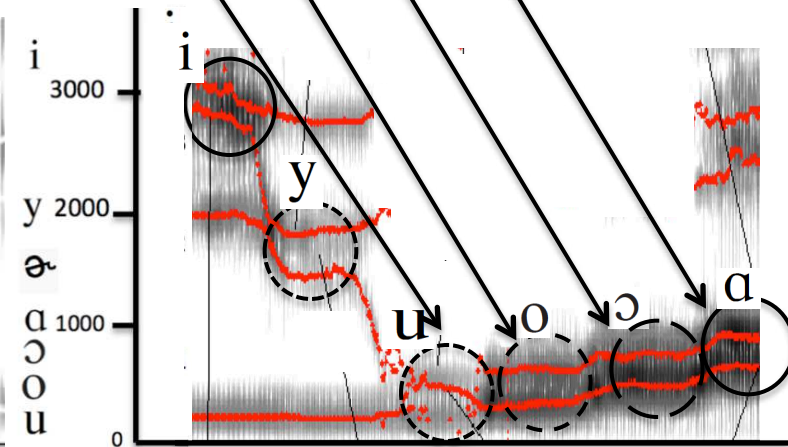
MID

BACK



Am.E. /i:/

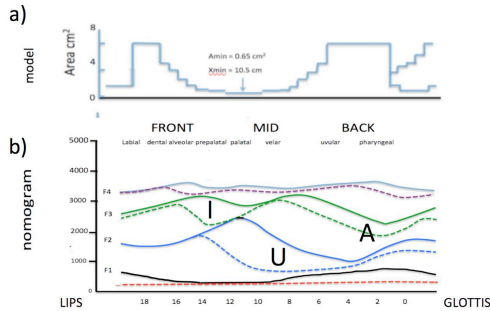
Br.E. /i:/



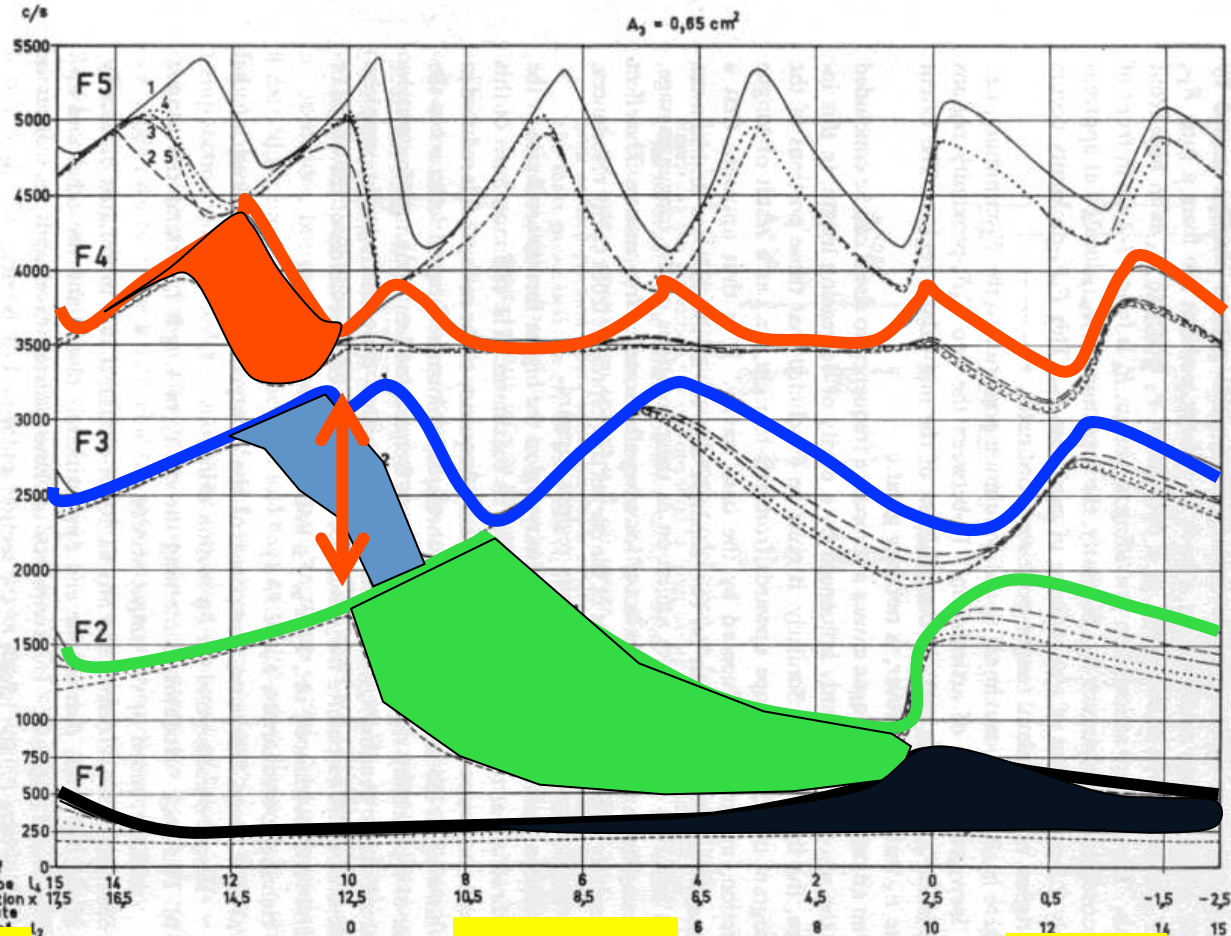




# From cardinal /i/ to cardinal /y/



**Prepalatal /i/  
Very very sensitive  
To lip configuration**



**front**

**central**

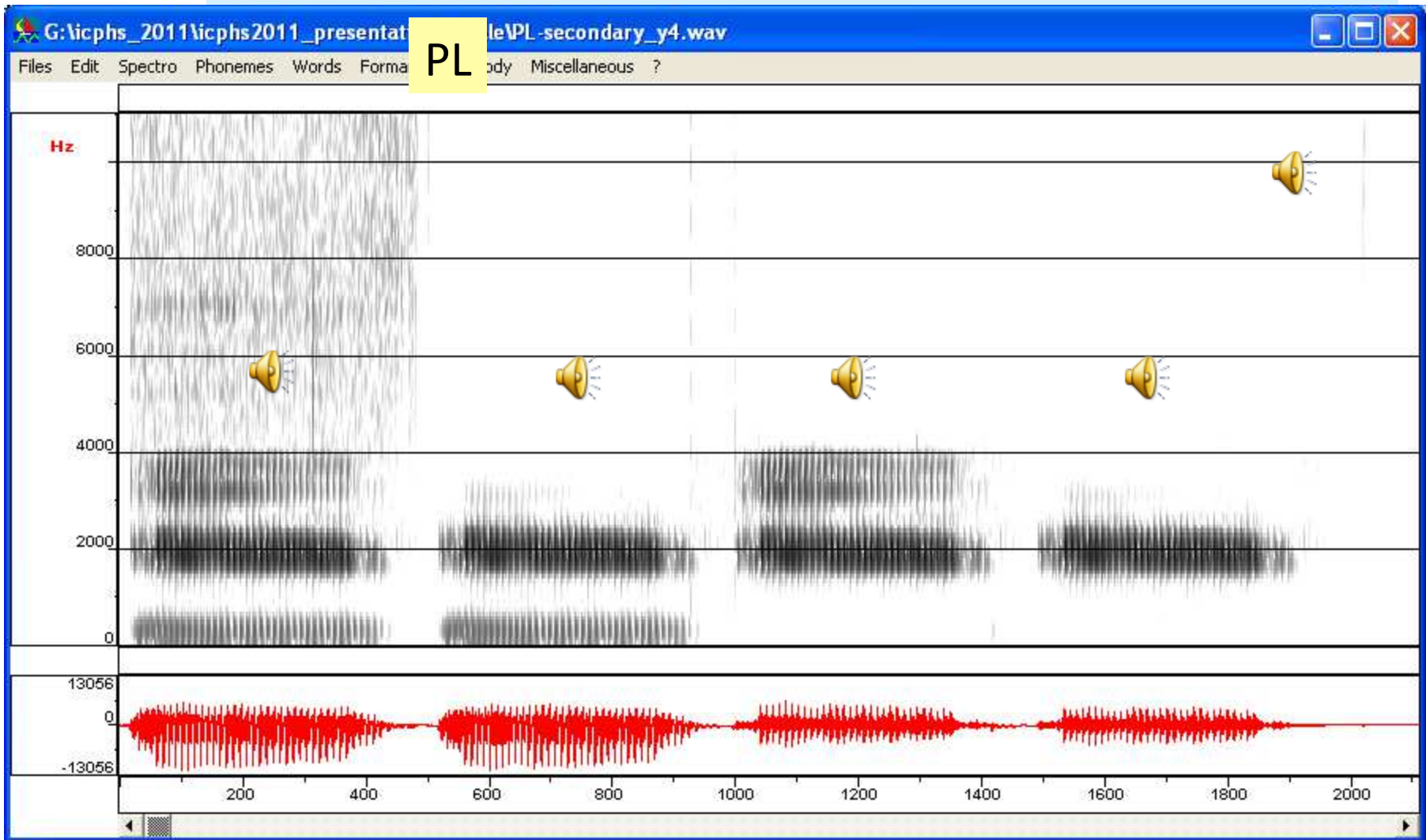
**back**

Fig. 1.4-9. Nomograms relating  $F_1, F_2, F_3, F_4,$  and  $F_5$  to the length of the back tube  $L_2$  and the cross-sectional area  $A_3$  of the constriction: a) Tongue position: cross-sectional area  $A_3 = 0.65 \text{ cm}^2$ ;

