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On acoustic salience of vowels and consonants predicted from articulatory models

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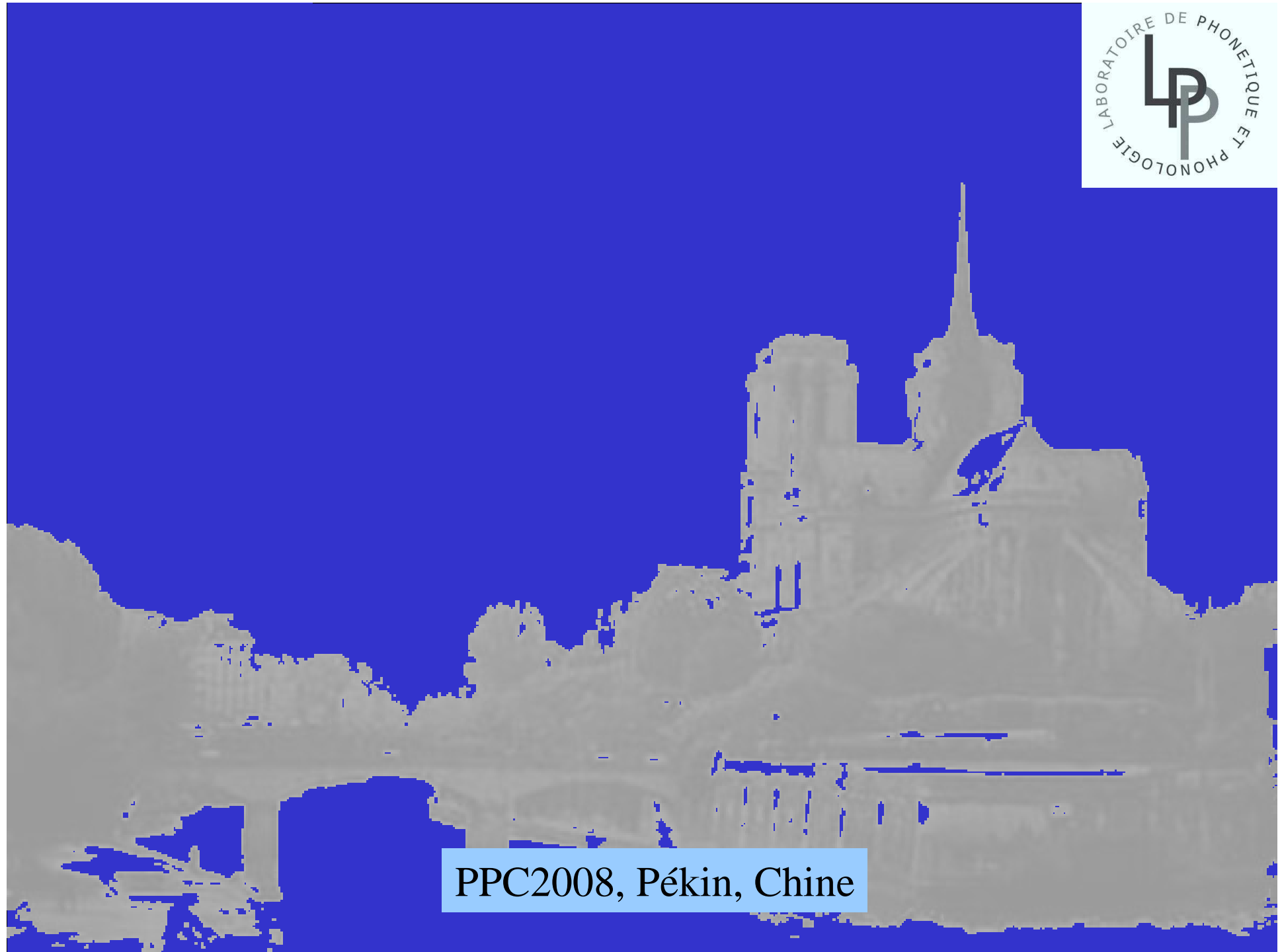
Submitted on 31 Mar 2012

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HAL Authorization



PPC2008, Pékin, Chine

*On acoustic salience of
vowels and consonants
predicted from
articulatory models*



Many thanks to
Shinji Maeda
And LPP students
In Paris

Jacqueline Vaissière
Université Sorbonne Nouvelle - Paris
Laboratoire de Phonétique et de Phonologie

PPC2008, Pékin, Chine



A



1. What is a model?
2. Why modelling?
3. Which models?
4. What is a useful model?
5. Demo (vowels consonants)
6. How done?
7. Other uses
 - speaker anatomy
 - speaker strategy
 - singing formant
 - inversion
 - etc

Menu?

B





The questions

2

What is a model?



What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
investigation
etc;



A model is a simplified description of a complex system

A model is not a goal per se, but a tool

- 1. to know what we know**
- 2. and what we don't know**
- 3. And where to look for ...**

3

Why modelling?

What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;



Modeling is needed to apprehend *complex* phenomena

Speech is *complex* enough to need modelisation

Modeling allows to evaluate the separate contribution of individual parameters and the acoustic and perceptual consequences of large and small movements

Modelisation in turn makes speech looking *less or sometimes more complex*



Which models?

- What is a model?
- Why modelling?
- Which models?**
- What is a useful model?
- How done?
- Demo
- vowels
- Other
- ts
- atomy
- ategy
- rmant
- etc;



Phonetics

- *Prosodic modelling*
- *Source modelling*
- *Vocal tract*
 - *2D articulatory*
 - *3D articulatory*
- *Articulatory modelling*

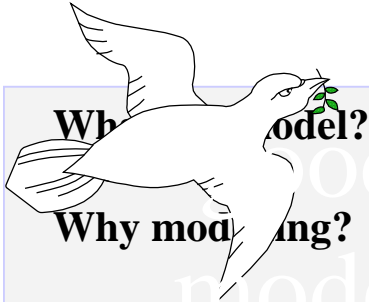
Psycholinguistics

- *perception and recognition*
 - *Phoneme*
 - *Word access*
 - *Sentences*
- **Etc.**



5

Useful models?



Why model?

Why modeling?

Which models?

What is a useful model?

How done?

Demo

vowels


consonants

Other uses

speaker anatomy

category

formant



Be compatible with the observations

Be testable

Describes well the data and to be able to reproduce them from

Few number of parameters

As motivated as possible

As independent as possible

And for AM, react as a human vocal tract

no stop without a burst, or no frication when humans do.

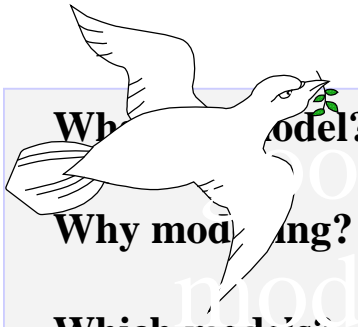
To draw a direct link between articulatory, acoustic and perceptual observations



6

How done?

- *By Shinji Maeda*
- *From X-ray data for French (from Strasbourg)*
- *By statistical analysis*
- *The most widely used AM*
- *Used for pedagogical purpose in our lab and research in Grenoble, Nancy, UCLA, MIT, etc.*



Why model?

Why modeling?

Which models?

What is a useful model?

How done?

Demo

vowels


consonants

Other uses

speaker anatomy

strategy

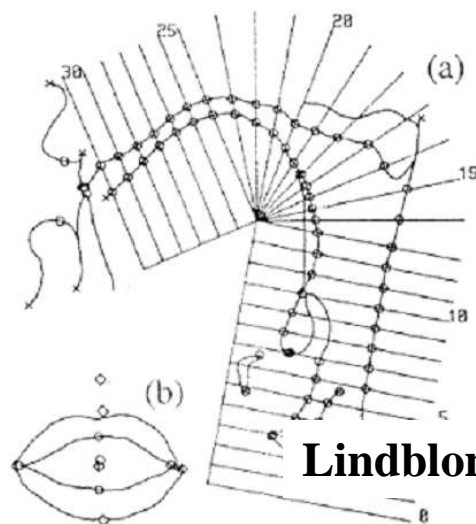
formant




1 X-ray data



2



Lindblom & al, 1971

3

Guided PCA

4

7 parameters

5

One speaker

10 sentences
 >1000 images

VT shapes

First substract the effect of the jaw

alisation



4 first parameters Jaw + tongue

How done:

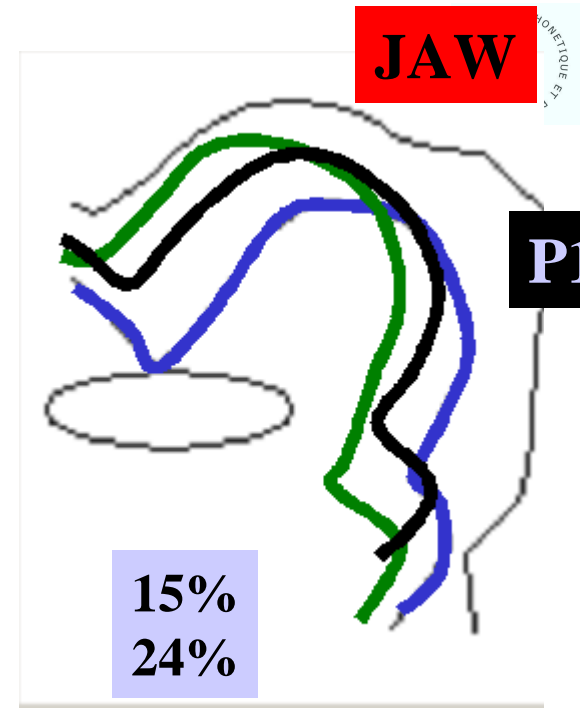
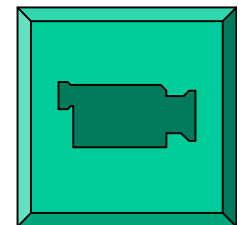
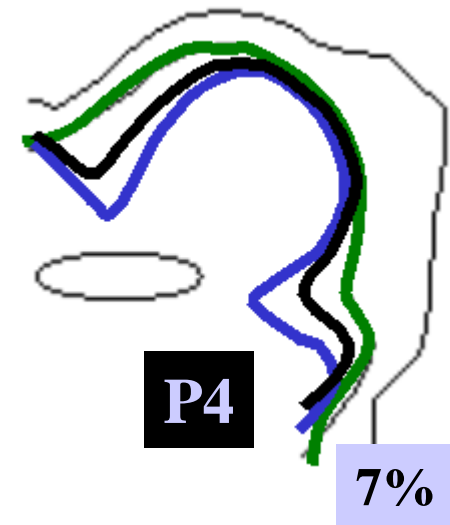
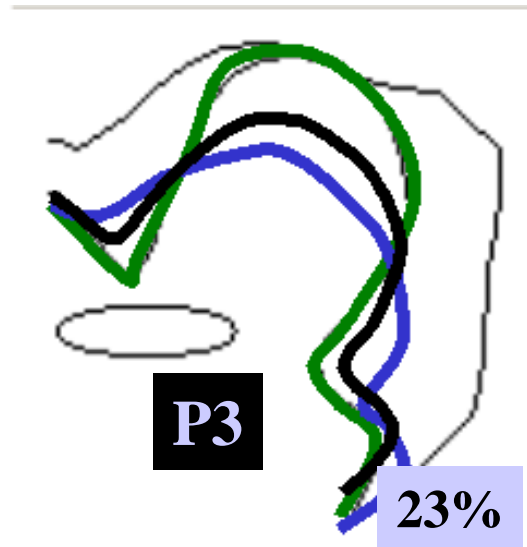
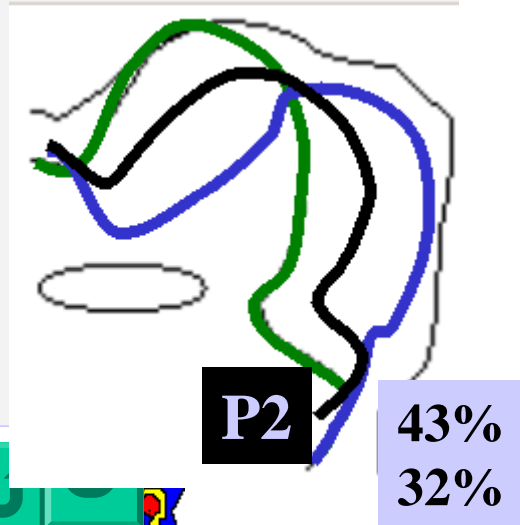
Demo

1+2= 58%, 56%

1+2+3= 81%, 79%

1+2+3+4= 88%, 86%

Other uses



v
v
v
v

4

3 more =
Lip and larynx

LIP

ht

5

pr

6

larynx

ht

7

JAW

ht

1

15%
24%

nasal

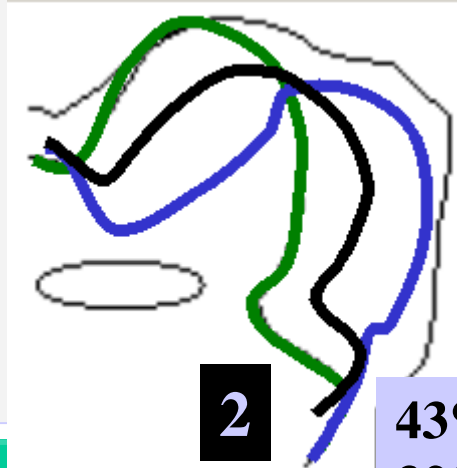
8

How done?

Demo

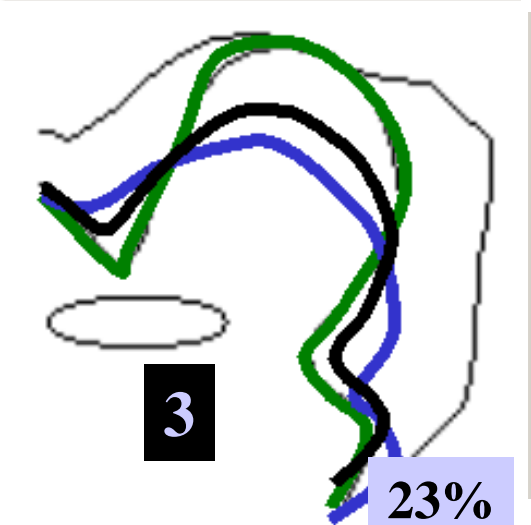
vowels
consonants

Other uses



2

43%
32%



3

23%



4

7%

4

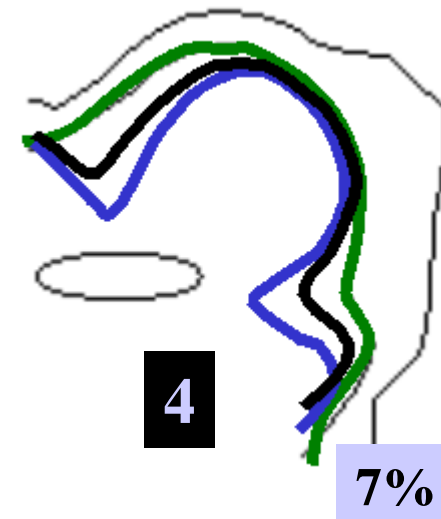
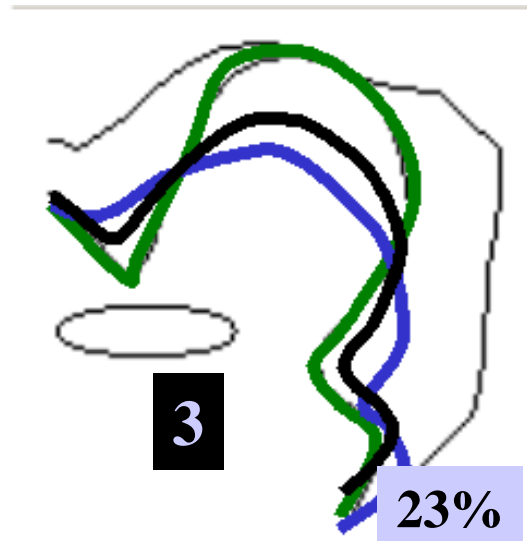
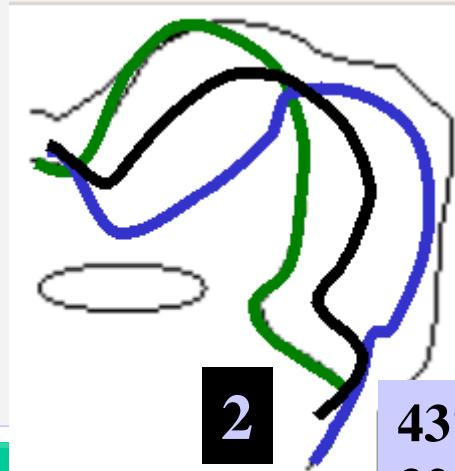
7 parameters =
Speech organs

How done?