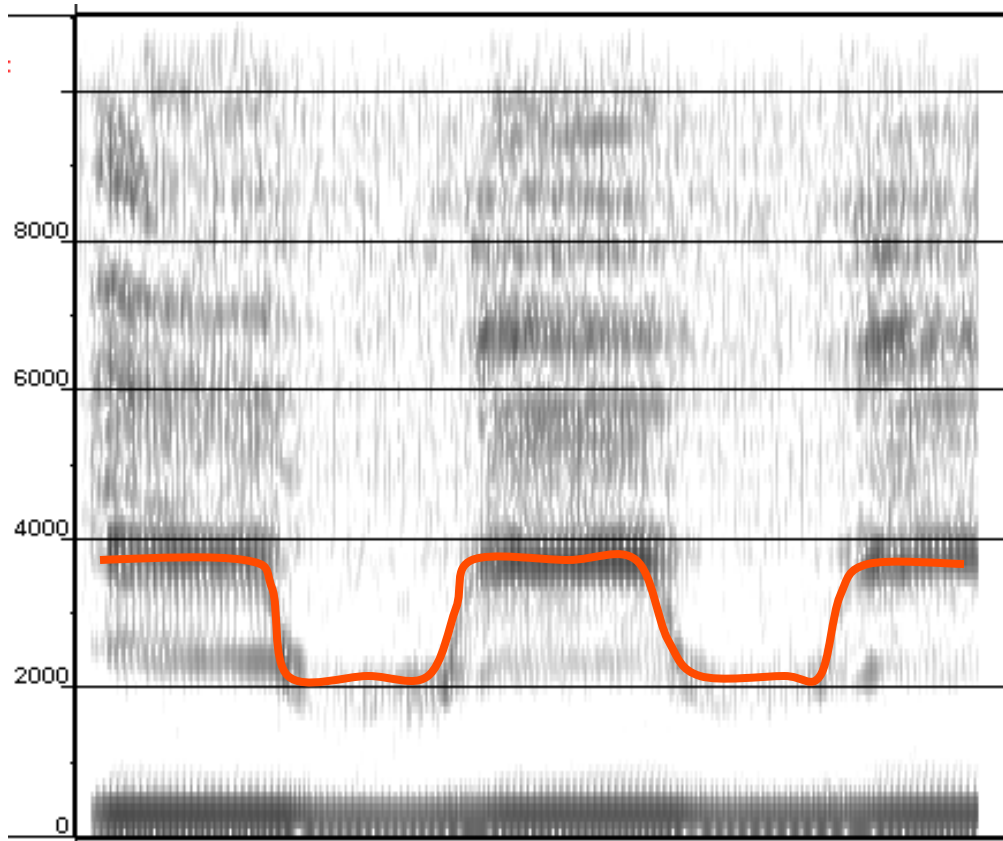




/y/



# Some language explore the sensibility of F3 to lip configuration



( F2. F3 )



- Cardinal /i/ and cardinal /y/ have a similar (very low) F1
- And close F2 (for some speakers, similar).
- F3 plays the main (distinctive) role between /i/ and /y/

# Links done between

/i/

articulatory

acoustic

perceptual

## Cardinal /i/ (↑F3F4)

46 COMPARING VOCALIC FEATURES

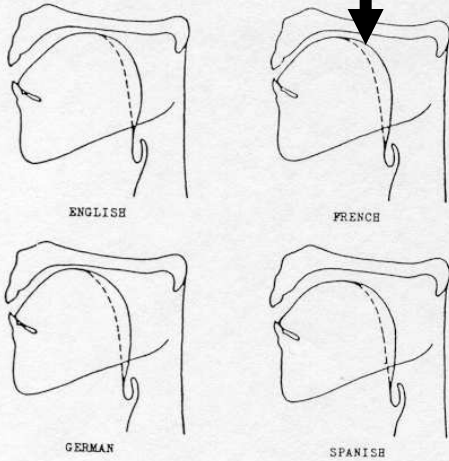
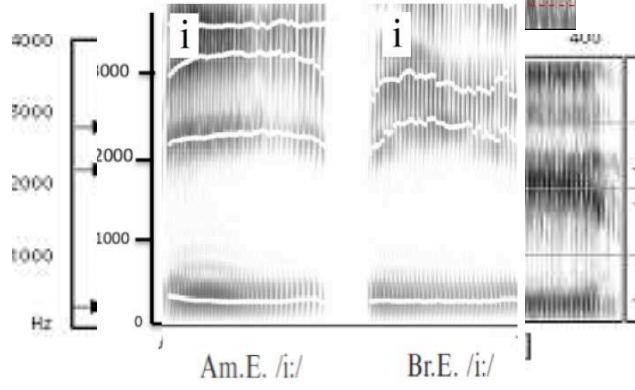
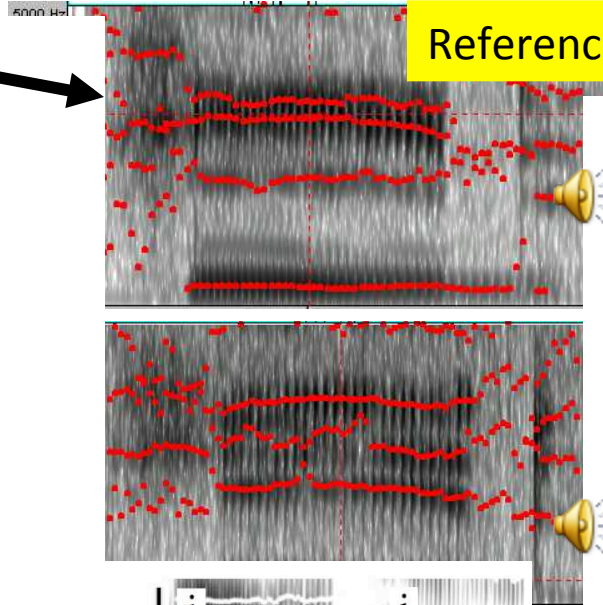


Figure 1. An example of what motion-picture X-ray can show which still X-cannot: the characteristic articulatory profiles of the vowel /i/ in English, German and Spanish, obtained by cineradiography, averaging several subjects in each language. Closure of the jaws (at the teeth) is narrower in French and German than in English and Spanish. Tongue constriction at the palate is narrower in English and German than in French and Spanish. The front cavity is characterized in English and German by a conical shape - tongue parallel to palate. The back cavity is larger in French and German than in English and Spanish.



Delattre



Wev UCLA

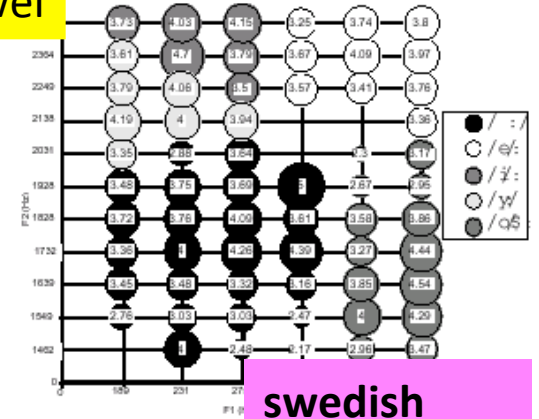
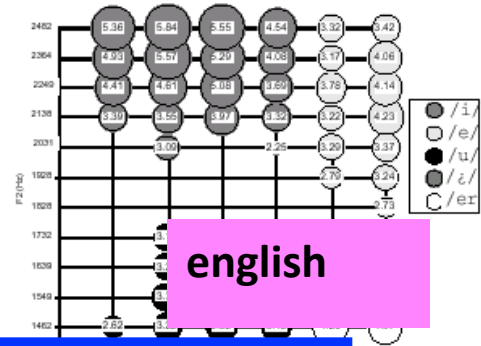
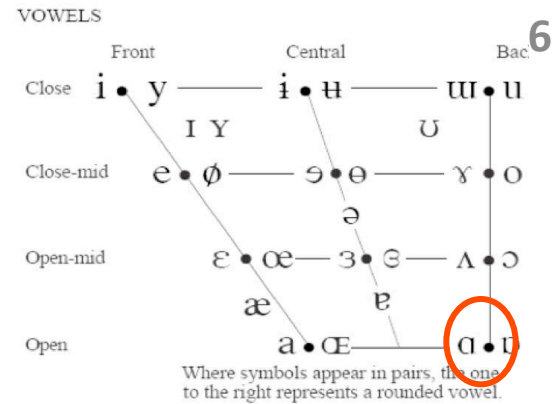


Figure 4: Swedish listener ratings.



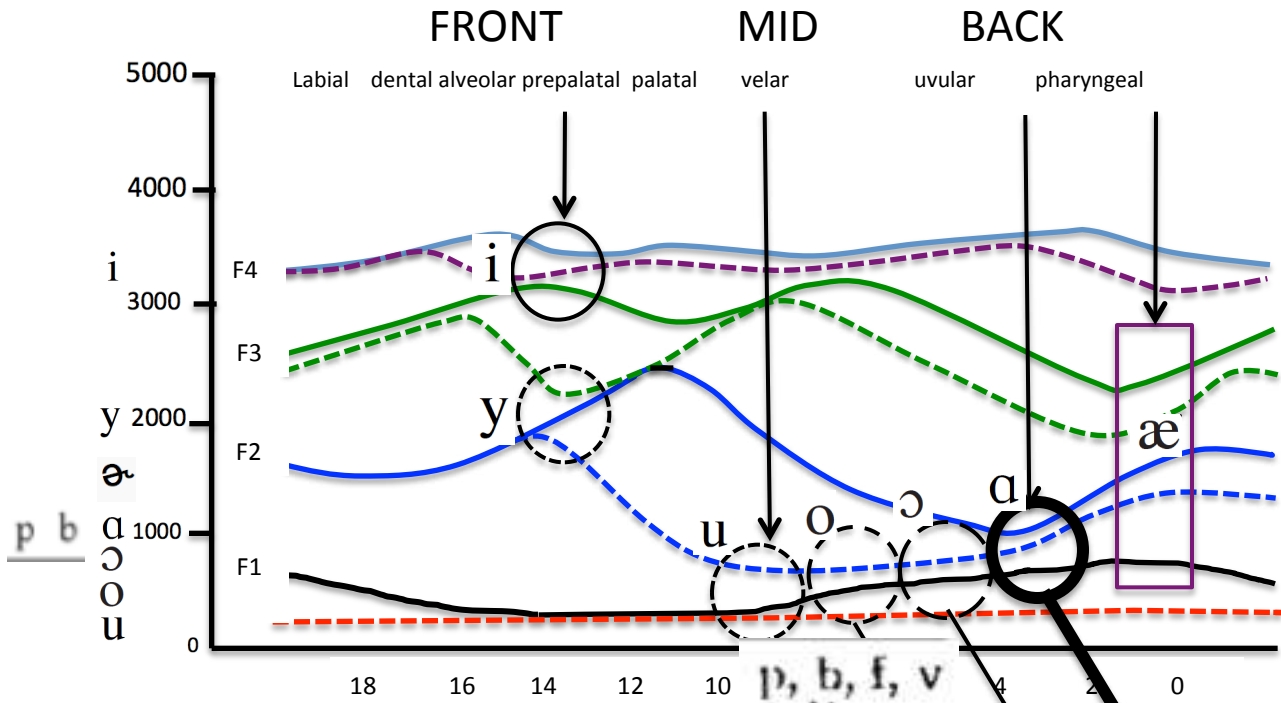
Willerman and Kuhl



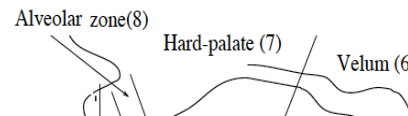
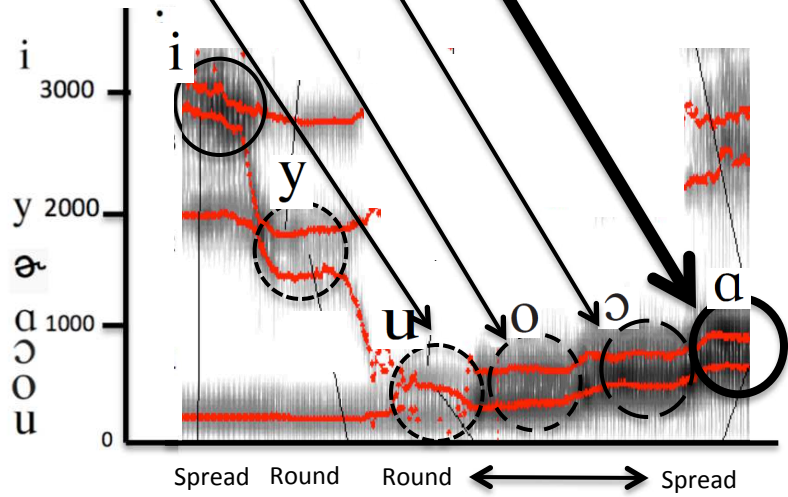
# Acoustic characteristics of some the cardinal vowels