Demo

vowels
consonants

Other uses



LIP

ht 5

pr 6

larynx

ht 7

JAW

ht

1

15%
24%

nasal

8

Surprisingly or not

The 7 statistically found parameters could be interpreted in phonetic terms

2 for lips, 3 for tongue, 1 for jaw, 1 for larynx



4 7 commands

model?

How done?

Demo

vowels
consonants

body

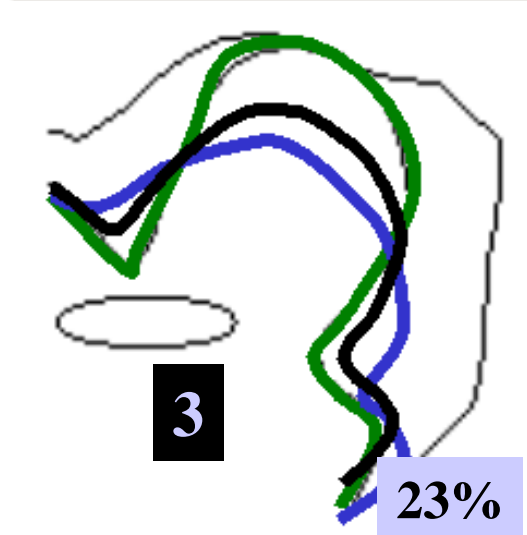
Other uses



TONGUE

shape

u, k



apex

i, e, dentals



LIP

ht 5

pr 6

larynx

ht 7

JAW

ht 1

nasal

8

15%
24%

Nasal cavity?

Sublingual cavity
Why modelling?

Which models?

What is a useful
model?

How done?

Demo

vowels

consonants

Other uses

speaker anatomy

speaker strategy

singing formant

inversion

etc;



radiation load: RL_CIRCUIT

wall: YIELDING

nasal tract: OFF

glottis: CLOSE

air density=0.00114

sound velocity=35000

wall resistance=1600

wall mass=1.5

wall compliance=300000

1

Examples?

- What is a model?
- Why modelling?
- Which models?
- What is a useful model?
- How done?**
- Demo
 - vowels
 - consonants
- Other uses
 - speaker anatomy
 - speaker strategy
 - singing formant
 - inversion
 - etc;

- 1) vowels

- 2) CVC sequences



1

1) vowels

What is a model?

Why modelling?

Which models?

What is a useful model?

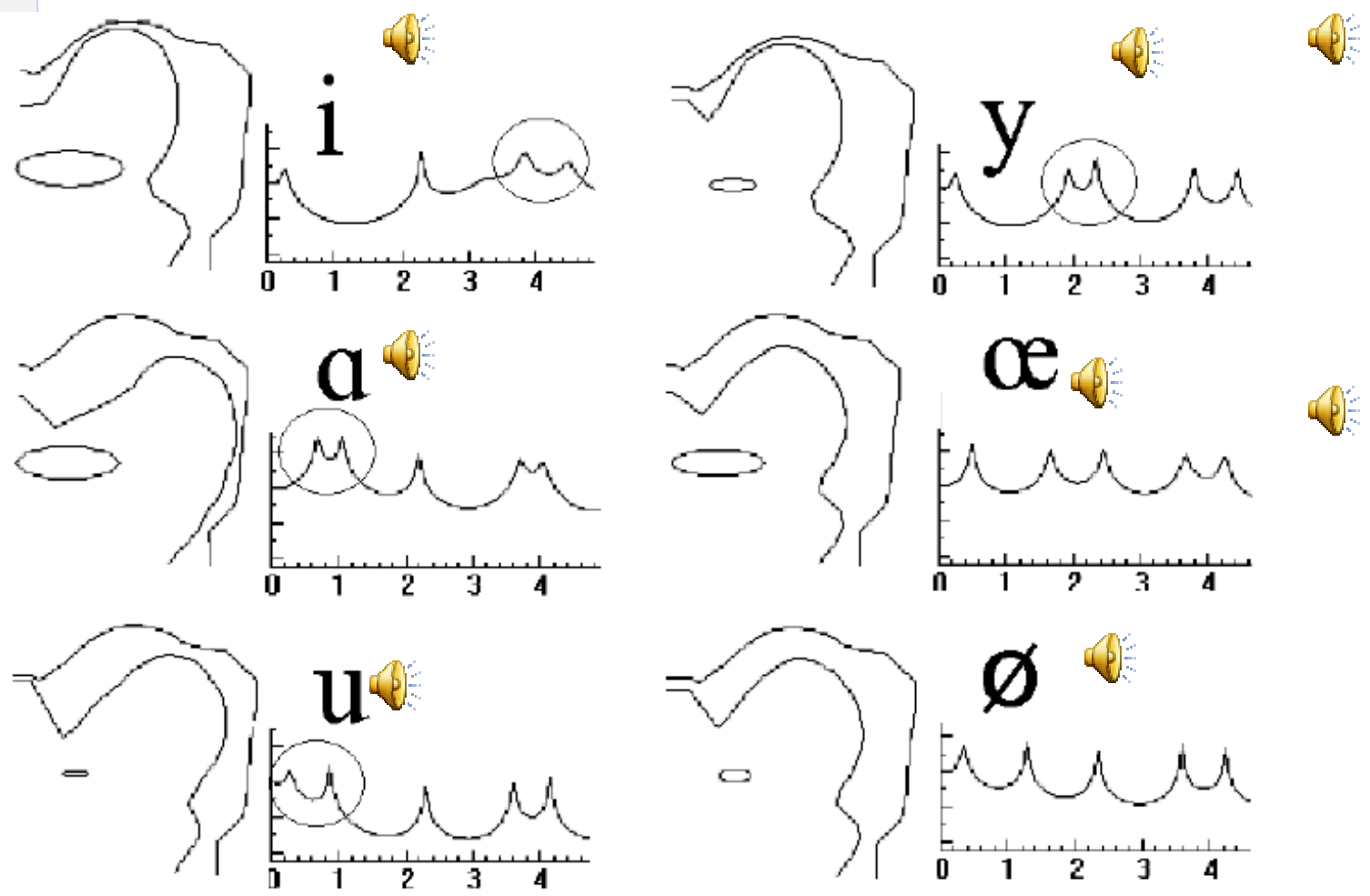
How done?

Demo

→ vowels
consonants

Other uses

speaker anatom
speaker strateg
singing forma
inversion
etc;



Vaissière, 2007

PPC2008, Pékin, Chine



What is a model?

Why modelling?

Which models?

**What is a useful
model?**

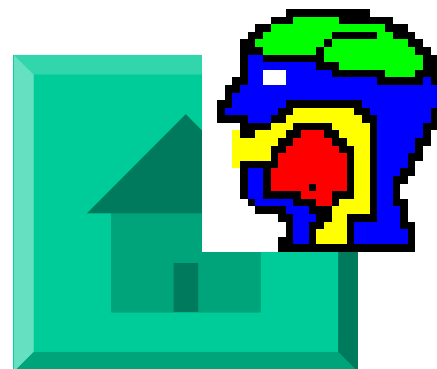
How done?

Demo

→ vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;



2) consonants

What is a model?

Why modelling?

Which models?

What is a useful model?

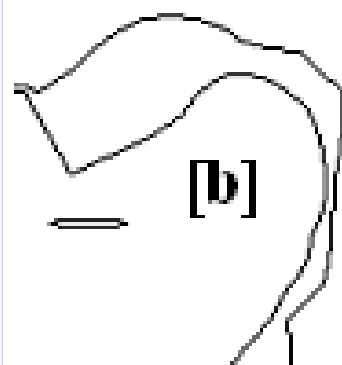
How done?

Demo

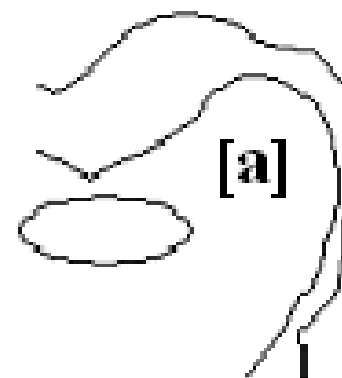
→ vowels
→ consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;



F1 371
F2 898
F3 2136
F4 3683
F5 4024

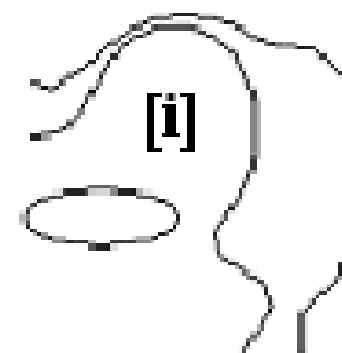


F1 712
F2 1145
F3 2229
F4 3745
F5 4024



F1 186
F2 1207
F3 2321
F4 3776
F5 4457

closure]



F1 248
F2 2290
F3 3838
F4 4457

after release



Beans on a string synthesis

1

2) consonants

What is a model?

Why modelling?

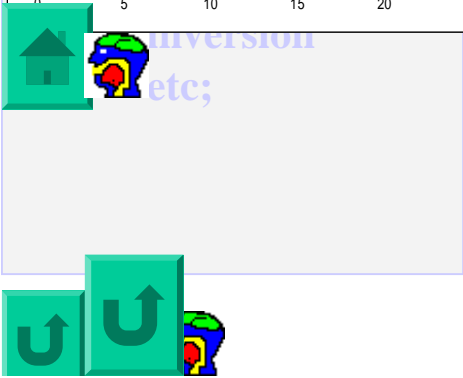
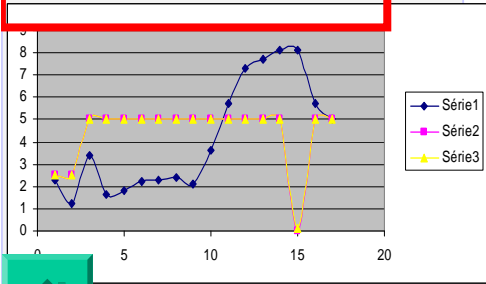
Which models?

What is a useful model?

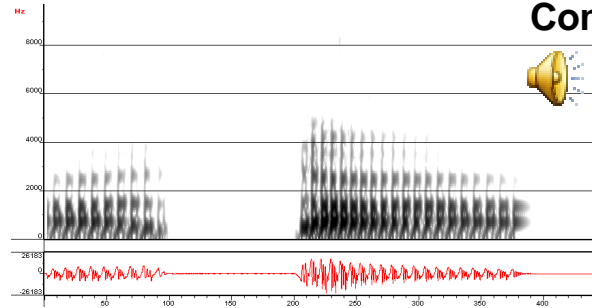
How done?

Demo

→ vowels
→ consonants

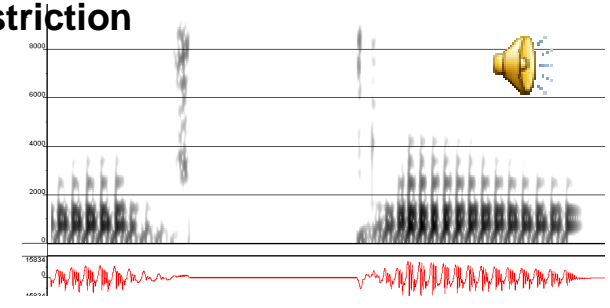


Glottis close

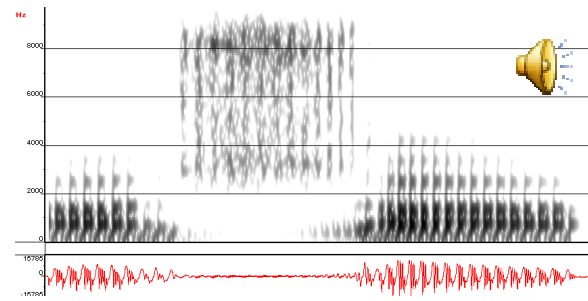


Complete constriction

Glottis open

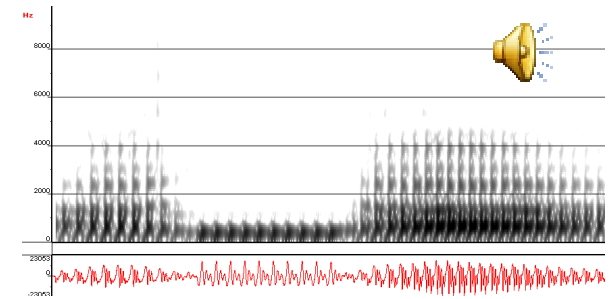


Complete constriction



Sublingual cavity

Nasal port open



Lip constriction

What is a model?

Why modelling?

Which models?

What is a useful model?

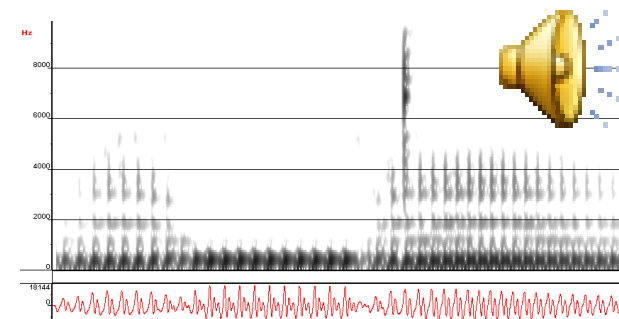
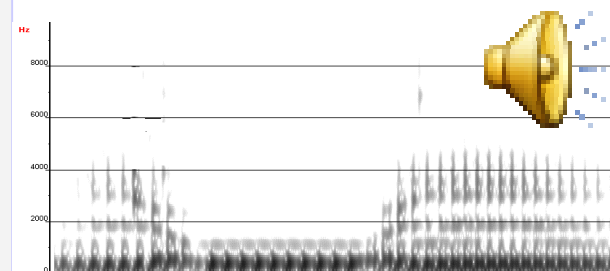
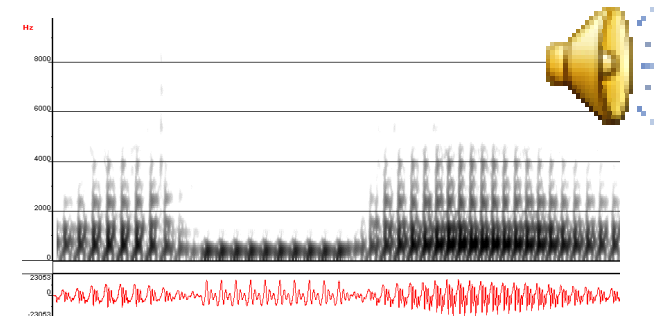
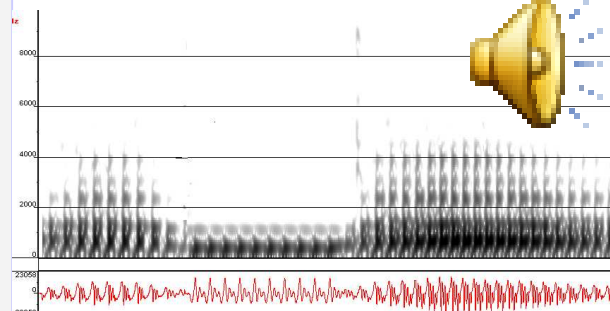
How done?