- 1) The cardinal vowel 1 and the cardinal vowel 9
- 1) The cardinal vowel 5

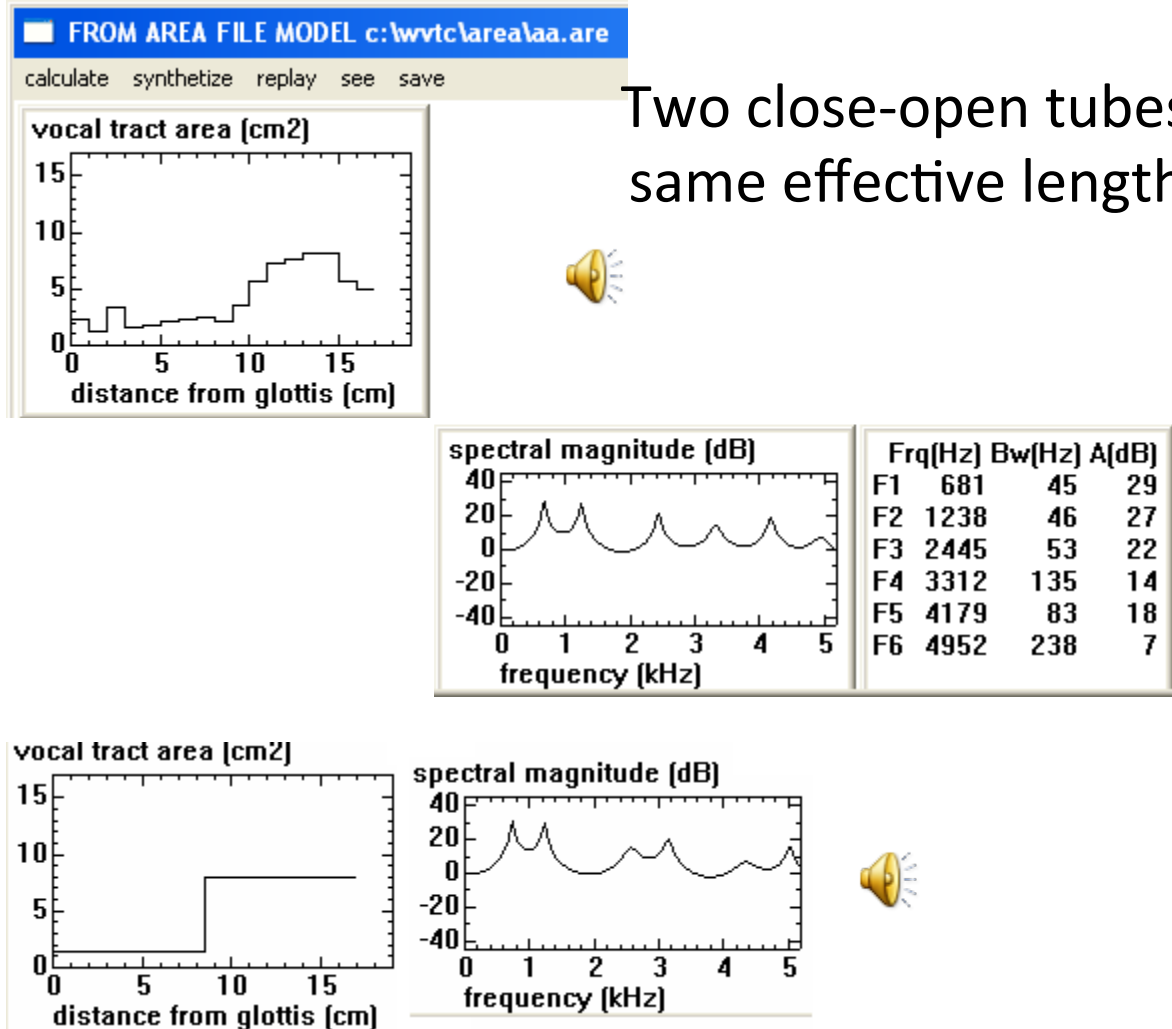


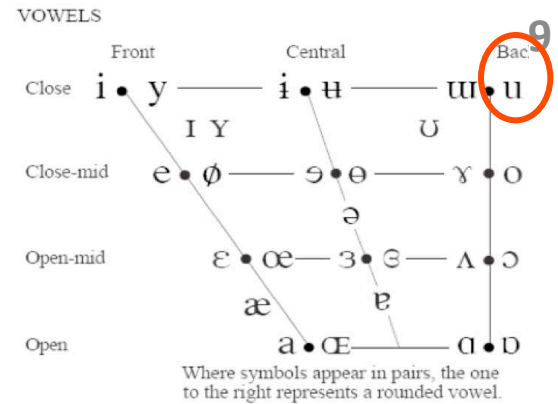


(F1F2) as high as possible



# [a] from area file model



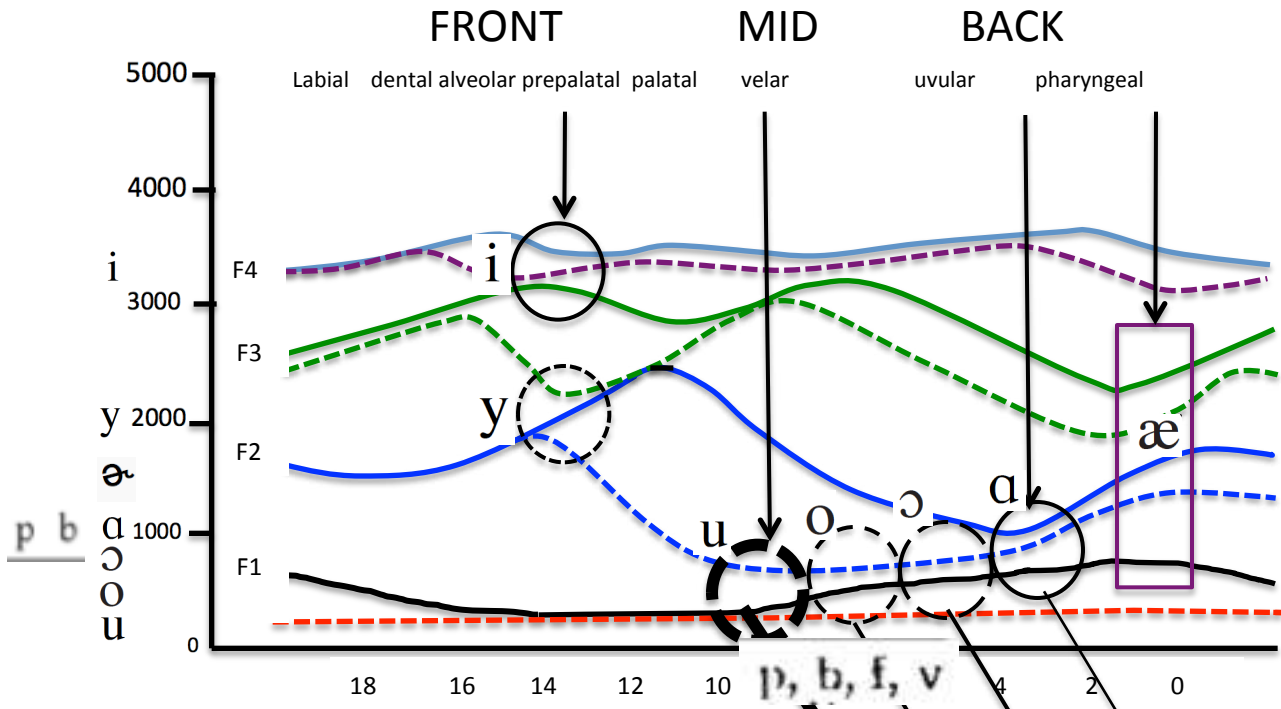


# Acoustic characteristics of some the cardinal vowels

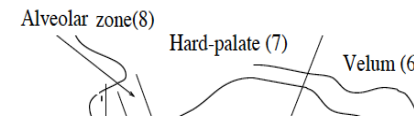
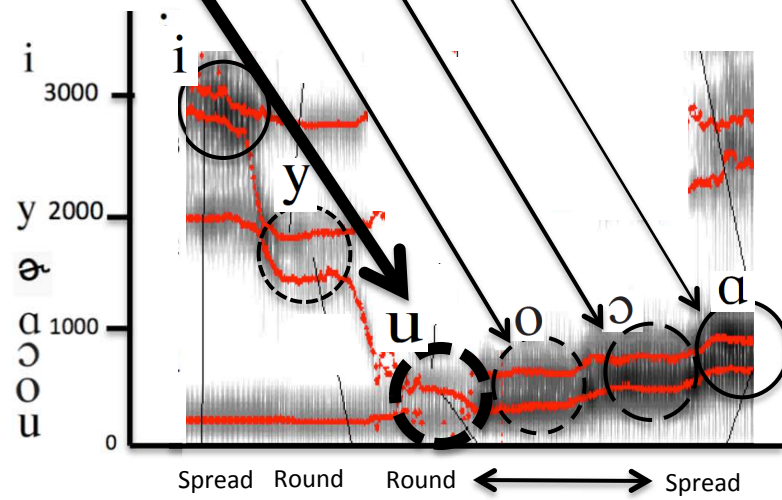
- 1) The cardinal vowel 1 and the cardinal vowel 9
- 1) The cardinal vowel 5
- 2) The cardinal vowel 8







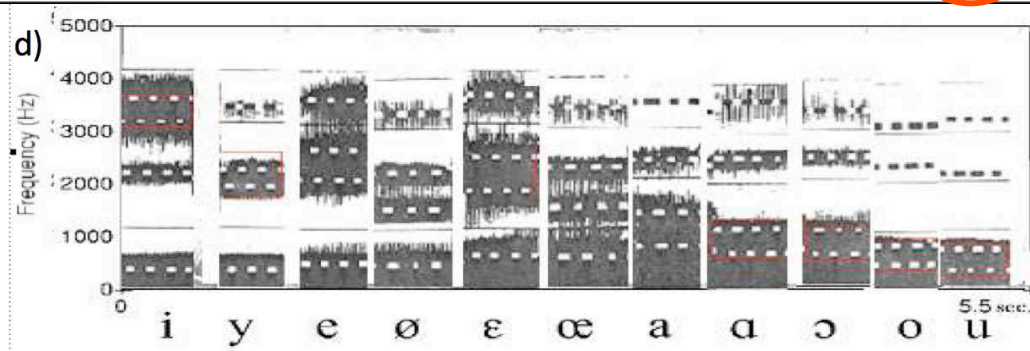
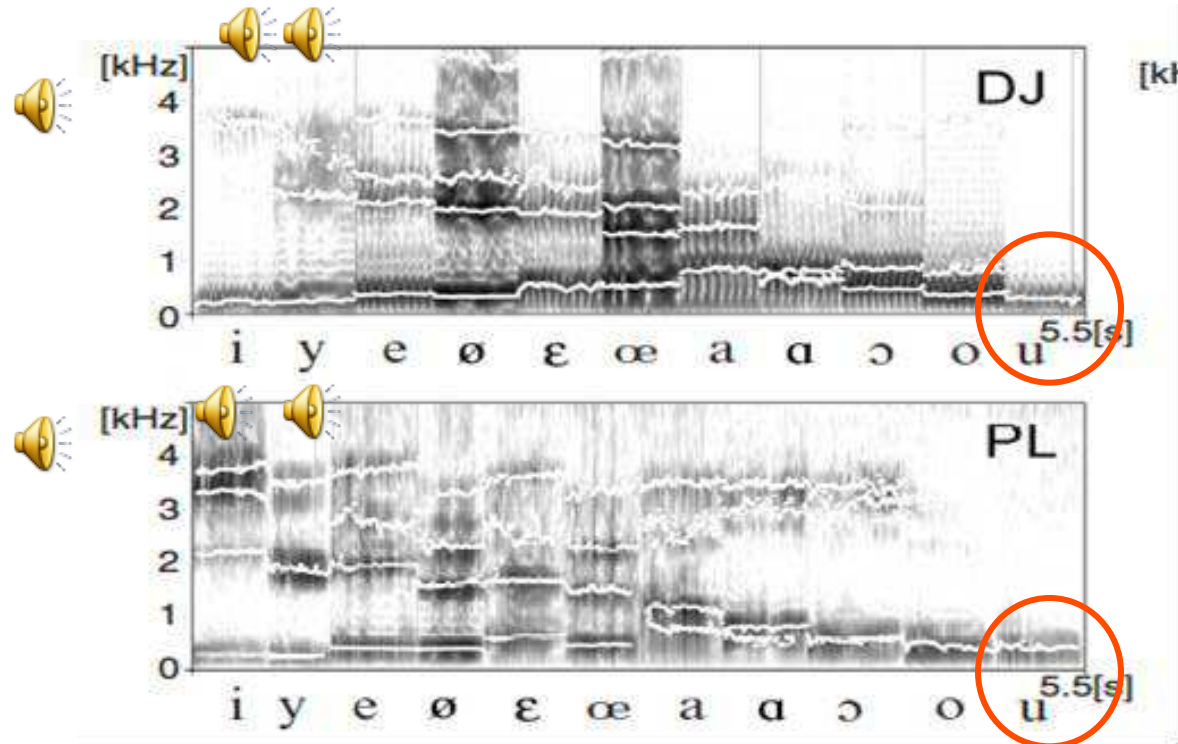
(F1F2) as low as possible

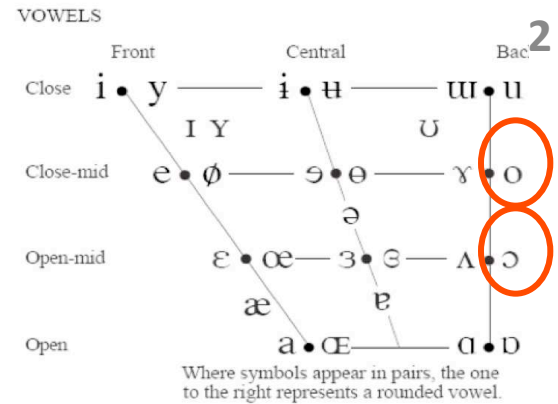






# Jones's and Ladefoged's rendition and the French vowels

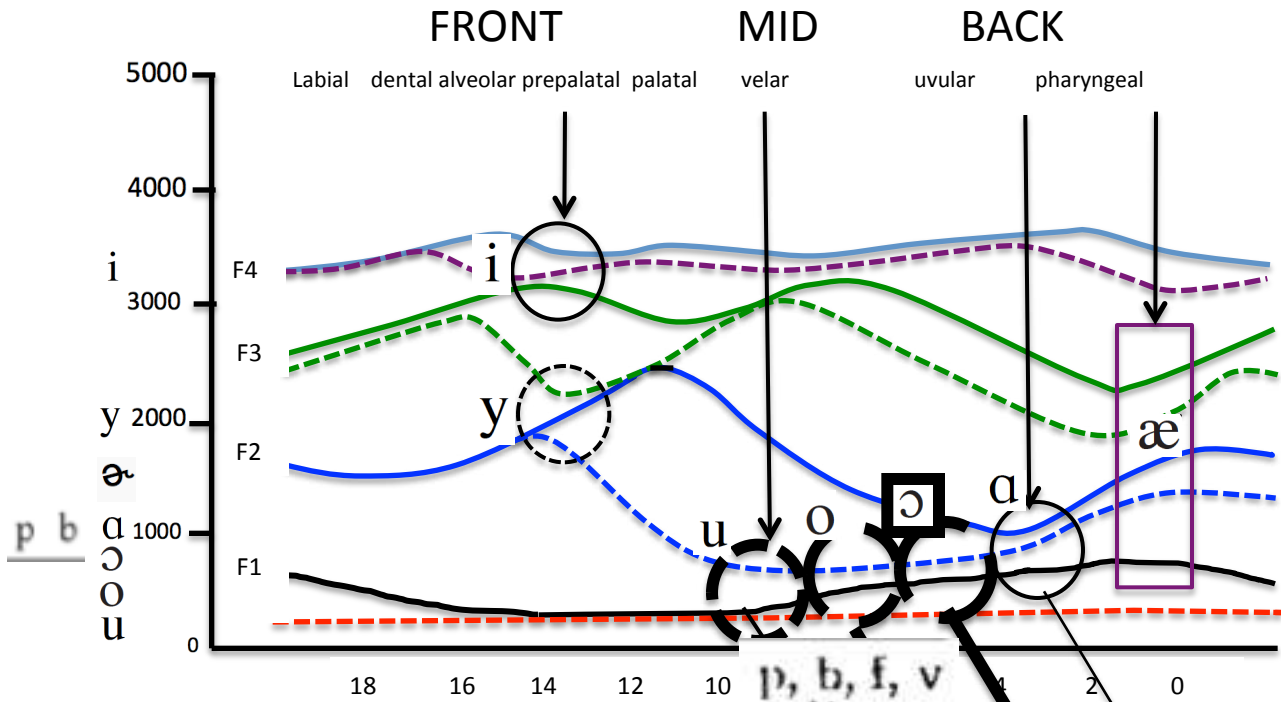




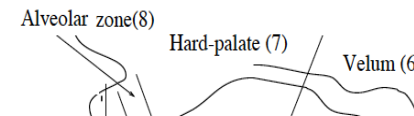
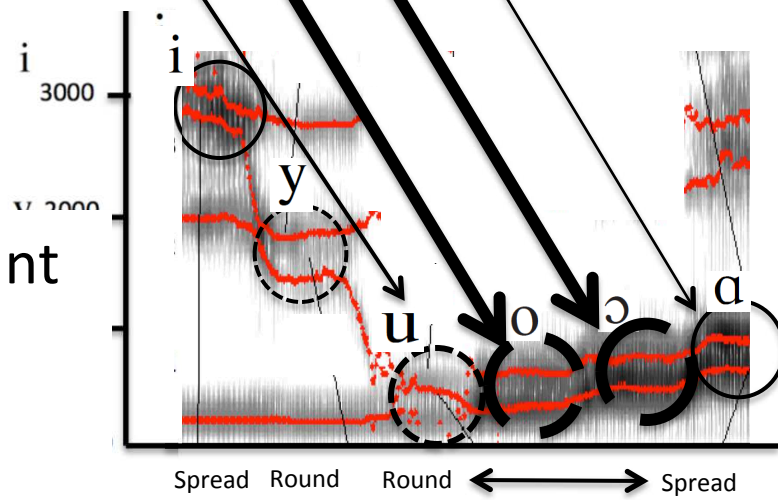
# Acoustic characteristics of some the cardinal vowels

- 1) The cardinal vowel 1 and the cardinal vowel 9
- 2) The cardinal vowel 5
- 3) The cardinal vowel 8
- 4) The cardinal vowels 6 and 7