Demo

→ vowels
consonants

Other uses

- speaker anatomy
- speaker strategy
- singing formant
- inversion
- etc;



- **/a/ during 30 msec**
 cosine transition for 50 ms
- /k/ closure for 100 ms**
- /k/ release for 17 msec**
 cosine transition for 17 ms
- /u/ for 150 msec**

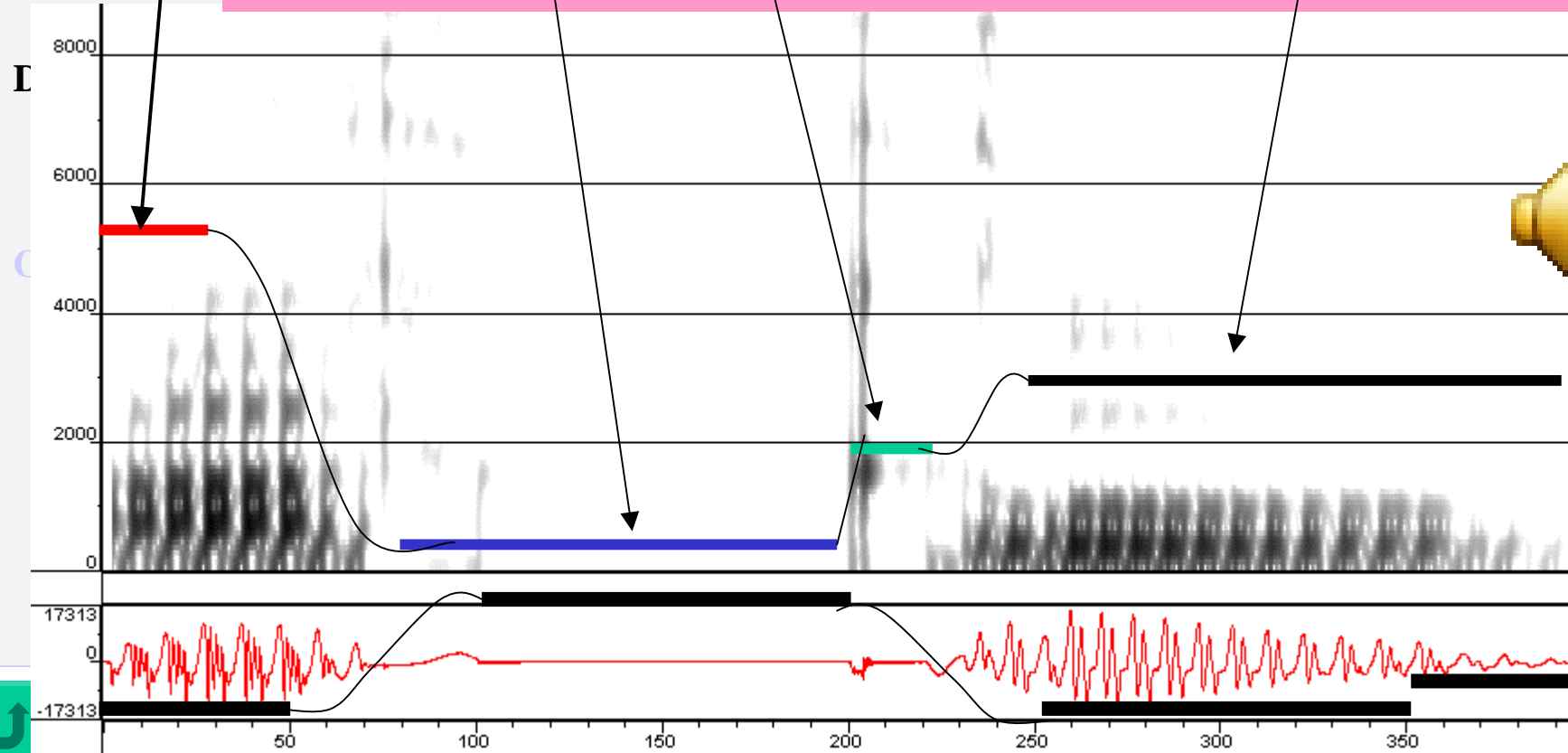
What is a model

Why modelling

Which model

What is a useful model?

How done?



- **Start by close VF for 50 msec**

Then cosine transition to open glottis (0.4) at 100 msec

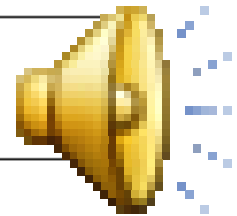
Stay open for 100 msec

Then cosine transition to close glottis at 250.

Stay close for 100 msec

Open slightly for the last 50 msec. (prepausal

opening)



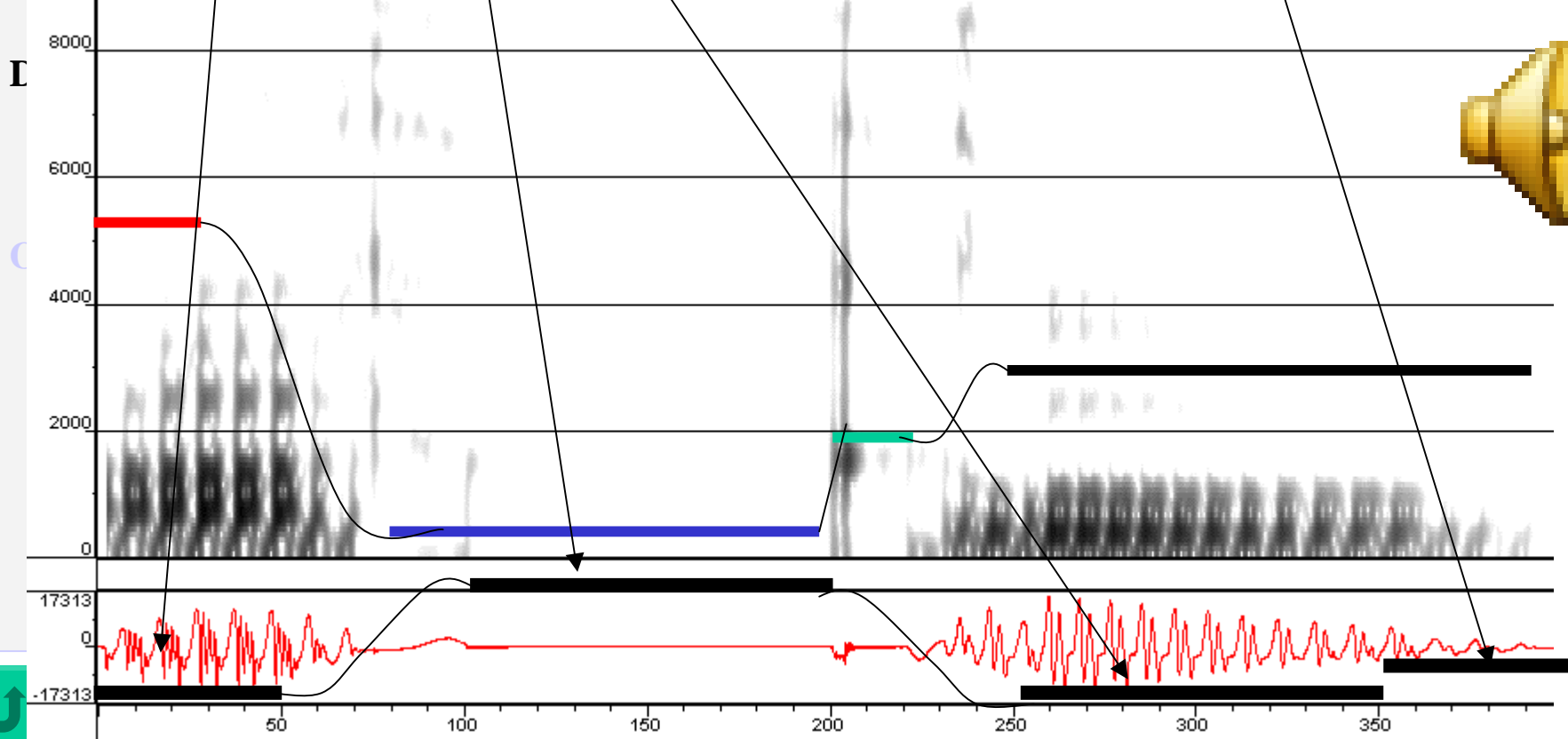
What is a

Why mode

Which mo

What is a
mode

How done:



What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

→ vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;

Glottis and the three sources in the model

- **A) closed**
- **voicing**
- **B) open**
- If less open than VT: **aspiration**
- If VT less open than glottis: **frication**



1)

Invariant place and shape

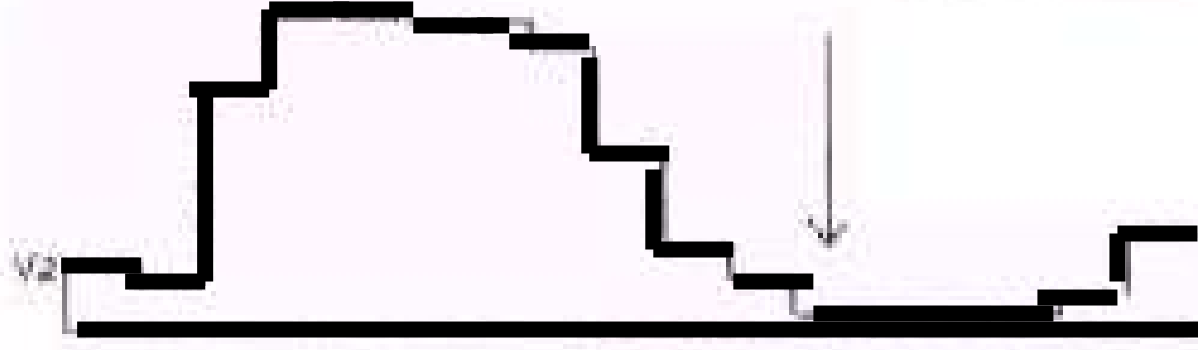
V



C



V



What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

vowels
consonants

Other uses

speaker anatom
speaker strategy
singing forma
inversion
etc;

Figure 2: Interpolation of target area function



What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

→ vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;

Different degrees of sophistication

1) Simple concatenation

/asa/ = 3 targets

= /a/ + /s/ + /a/

/ata/ = 4 targets

= /a/ + /tclosure/ + /t release/ + /a/

+ Cosine transitions

2) Contextual allophones

Ease of articulation

Necessary for velar



What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

→ vowels
consonants

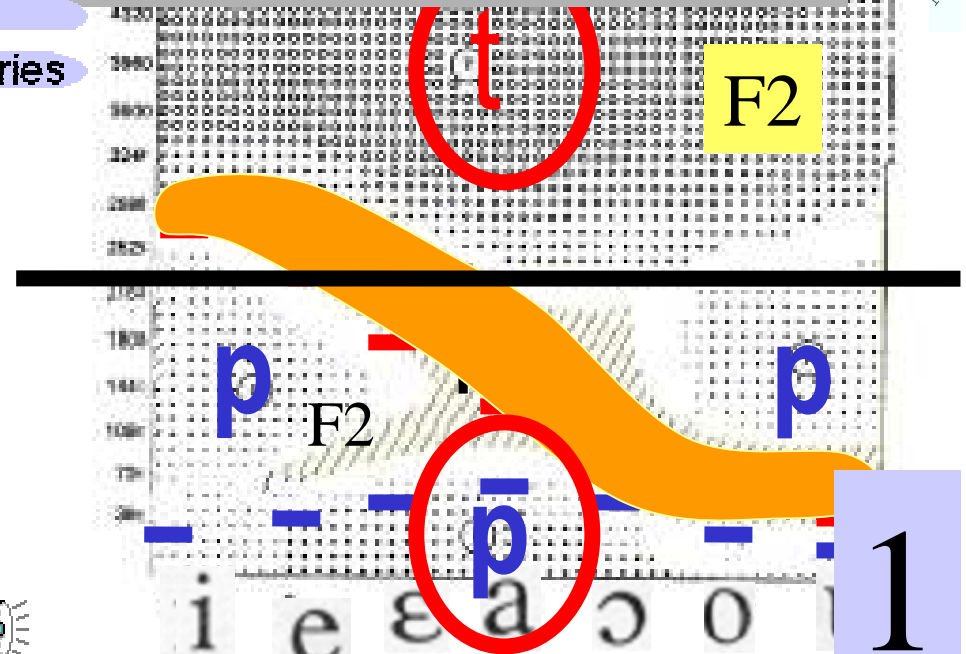
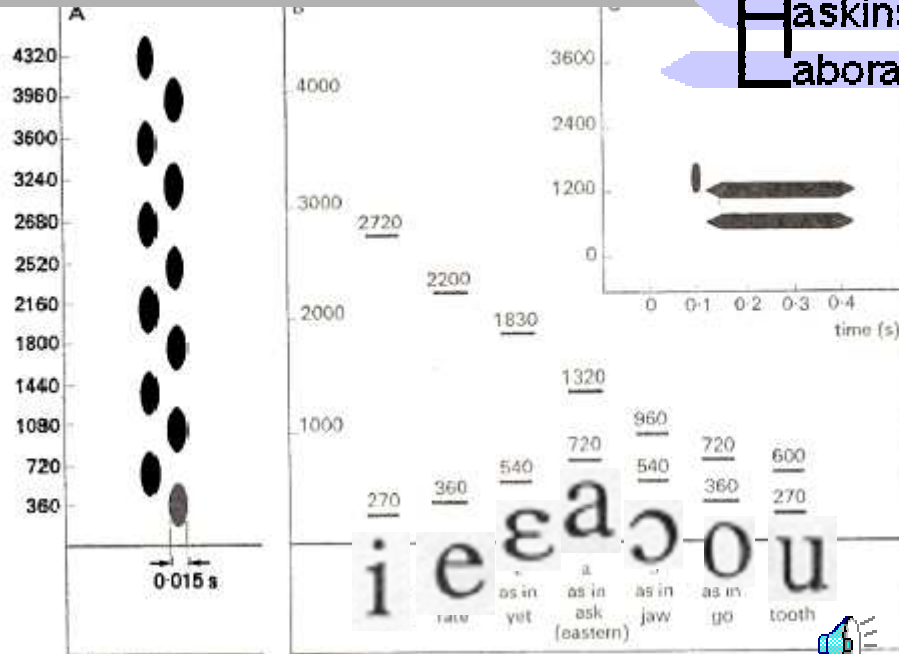
Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;

- /k/ and /g/ require the burst to be in special position to the ‘main pitch’ of the vowel
- Different /k/ allophones
- Main pitch /i/= 3000 Hz, /y/= 2000 Hz, etc.
- Not articulatory ease, but perceptual requirement
- It seems to be not a linguistic but a purely psychoacoustic phenomena (temporal masking)



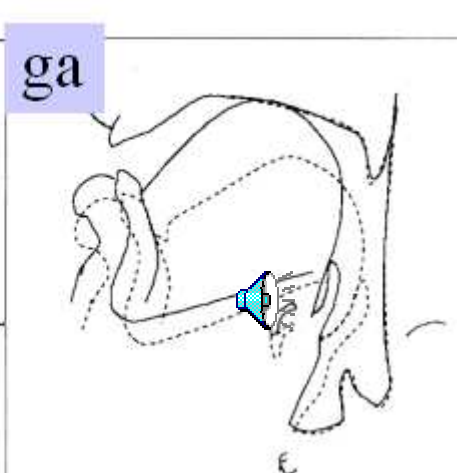
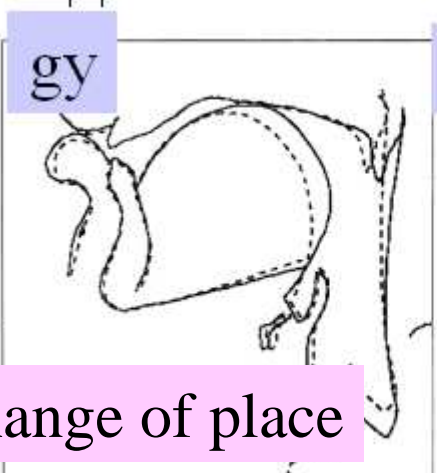
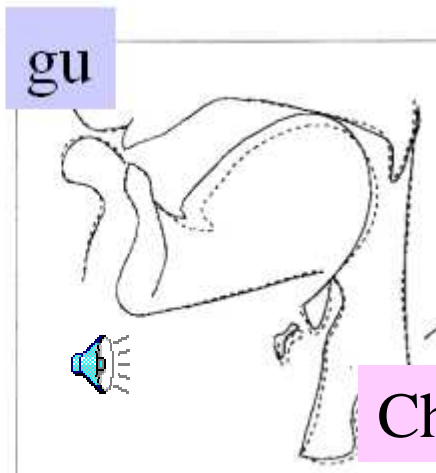
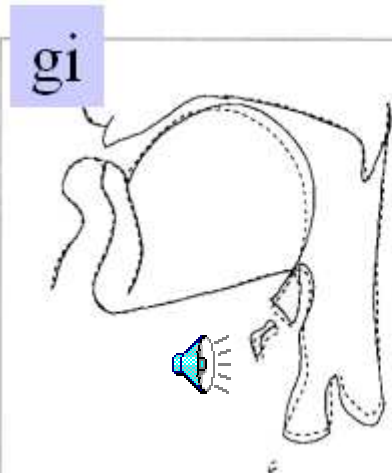
the reference to the vowel is not needed for discriminating [p] and [t]



velar

Other uses

Perceptual requirement?



Change of place



What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

→ vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;

Different degrees of sophistication

1) **Simple concatenation**

2) **Contextual allophones**
Velar

3) **Anticipation and carry over phenomena**



What is a model?

Why modelling?

Which models?

What

How

Demo

Other

- The X-ray data are due to the University in Strasbourg
- Laboratoire de phonétique
- R. Sock
- Frame by frame
- Illustration of anticipation

See the work at IPS Strasbourg (web)



/aku/

model?

Why modelling?

Which models?

What is a **useful**
model?