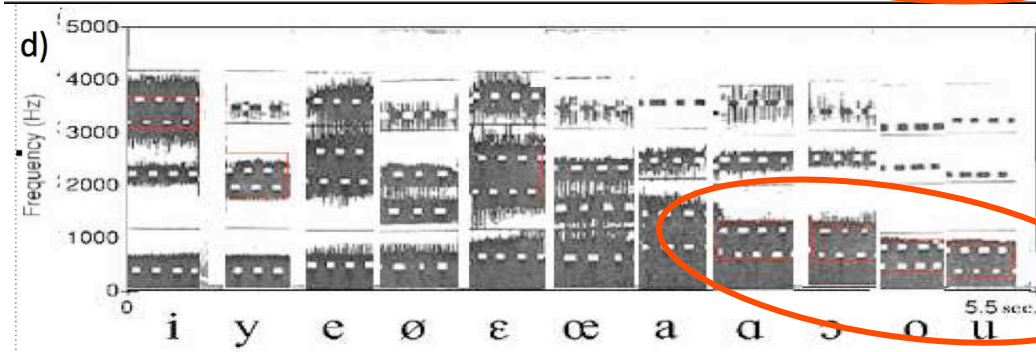
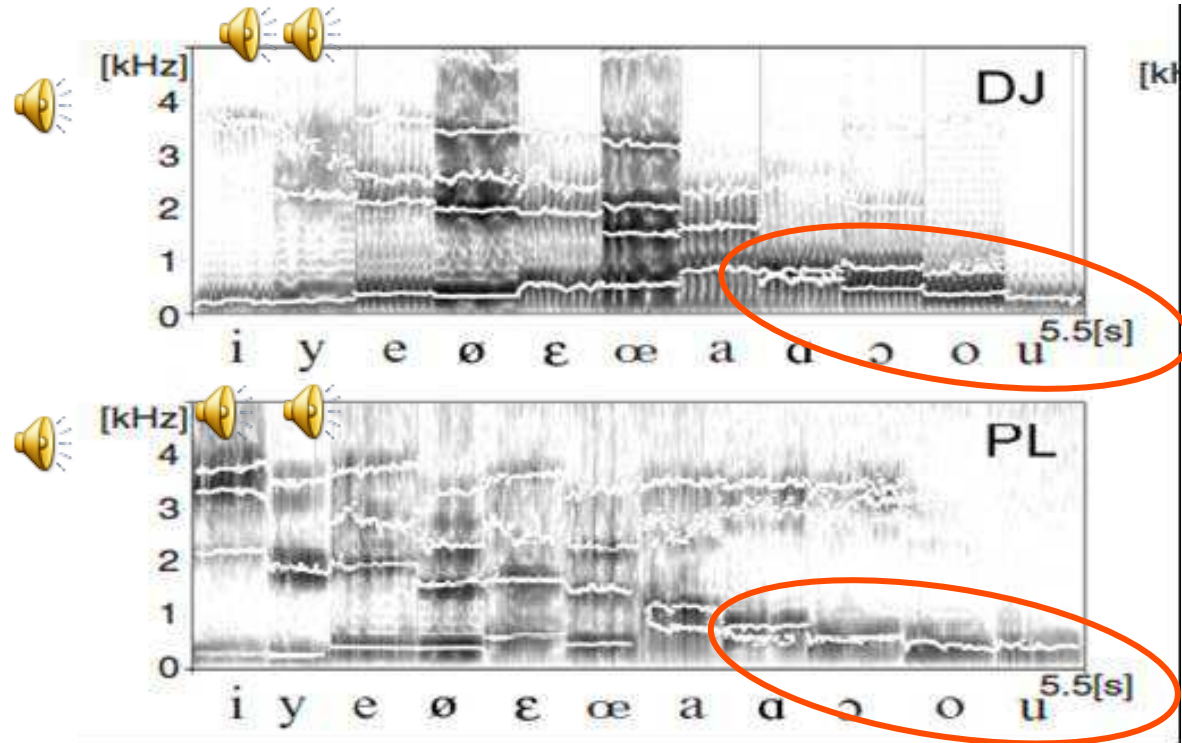
(F1F2) auditorily equidistant  
 between (F1F2)  
 as high as possible  
 and as low as possible

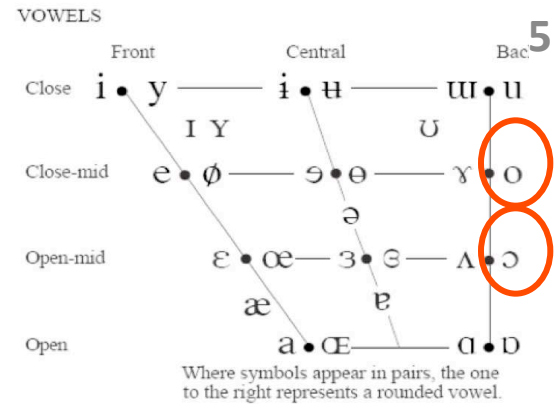




# Jones's and Ladefoged's rendition and the French vowels: the 4 back primary vowels

More discrepancy  
For the non focal  
vowels





# Acoustic characteristics of some the cardinal vowels

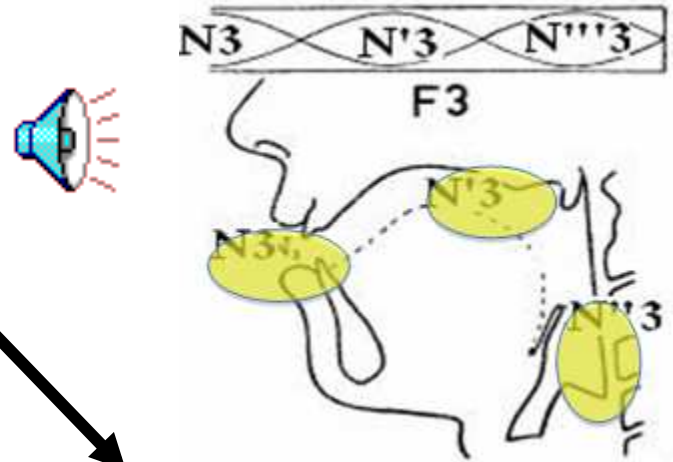
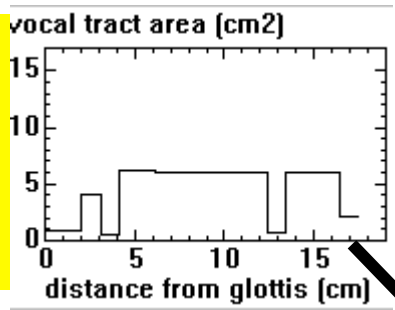
- 1) The cardinal vowel 1 and the cardinal vowel 9
- 2) The cardinal vowel 5
- 3) The cardinal vowel 8
- 4) The cardinal vowels 6 and 7
- 5) The lowest F2F3 concentration vowel



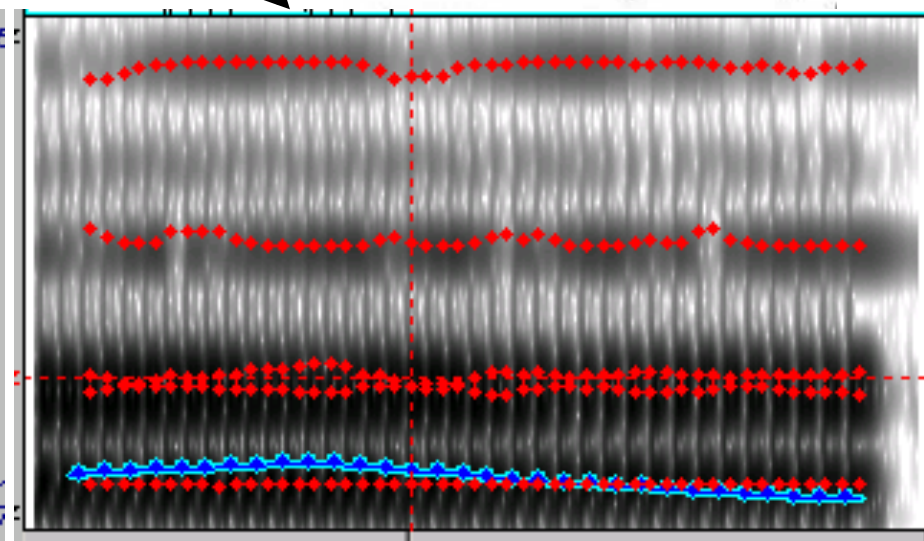
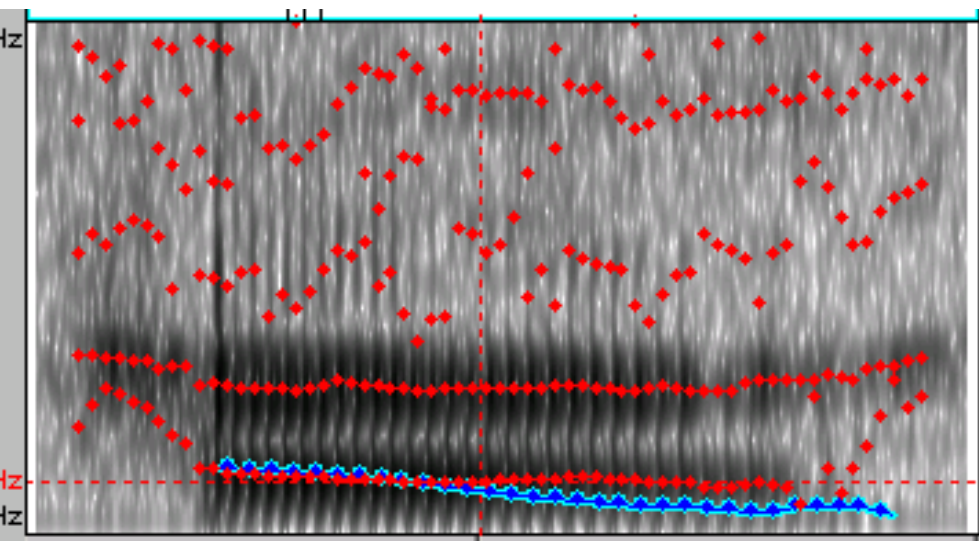


# Another remarkable focal vowel lowest $\downarrow$ (F2F3), but not cardinal

Lengthening of the front cavity  
By  
Lip spreading  
And/or fronting of the tongue



PL



Shorter palatal constriction entails higher F3

- Then it is possible to interpolate other timbers by using articulatory synthesis
- Neutral vowel with one, two or three constrictions





**neutral**

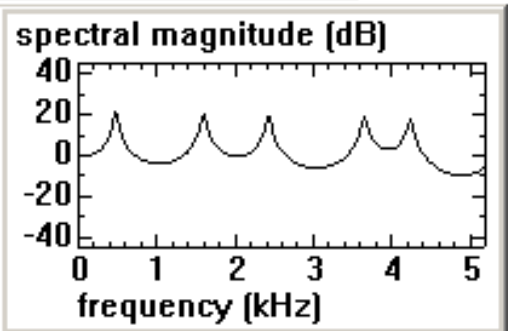
jaw=-1	<input type="checkbox"/>	lip_ht=0	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>	lip_pr=0	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>	larynx=0	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>		

ht a

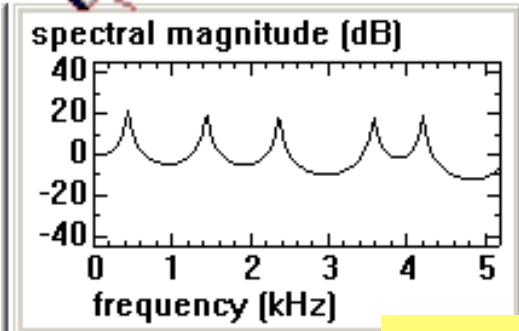


**+ protrusion**

jaw=-1	<input type="checkbox"/>	lip_ht=0	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>	lip_pr .11	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>	-5 <3< 5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>		



Frq(Hz)	Bw(Hz)	A(dB)
F1 464	47	22
F2 1610	64	20
F3 2414	56	20
F4 3652	57	19
F5 4240	58	18

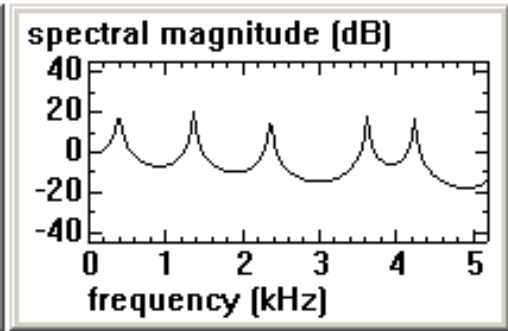


Frq(Hz)	Bw(Hz)	A(dB)
F1 433	37	21
F2 1455	46	19
F3 2352	47	18
F4 3590	46	18
F5 4210	34	19

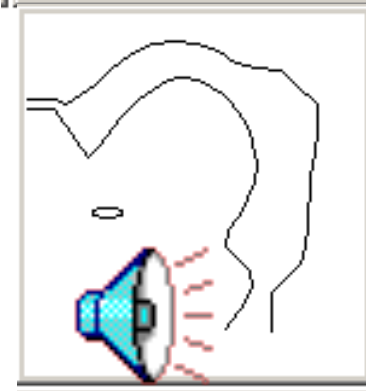


**+ compression**

jaw=-1	<input type="checkbox"/>	lip_ht .11	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>	-5 <-0.9< 5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>		
apex=-2	<input type="checkbox"/>		

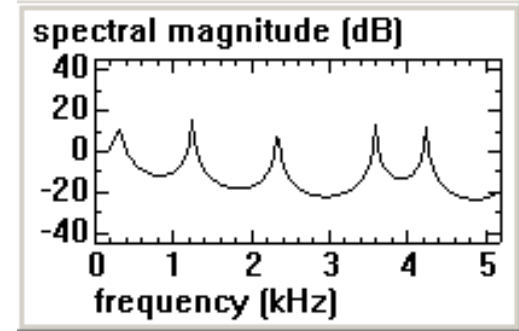


Frq(Hz)	Bw(Hz)	A(dB)
F1 402	59	16
F2 1362	23	21
F3 2352	42	14
F4 3621	24	18
F5 4240	23	17



**+ both**

nasal coupling [cm2]=0	<input type="checkbox"/>		
jaw=-1	<input type="checkbox"/>	lip_ht=-0.9	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>	lip_pr=3	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>	larynx=0	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>		



Frq(Hz)	Bw(Hz)	A(dB)
F1 310	68	11
F2 1238	21	16
F3 2321	41	7
F4 3590	20	13
F5 4240		11



## 5) From vowels to glides to consonants and processes



# 1) From vowels to glides to consonants using the same notation

Place of constriction	Spread lips	Rounded lips
Back	$\uparrow (\uparrow F1 \downarrow F2)^{1000\text{Hz}}$ C5[a]	
Mid		$(\downarrow F1 \downarrow F2)^{400\text{Hz}}$ C8[u]
Front Prepalatal	$(\uparrow \underline{F3} \downarrow F4) F3^{3200\text{Hz}}$ C1[i]	$(\uparrow \underline{F2} \downarrow F3)^{1900\text{Hz}}$ C9 [y]



Focal vowels correspond to one or more strong constrictions  
so they have corresponding glides

Same natural acoustic classes

vowel	Corresponding glide	Type of clustering	Main effect on the surrounding phonemes
i	j	High (F3F4)	Raises <u>F</u>
y	ɥ	High (F2F3)	Lowers <u>F</u>
ɝ	ɹ	Low (F2F3)	<u>Lowers F3</u>
ɑ	ɶ	High (F1F2)	Raises F1, lowers <u>F</u>
u	w	Low (F1F2)	Lowers F1 and <u>F</u>



## 2) From vowels to coarticulatory processes using the same notation

	/i/-ness	/ɑ/-ness	/u/-ness	others
	F1↘F2↗F3↗	F1↗F2↘	F1↘F2↘	F3↘ or F4↘
	closing of open phonemes and fronting of back phonemes	opening of closed phonemes and backing of front phonemes		
Tongue or lip configuration	fronted	retracted	tongue mid (+ labialisation)	retroflexed
1) Contextual influences	front consonant or vowel	back consonant or vowel	round consonant or vowel	retroflex consonant or vowel
	palatal	pharyngeal	labio-velar	retroflex
2) Secondary constriction	palatalized	pharyngealized	labio-velarized	retroflexed
Processes	palatalization	pharyngealization	labialization and velarization	F3↘ : palatal retroflexion F4↘: alveolar retroflexion

# coarticulation

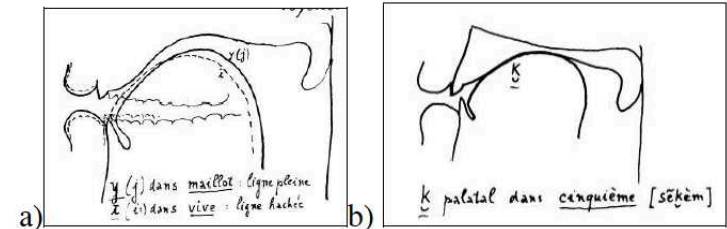


Figure 17: Sagittal profiles corresponding to (/i/) –in the solid line) and /j/ (in dashed line) in French (a) and of alized /k/ (b) (from Straka 1965).