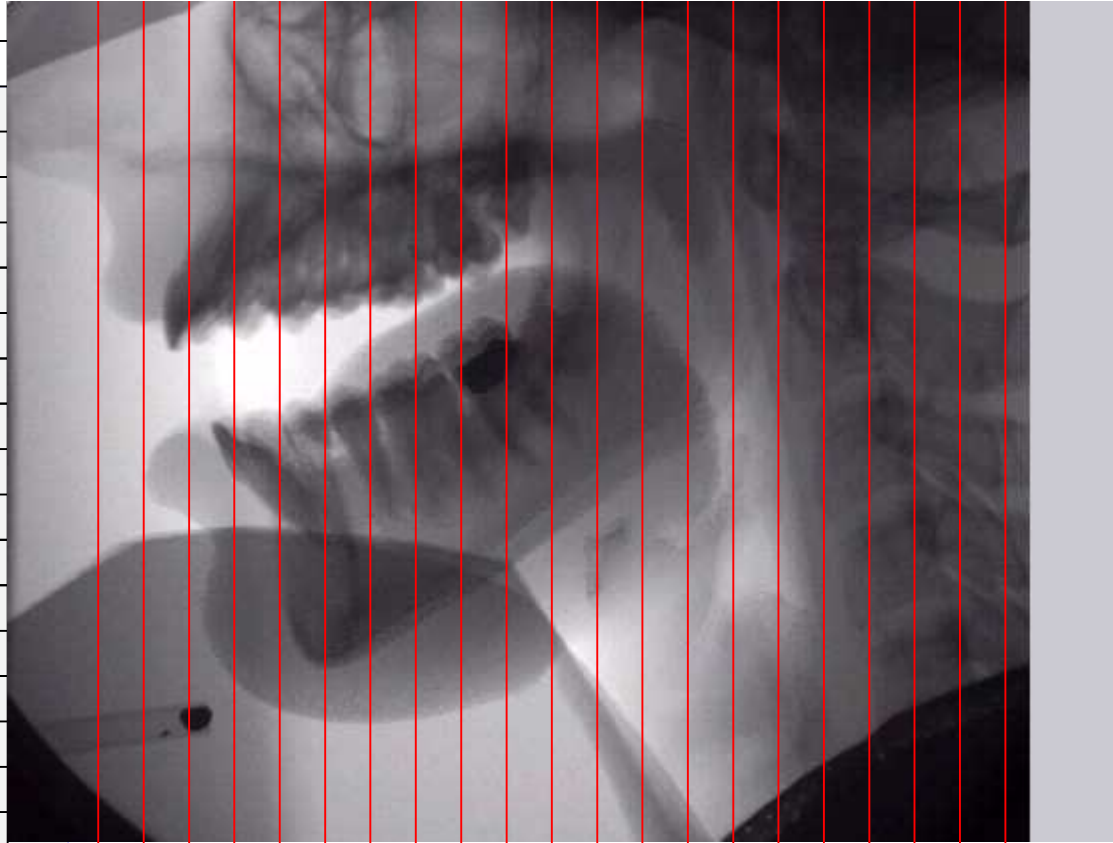
How done?

Demo

vowels



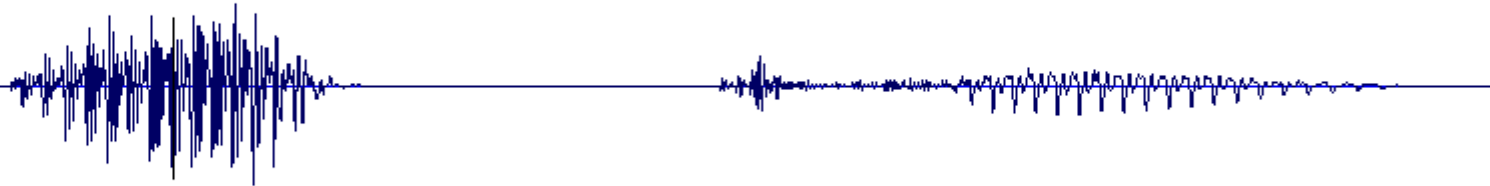
consonants



Other uses

t0

Mouth already largely open



Before /a/

/aku/

odel?

Why modelling?

Which models?

What is a **useful**
model?

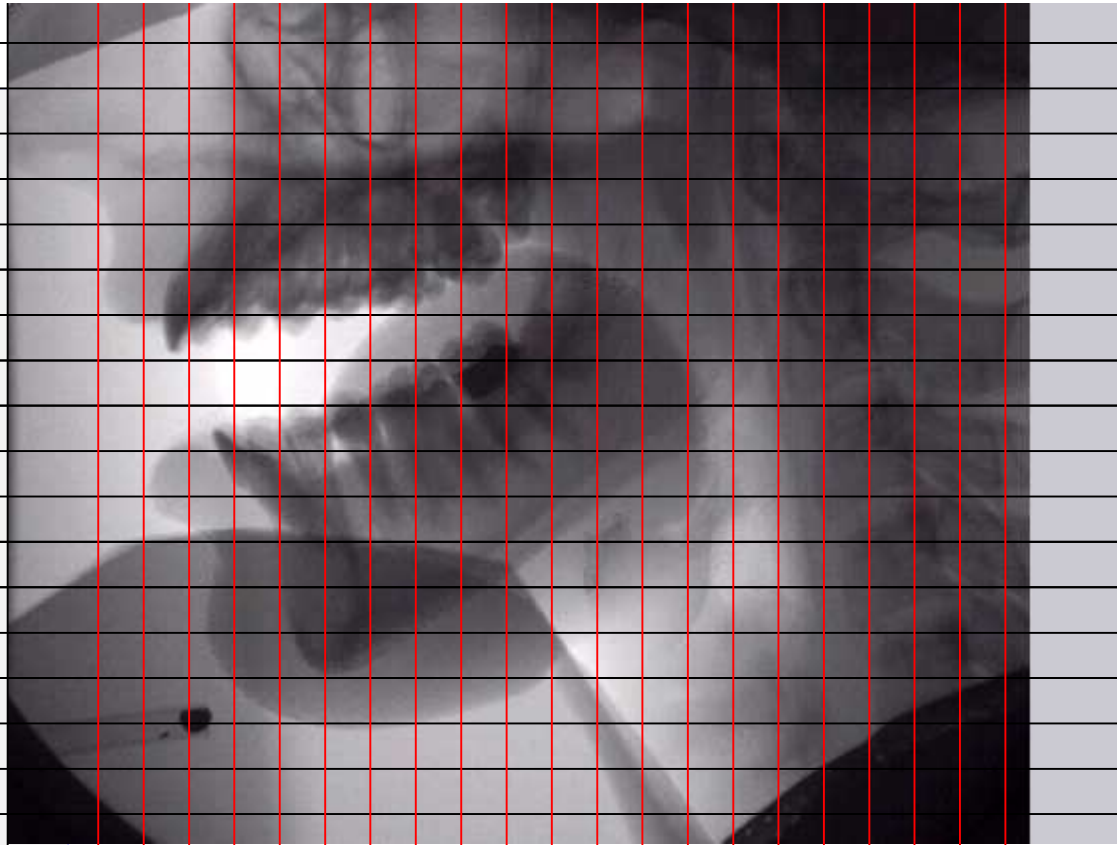
How done?

Demo

vowels



consonants



Other uses

t1

Maximum opening for /a/
Jaw starts to rise again



/a/ onset

/aku/

Model?

Why modelling?

Which models?

What is a **useful** model?

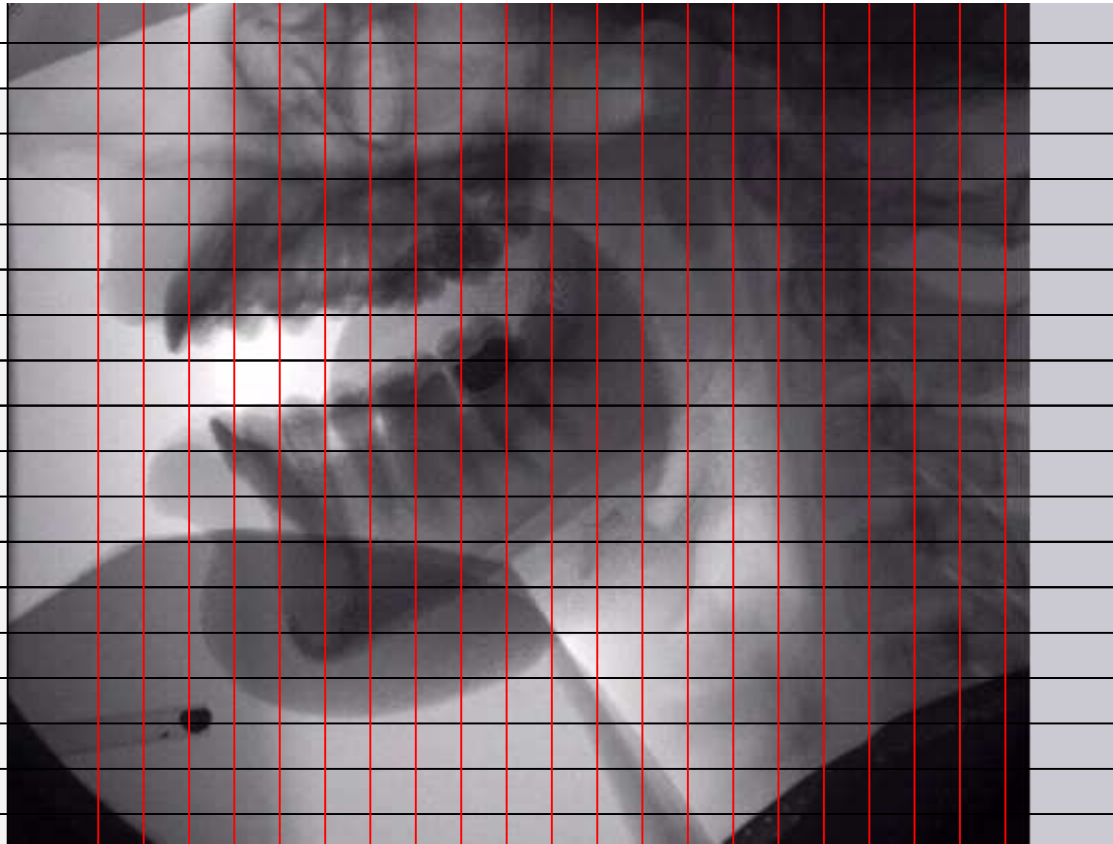
How done?

Demo

vowels



consonants



Other uses

t2

/k/ closing gesture starts
Rounding starts



/a/ midle

/aku/

odel?

Why modelling?

Which models?

What is a **useful**
model?

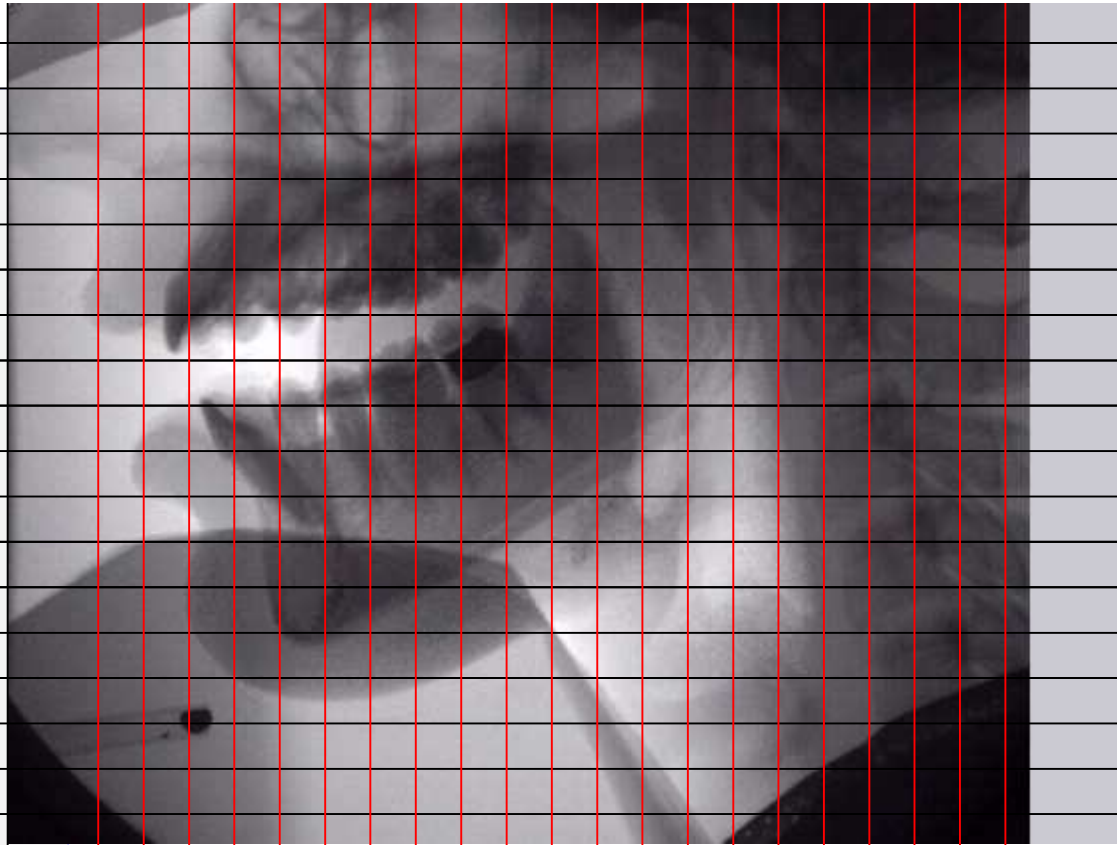
How done?

Demo

vowels



consonants



Other uses

t3



/a/ offset

/aku/

model?

Why modelling?

Which models?

What is a **useful** model?

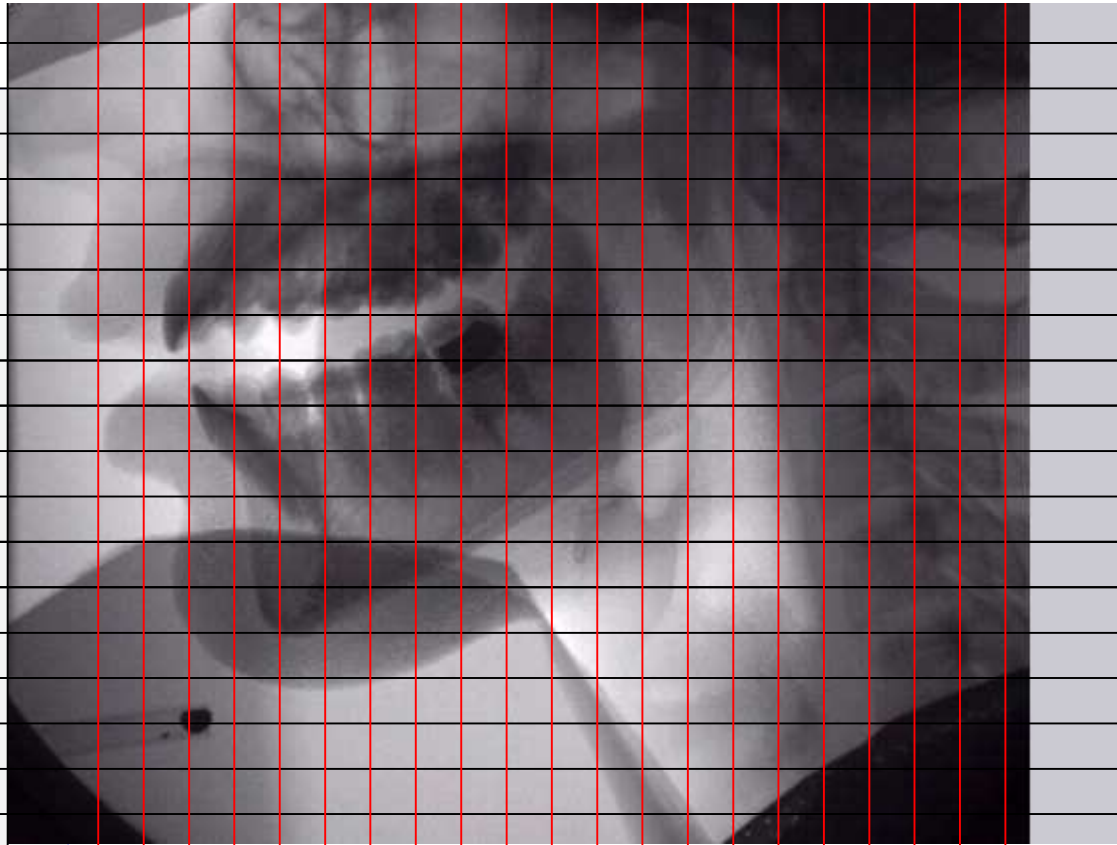
How done?

Demo

vowels



consonants



Other uses

t4

Closure

Lip continue to round



/k/ first part

/aku/

odel?

Why modelling?

Which models?

What is a **useful**
model?