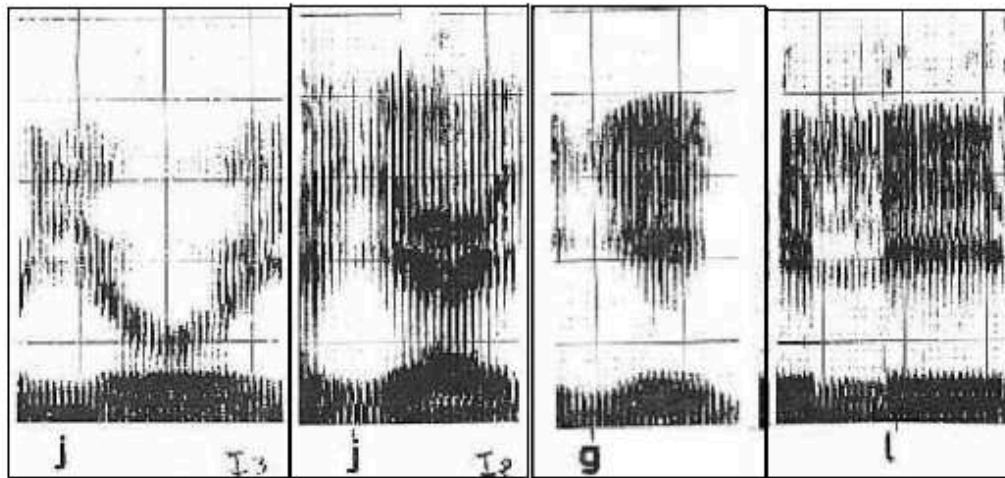


Figure 18: Spectrograms of /juj/, /jaj/, /gi/ and /li/.



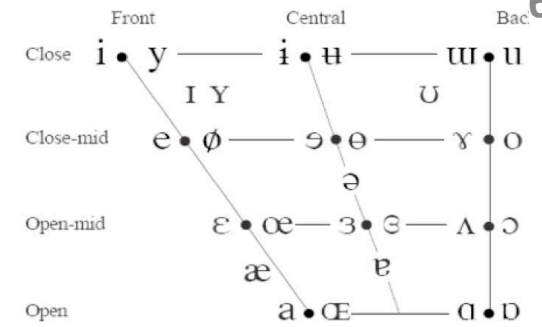
/j/ , and /g/ and /l/ in /i/ context share (F3F4) features<sub>93</sub>

- 1) introduction
- 2) IPA chart and cardinal vowels
- 3) Some remarks on the formants
- 4) Acoustic characteristics of some DJ's and PL's cardinal vowels
- 5) From vowels to glides to consonants and processes
- 6) Conclusions



- 1) introduction
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- 6) Conclusions





Where symbols appear in pairs, the one to the right represents a rounded vowel.

# Three conclusions





# 1) Take advantages of the progress

## A) *theoretical progress*

### Acoustic theory of speech production

#### Modelisation production > acoustics > percept

Fant, Stevens and House

3 parameters: place of the constriction, degree of constriction, lip configuration

Articulatory models based on statistics (X-ray):

*with 4 more parameters (larynx height, nasal opening, ...)*

*to hear the sounds*

### Theories

Stevens's quantal theory

Lindblom's dispersion theory

Grenoble focalisation-dispersion theory

Chistovich's spectral integration



# 1) Take advantage of the progress

## *B) Technical progress*

### **Articulatory exploration**

Exploratory techniques (X-ray, MRI, ultrasounds, etc.)

### **Acoustic analysis**

(real time) visualisation on spectrograms  
signal analysis, formant synthesis

### **Data bases and statistical analysis**

Praat and scripts on Praat

### **Modelling on computer**

- Spectral changes
- Formant synthesis
- Articulatory synthesis



# 1) Take advantage of the progress

## *A) theoretical progress*

## *B) Technical progress*

- To revisit the relationship between articulatory gestures, their acoustic consequences, and the resulting percept
- To develop a way to represent some reference vowels



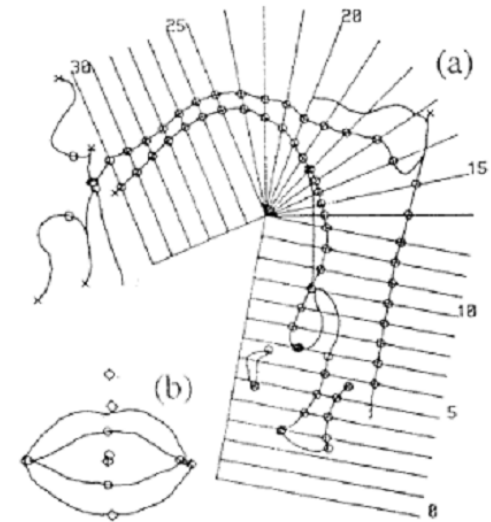
## 2) How to teach the cardinal vowels concerned here?

0

- Easy because they correspond to a well defined acoustic characteristics
- That can be displayed using real time spectrograms
- Self training, very precise goal
- Language-independent teaching

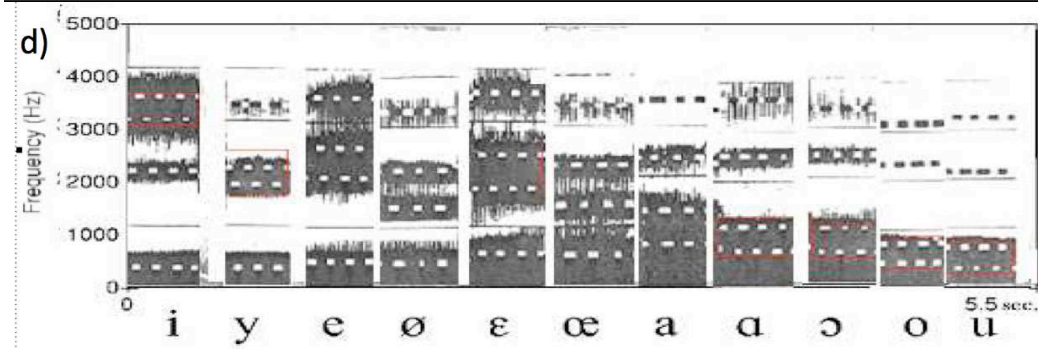
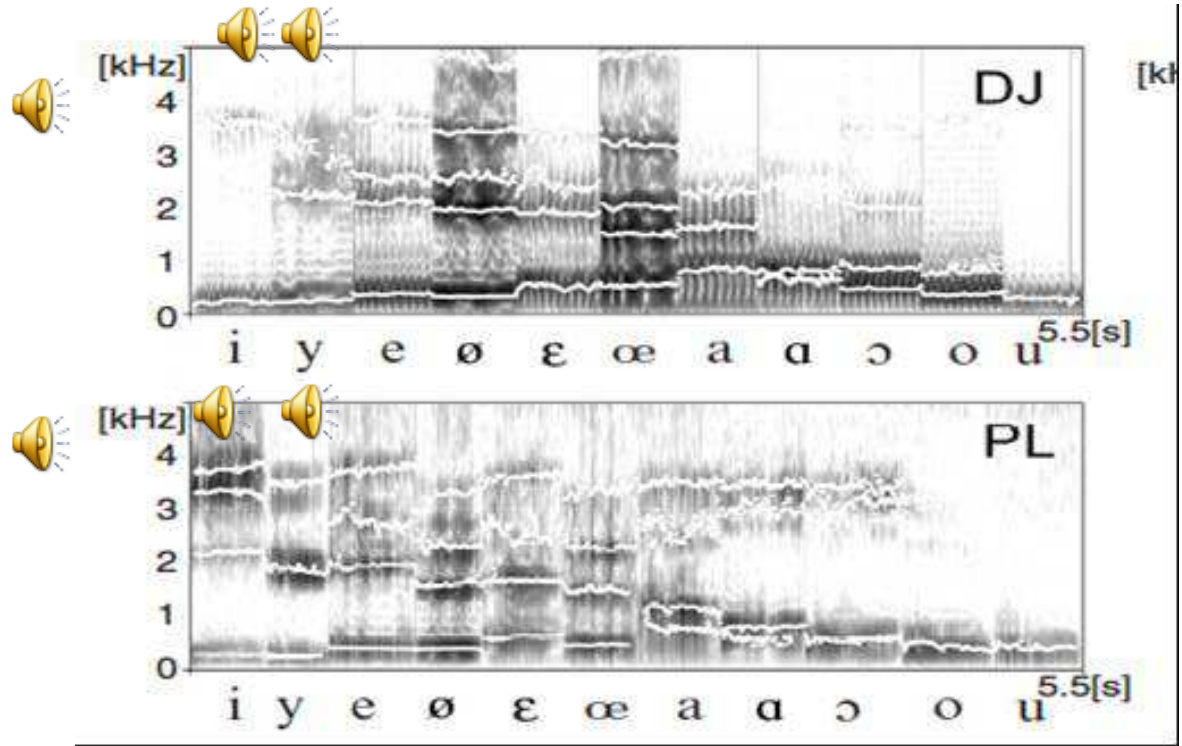


# 3) Articulatory modeling



Feel more secure for teaching





Lienard's book

image



Merci !