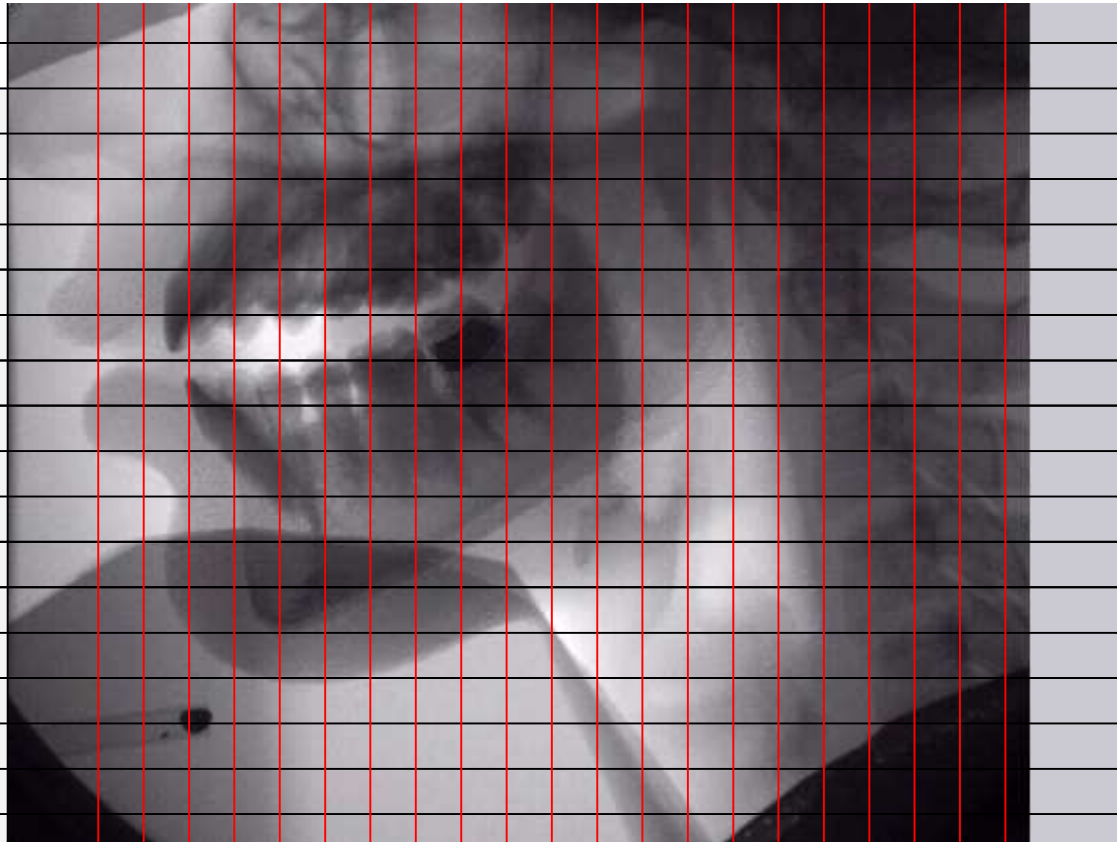
How done?

Demo

vowels



consonants



Other uses

t5



/k/ midle

/aku/

odel?

Why modelling?

Which models?

What is a **useful** model?

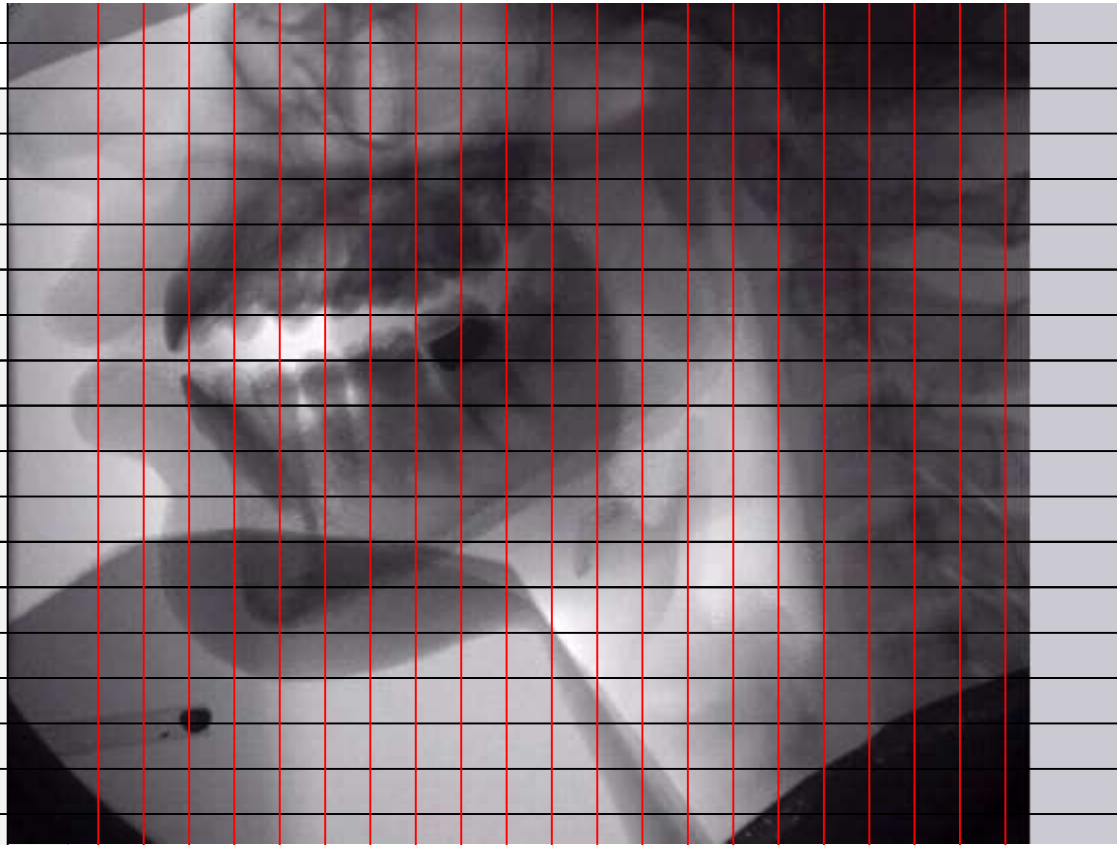
How done?

Demo

vowels

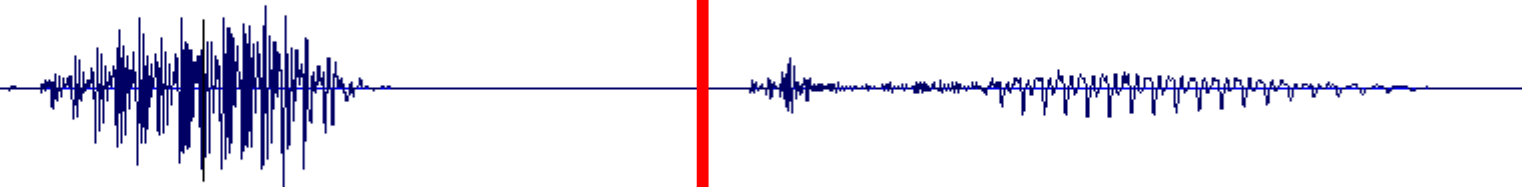


consonants



Other uses

t6



/k/ before release

/aku/

model?

Why modelling?

Which models?

What is a **useful**
model?

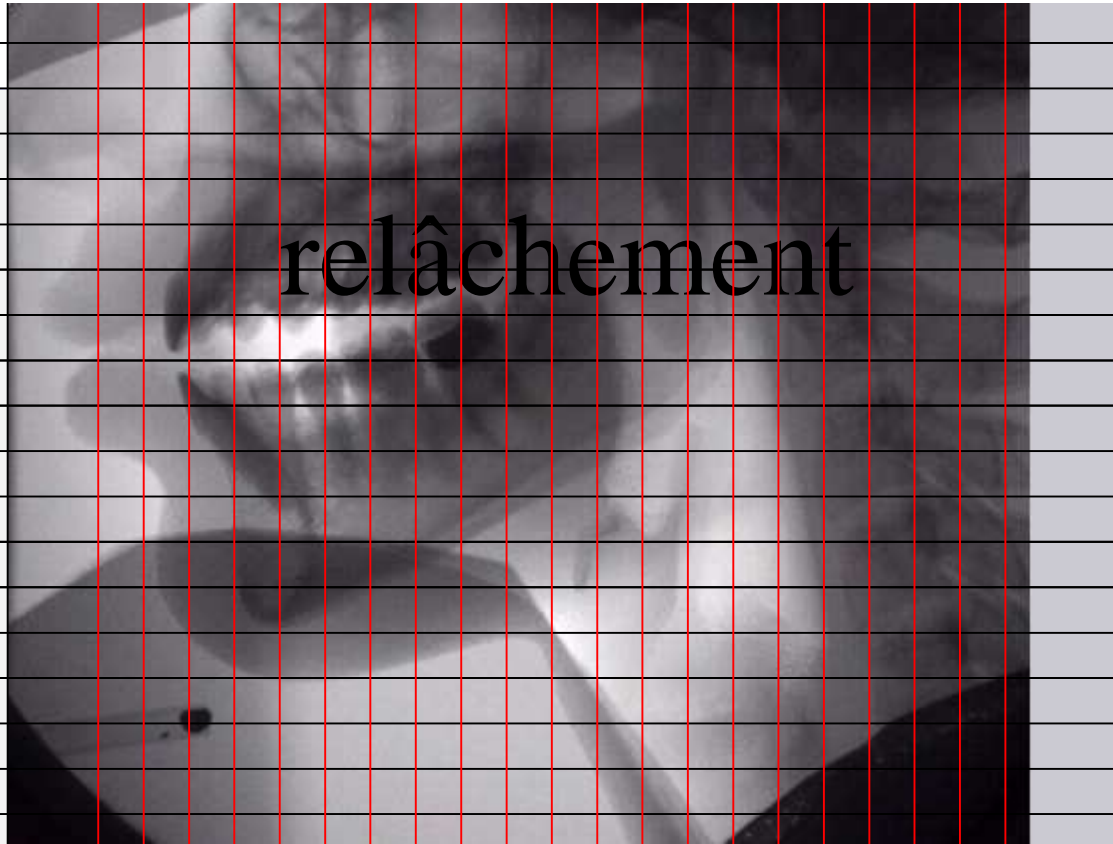
How done?

Demo

vowels

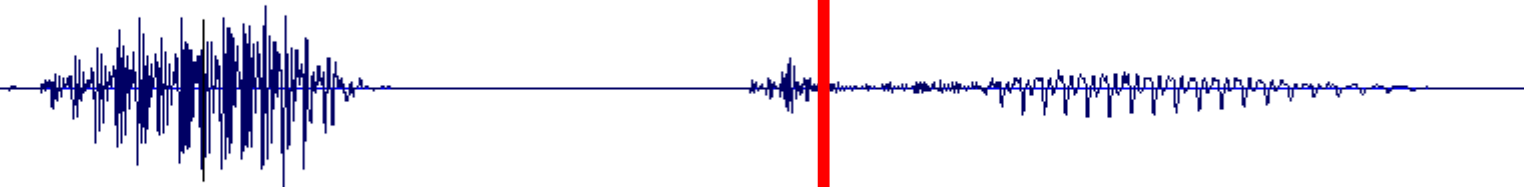


consonants



Other uses

t7



/k/ after release

/aku/

model?

Why modelling?

Which models?

What is a **useful** model?

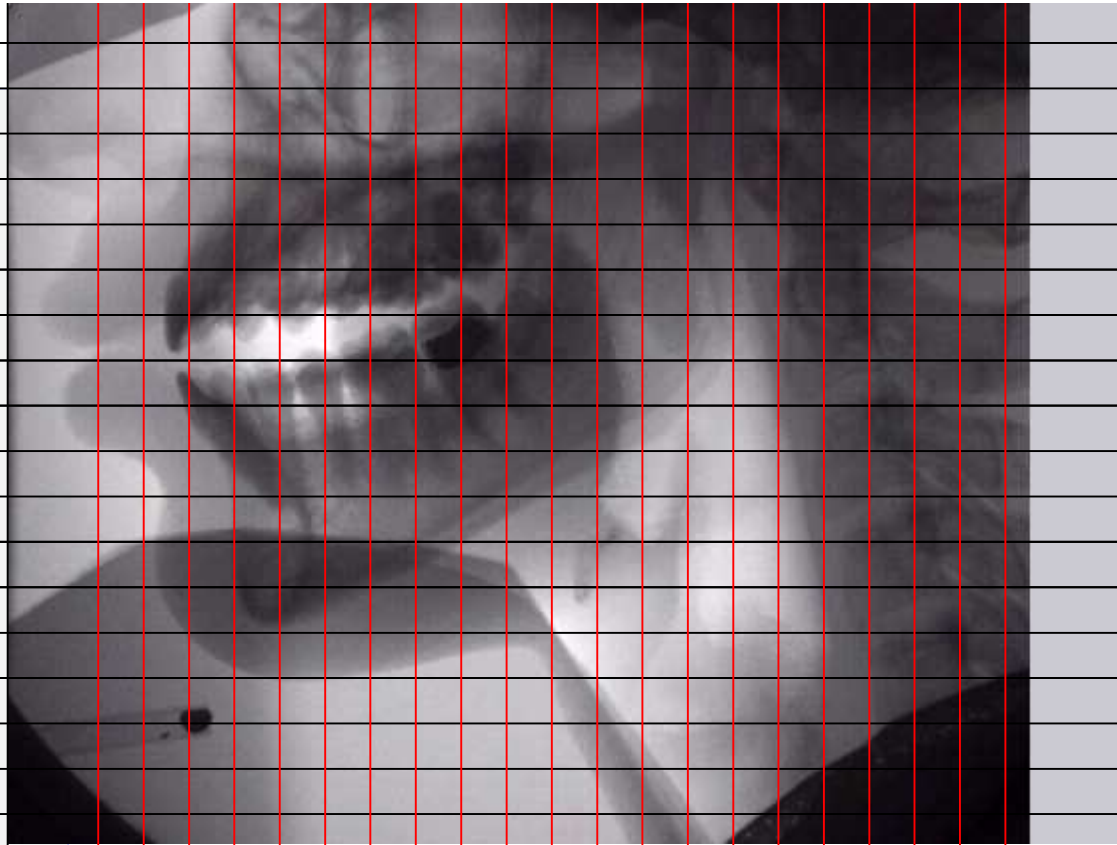
How done?

Demo

vowels



consonants



Other uses

t8



/k/ friction

/aku/

odel?

Why modelling?

Which models?

What is a **useful** model?

How done?

Demo
vowels
→ consonants

Other uses

t9

Maximum rounding



/u/ onset

/aku/

Model?

Why modelling?

Which models?

What is a **useful** model?

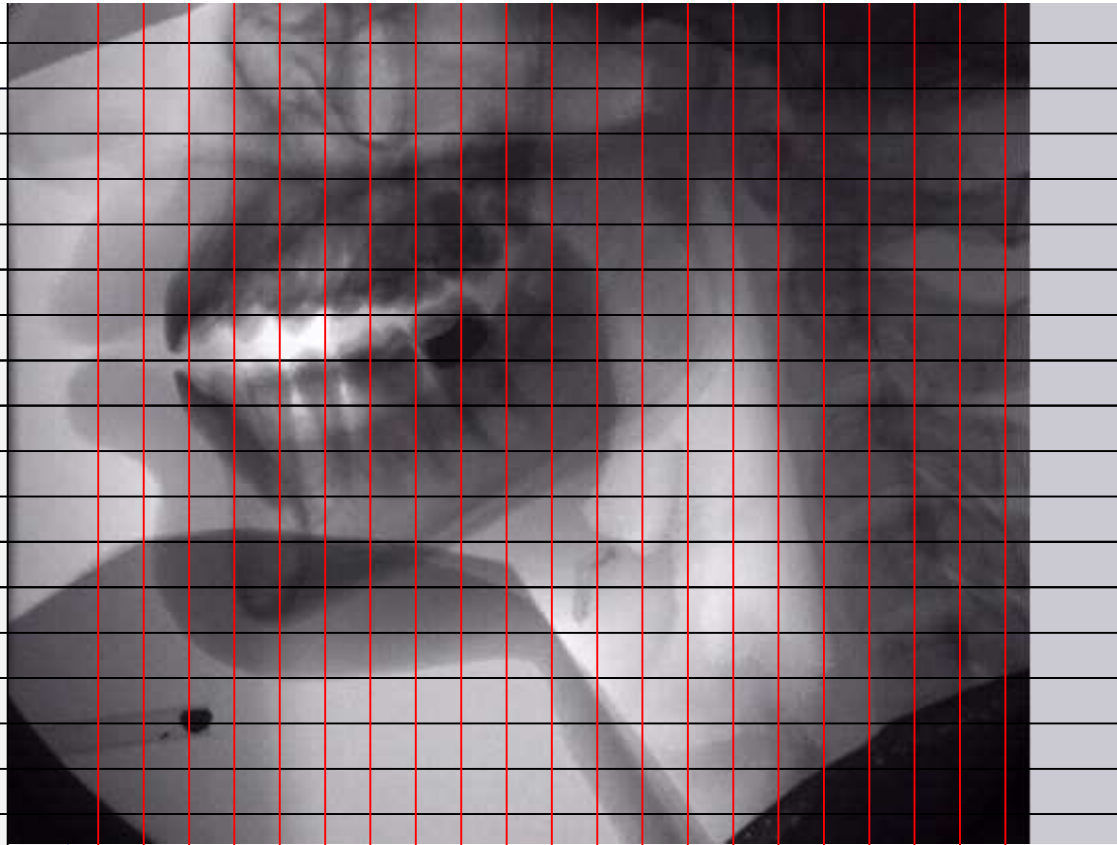
How done?

Demo

vowels



consonants



Other uses

t10

Velum starts to lower
Derounding starts

/u/ middle

/aku/

odel?

Why modelling?

Which models?

What is a **useful** model?

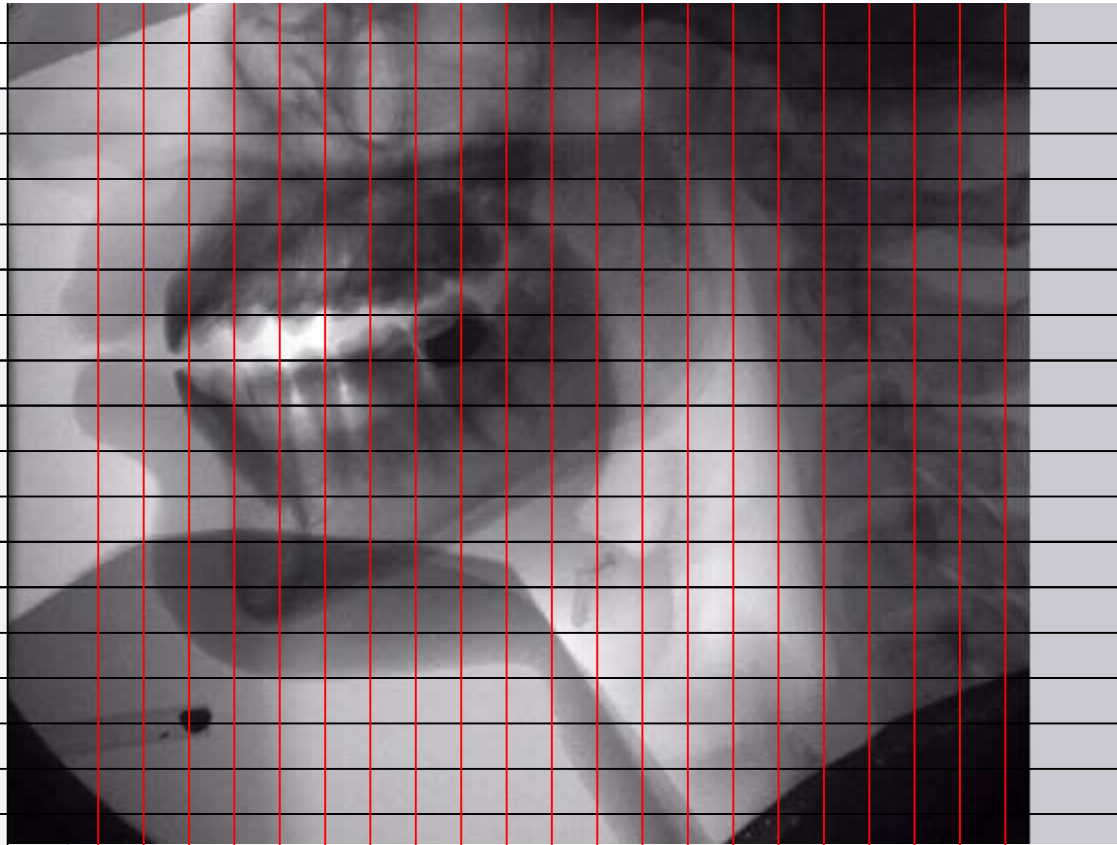
How done?

Demo

vowels



consonants



Other uses

t11

Larynx maximally low



/u/ end

/aku/

model?

Why modelling?

Which models?

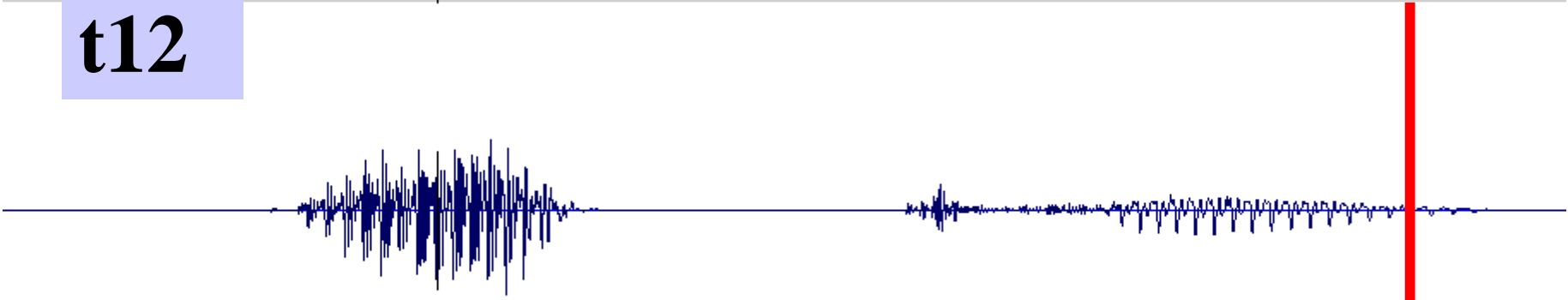
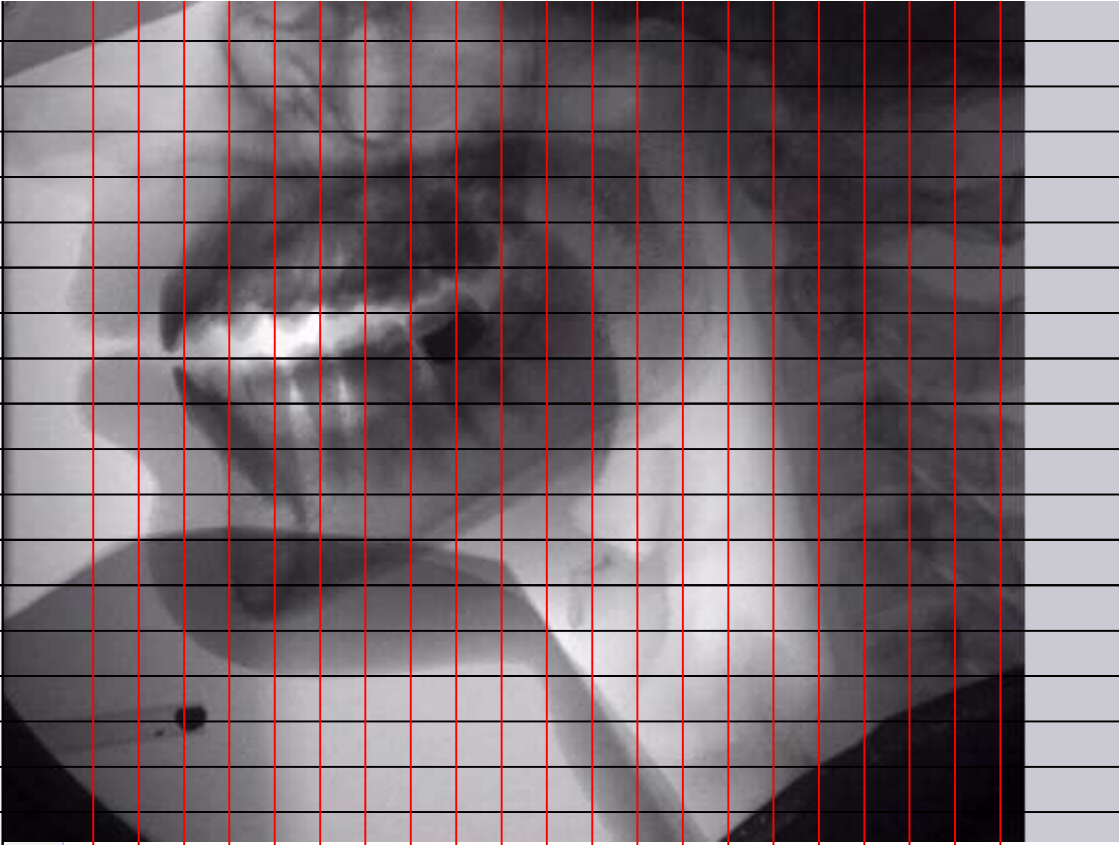
What is a **useful** model?

How done?

Demo
vowels
→ consonants

Other uses

t12



end

What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

→ vowels
→ consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;



Different degrees of sophistication

1) Simple concatenation

2) Contextual allophones

Velar

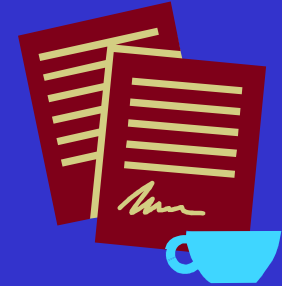
3) Anticipation and carry over phenomena

4) Suprasegmental influences

- Position in the syllable (nasal in preparation, masking)
- Position in the word or relative to stress (lenition and fortition) seen



The points



1) Pedagogical point of view

Draw the link between

-articulatory data,

-acoustic data

-and perception

>> Understanding for linguists

the basics of

Acoustic Theory of Speech production

Ps, Pio



1) DATA

What is a model?

production

What is a model?

linguist

How does it work?

phonetician

Other uses

phonologist

speaking

singing

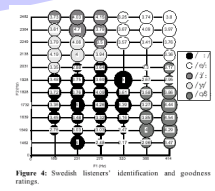
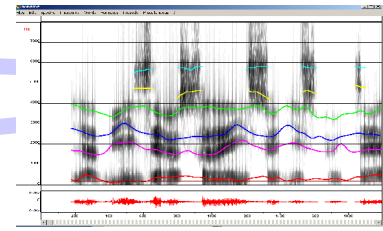
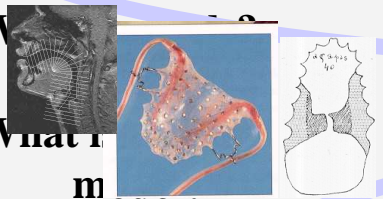
inversion

etc.

production

acoustics

perception



linguist

Language teacher

2) Coherent teaching Research tool

engineer

Speech therapist

Medical students

Modellisation



What is a model?

Why modelling?

Which models?

**What is a useful
model?**

How done?

Demo

vowels

consonants

Other uses

speaker anatomy

speaker strategy

singing formant

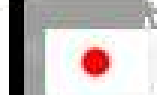
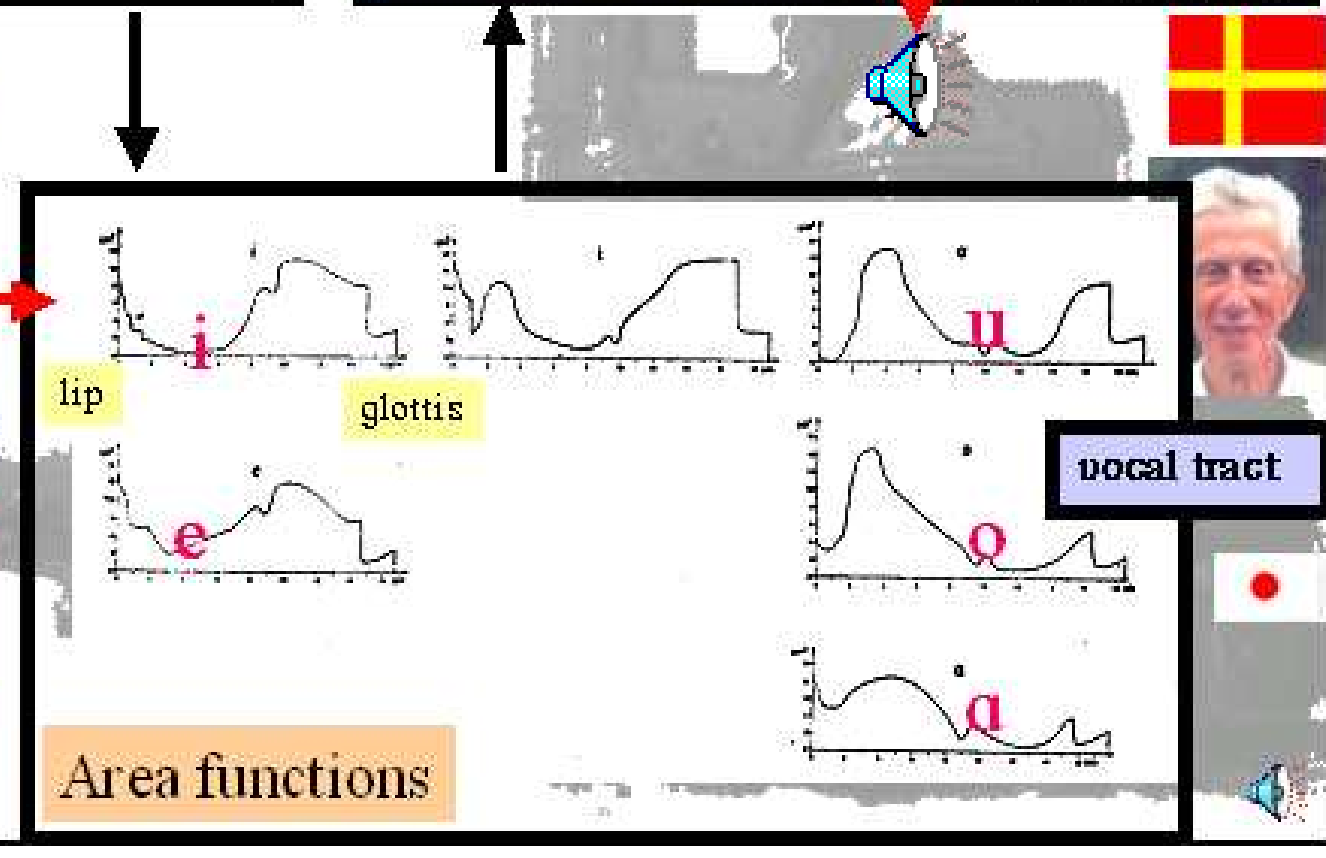
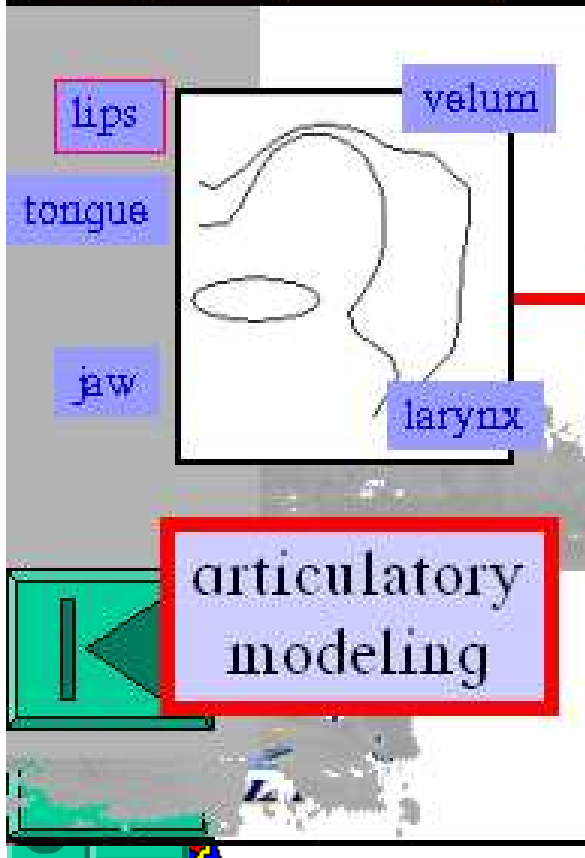
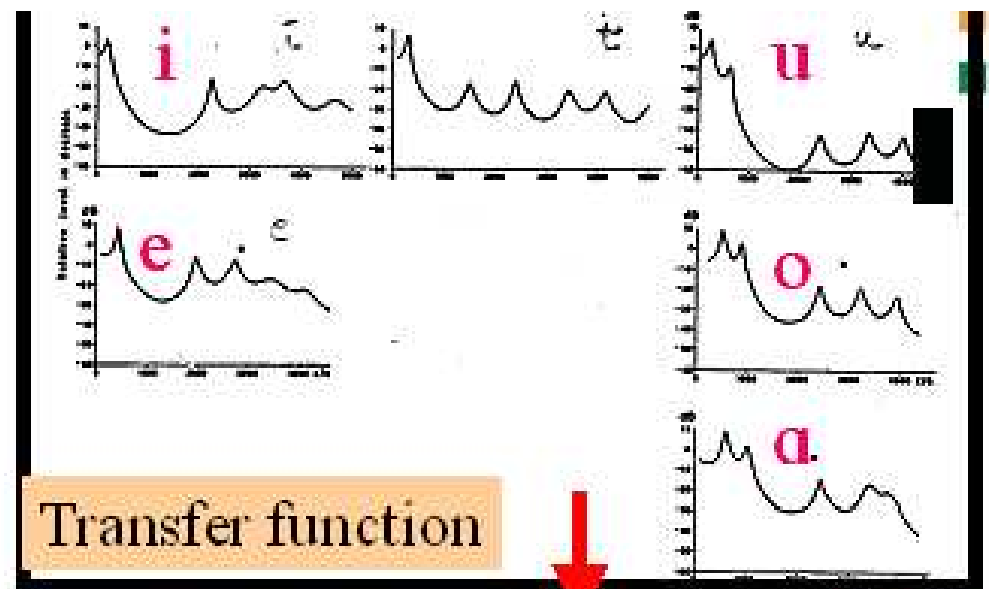
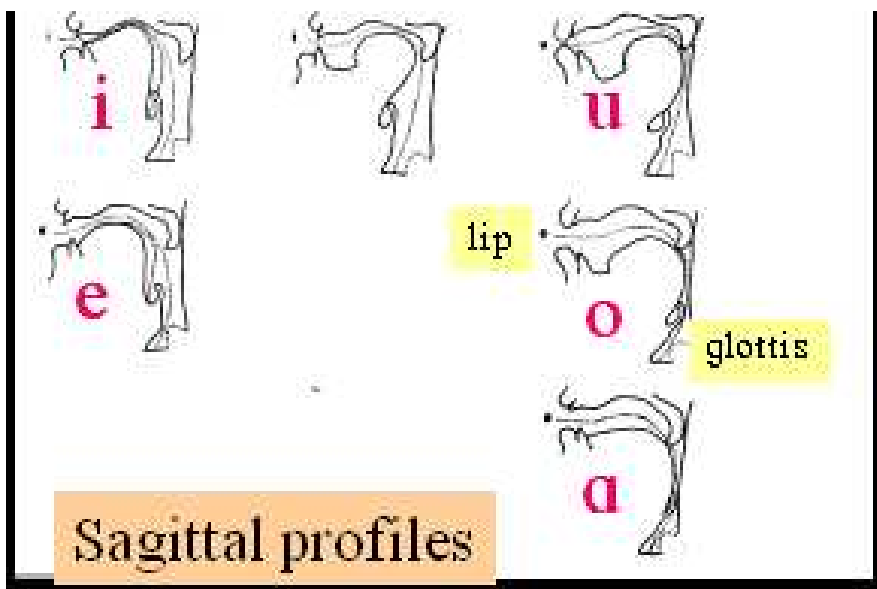
inversion

etc;



Modelisation





vocal tract

2) For what concerns the vowels

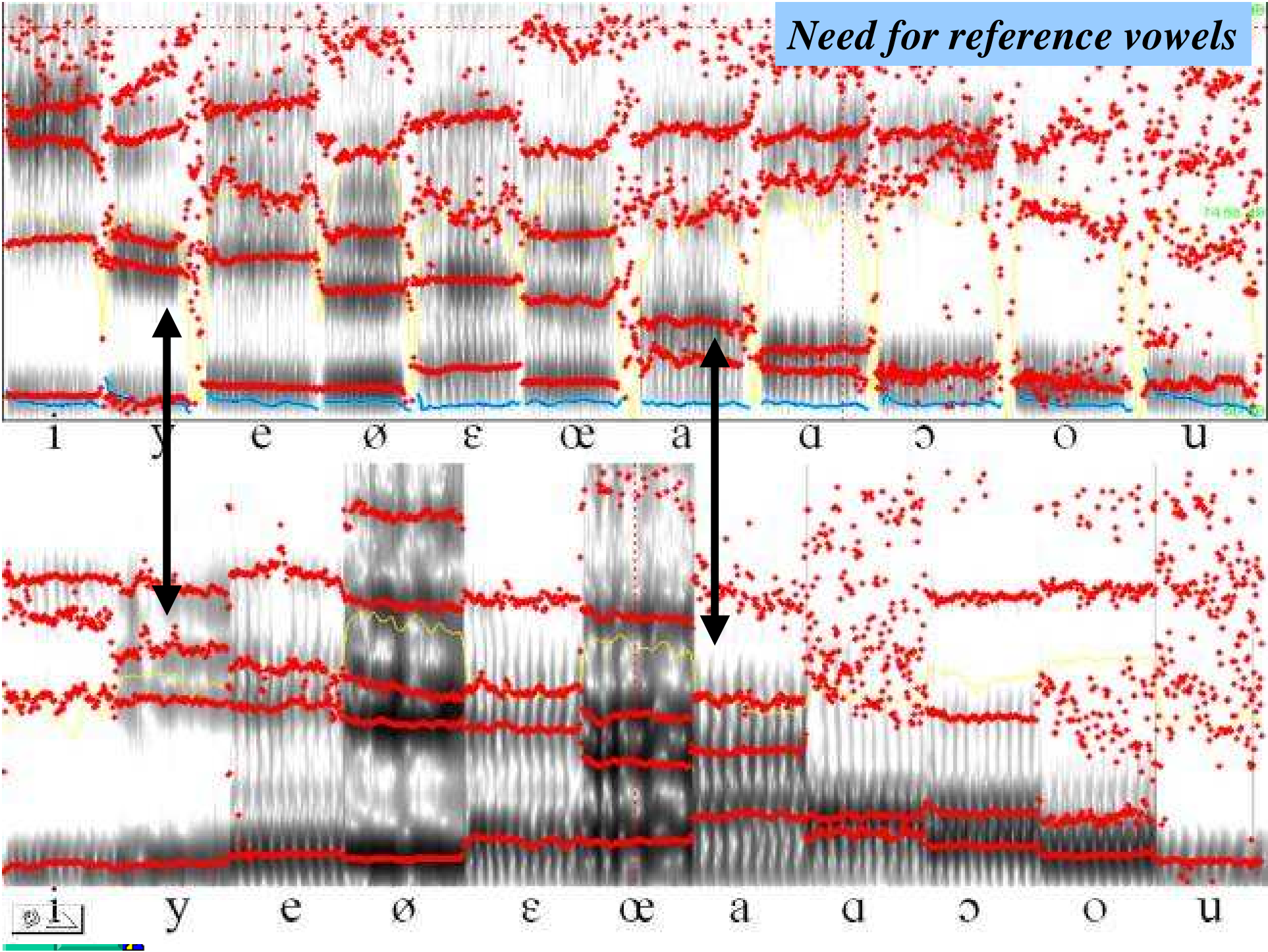
a) Need for reference vowels

Cardinal vowels

Sensibility to formant amplitude and bandwidth

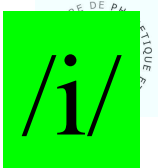
AM could help

Need for reference vowels



observations

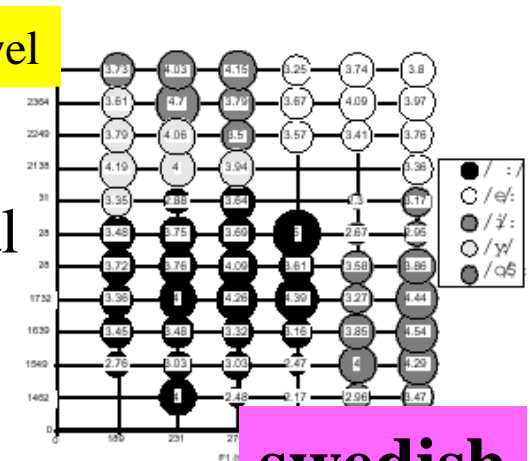
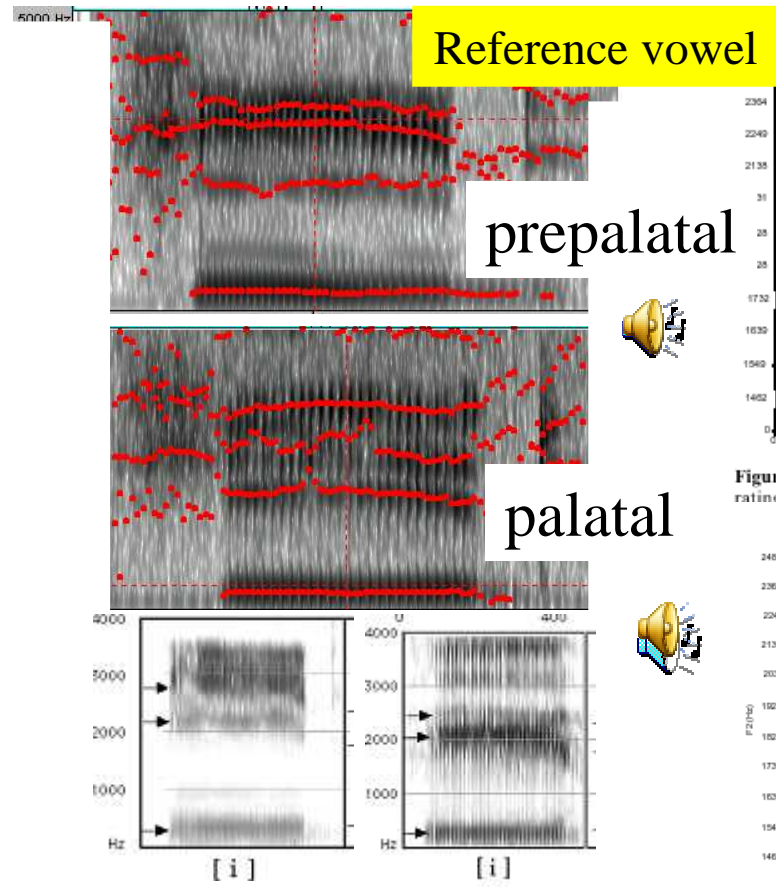
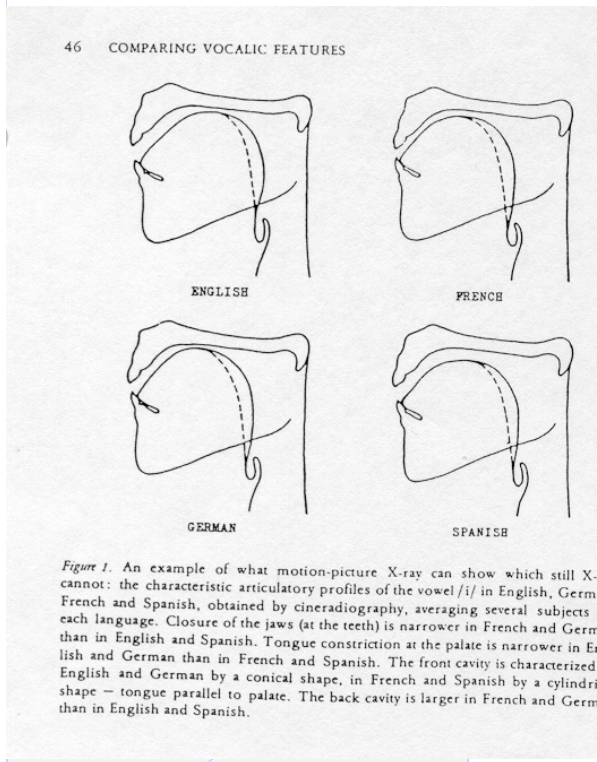
Need for reference vowels



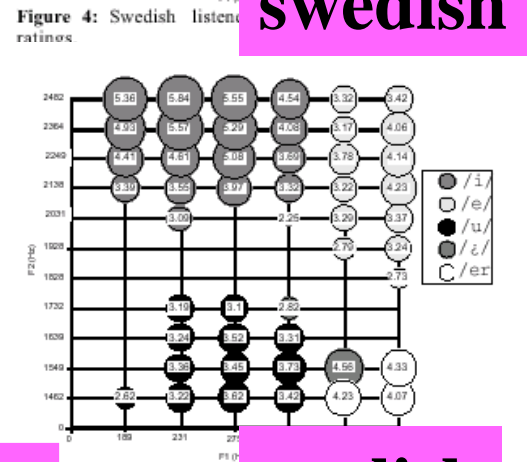
articulatory

acoustic

perceptual



swedish

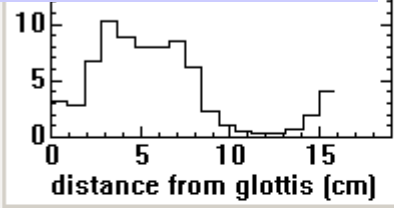


english

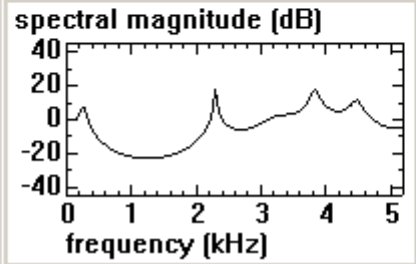
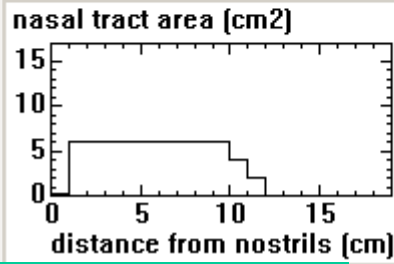
1) Helps to represent in a comprehensive way the language-specific prototypes



articulatory



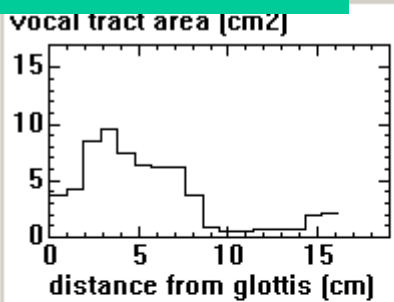
number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input checked="" type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=0.5	<input type="checkbox"/>
tongue=-2	<input type="checkbox"/>
shape=1	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=1	<input type="checkbox"/>
lip_pr=-1	<input type="checkbox"/>
larynx=0	<input type="checkbox"/>



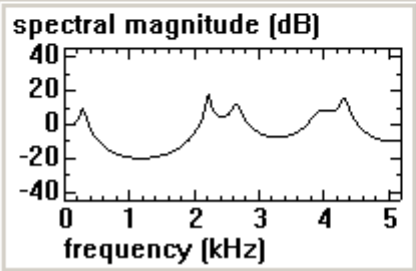
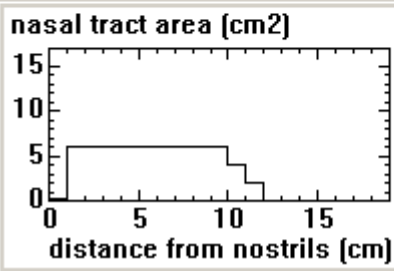
Frq(Hz)	Bw(Hz)	A(dB)
F1	248	79
F2	2290	29
F3	3838	109
F4	4488	168

acoustic

simulation

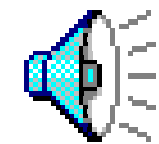
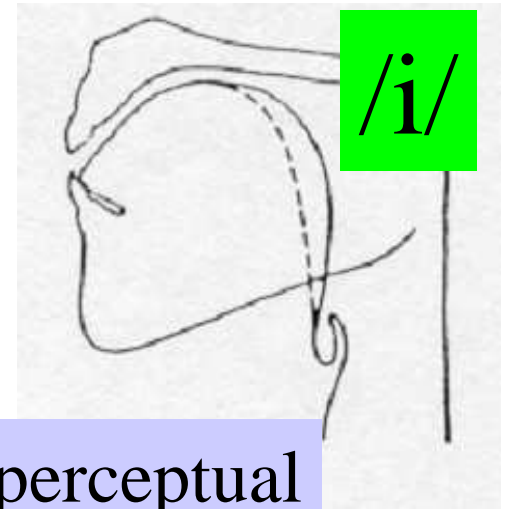


number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input checked="" type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=4.4	<input type="checkbox"/>
tongue=0.4	<input type="checkbox"/>
shape=1.5	<input type="checkbox"/>
apex=-2.8	<input type="checkbox"/>
lip_ht=1	<input type="checkbox"/>
lip_pr=-1	<input type="checkbox"/>
larynx=0	<input type="checkbox"/>



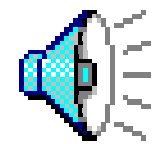
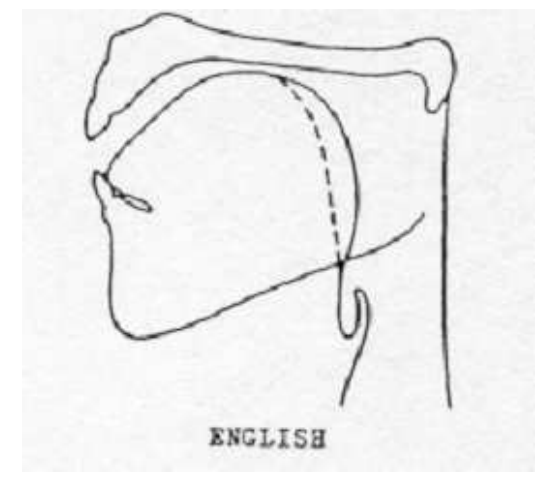
Frq(Hz)	Bw(Hz)	A(dB)
F1	279	73
F2	2229	48
F3	2662	118
F4	3962	203
F5	4333	92

1) Helps to represent in a comprehensive way the language-specific prototypes



perceptual

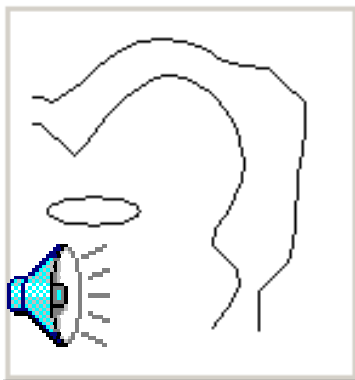
F1 (↑F3. F4)



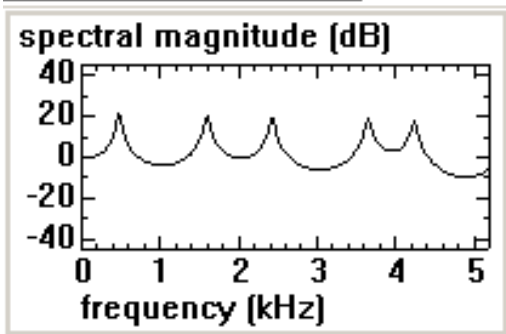
F1 ↑ F2



Need for reference vowels



neutral		s=17	<input type="checkbox"/>
		ion=9	<input type="checkbox"/>
		(h2)=0	<input type="checkbox"/>
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"/>		



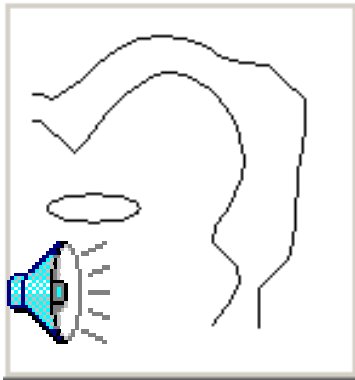
	Frq(Hz)	Bw(Hz)	A(dB)
F1	464	47	22
F2	1610	64	20
F3	2414	56	20
F4	3652	57	19
F5	4240	58	18

vowels
consonants

Other uses

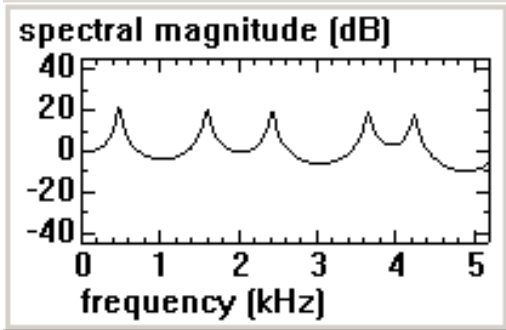
- speaker anatomy
- speaker strategy
- singing formant
- inversion
- etc;



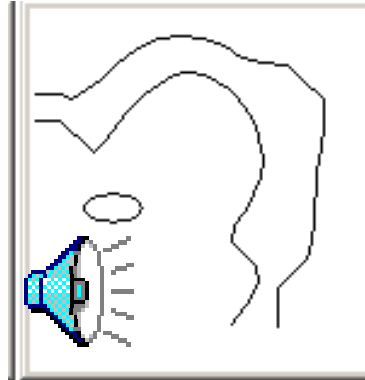


neutral

number of sections=17	I
nasal branch section=9	I
nasal protrusion=0	F
jaw=-1	F
lip_ht=0	F
tongue=-0.5	F
lip_pr=0	F
shape=0.5	F
larynx=0	F
apex=-2	F

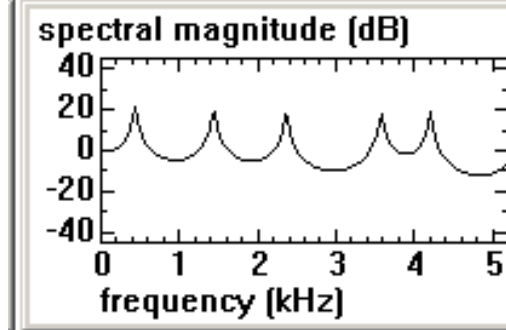


Frq(Hz)	Bw(Hz)	A(dB)
F1	464	47
F2	1610	64
F3	2414	56
F4	3652	57
F5	4240	58



+ protrusion

number of sections=17	I
nasal branch section=9	I
nasal protrusion=1	F
lip_pr .11	X
lip_ht=0	F
tongue=-0.5	F
lip_pr	-5 <3< 5
shape=0.5	F
larynx=0	F
apex=-2	F



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

vowels
consonants

Other uses

- speaker anatomy
- speaker strategy
- singing formant
- inversion
- etc;

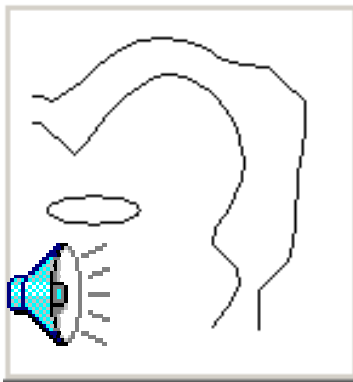
Need for reference vowels

(F2 ↓ ↓ ↓ F3)

ion

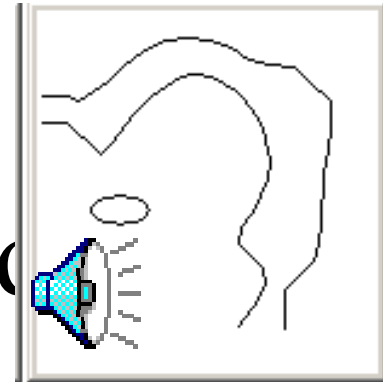


neutral

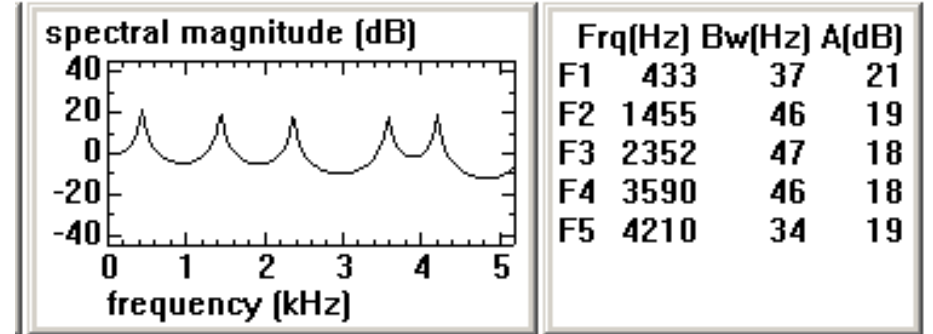
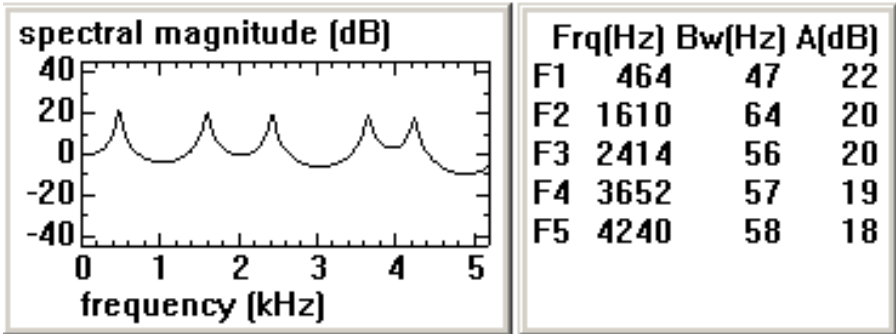


number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm2)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=0	<input type="checkbox"/>
lip_pr=0	<input type="checkbox"/>
larynx=0	<input type="checkbox"/>

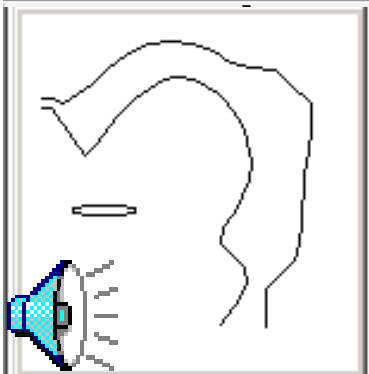
+ protrusion



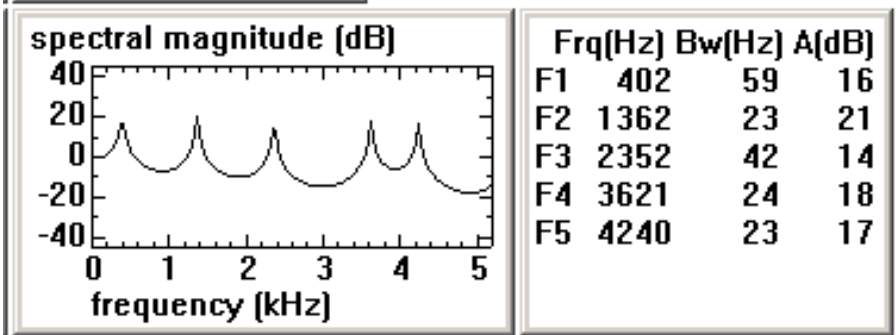
number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm2)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=0	<input type="checkbox"/>
lip_pr	<input type="checkbox"/>
lip_pr	-5 <3< 5



+ compression



number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm2)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht	<input type="checkbox"/>
lip_pr	-5 <-0.9< 5



Need for reference vowels

odelisation

neutral

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=0	<input type="checkbox"/>
lip_pr=0	<input type="checkbox"/>
larynx=0	<input type="checkbox"/>

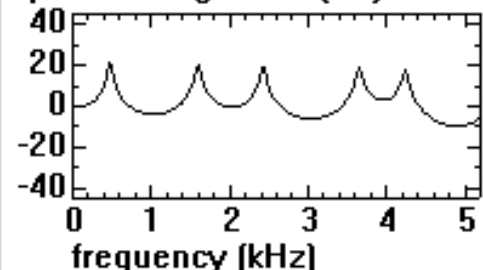
and

+ protrusion

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=0	<input type="checkbox"/>
lip_pr=11	<input type="checkbox"/>
lip_pr .11	<input type="checkbox"/>
-5 <3< 5	<input type="checkbox"/>

+ compression

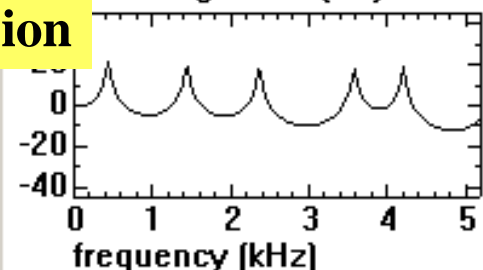
spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

Frq(Hz)	Bw(Hz)	A(dB)
F1 464	4	20
F2 1610	64	20
F3 2414	56	20
F4 3652	57	19
F5 4240	58	18

spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

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

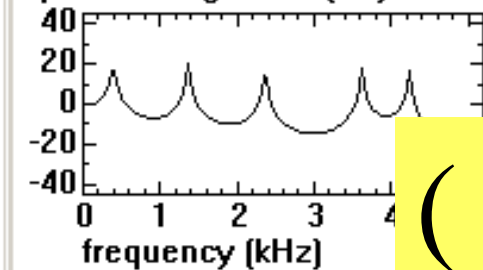
LIP

+ compression
+ protrusion

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=11	<input type="checkbox"/>
lip_pr=3	<input type="checkbox"/>
lip_pr .11	<input type="checkbox"/>
-5 <-0.9< 5	<input type="checkbox"/>

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=-0.9	<input type="checkbox"/>
lip_pr=3	<input type="checkbox"/>
lip_pr .11	<input type="checkbox"/>
-5 <-0.9< 5	<input type="checkbox"/>

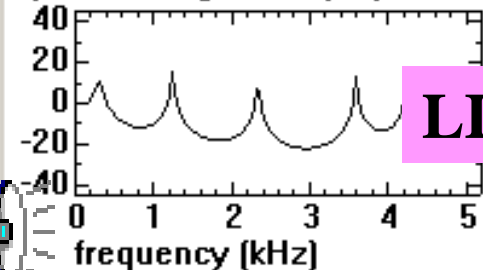
spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

Frq(Hz)	Bw(Hz)	A(dB)
F1 402	59	16
F2 1362	23	21
F3 2352	42	14

spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

Frq(Hz)	Bw(Hz)	A(dB)
F1 310	68	11
F2 1238	21	16
F3 2352	42	14
F4 3652	57	19
F5 4240	20	11

LIP + TONGUE

(F2 ↓ ↓ ↓ F3)

neutral

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=0	<input type="checkbox"/>
lip_pr=0	<input type="checkbox"/>
larynx=0	<input type="checkbox"/>

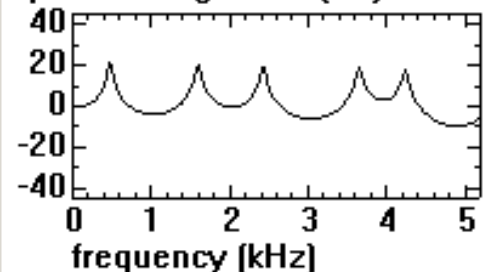
and

+ protrusion

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=0	<input type="checkbox"/>
lip_pr=11	<input type="checkbox"/>
lip_pr	<input type="checkbox"/>
-5 <3< 5	<input type="checkbox"/>

+ compression

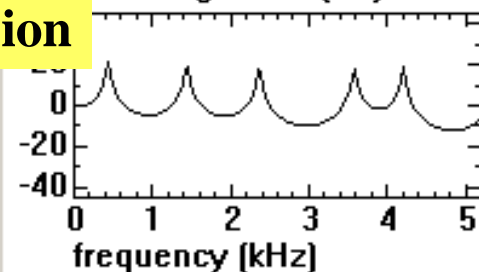
spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

Frq(Hz)	Bw(Hz)	A(dB)
F1 464	4	20
F2 1610	64	20
F3 2414	56	20
F4 3652	57	19
F5 4240	58	18

spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

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

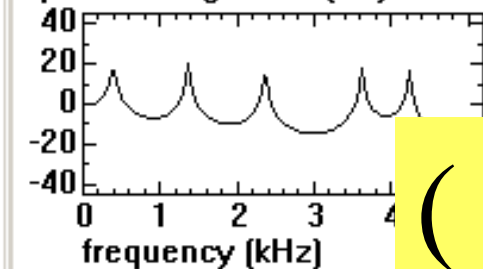
LIP

+ compression
+ protrusion

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=11	<input type="checkbox"/>
lip_pr=3	<input type="checkbox"/>
lip_pr	<input type="checkbox"/>
-5 <-0.9< 5	<input type="checkbox"/>

number of sections=17	<input type="checkbox"/>
nasal branch section=9	<input type="checkbox"/>
nasal coupling (cm ²)=0	<input type="checkbox"/>
jaw=-1	<input type="checkbox"/>
tongue=-0.5	<input type="checkbox"/>
shape=0.5	<input type="checkbox"/>
apex=-2	<input type="checkbox"/>
lip_ht=-0.9	<input type="checkbox"/>
lip_pr=3	<input type="checkbox"/>
lip_pr	<input type="checkbox"/>
larynx=0	<input type="checkbox"/>

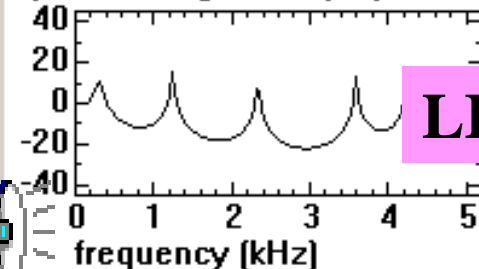
spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

Frq(Hz)	Bw(Hz)	A(dB)
F1 402	59	16
F2 1362	23	21
F3 2352	42	14

spectral magnitude (dB)



Frq(Hz) Bw(Hz) A(dB)

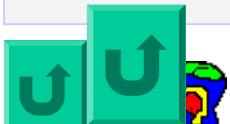
Frq(Hz)	Bw(Hz)	A(dB)
F1 310	68	11
F2 1238	21	16
F3 2352	42	14
F4 3590	46	18
F5 4240	20	11

LIP + TONGUE

(F2 ↓ ↓ ↓ F3)

Location of the constriction			
Lowest possible formant		Highest possible formant	
↓F1	anterior part of the VT	↑F1	posterior part of the VT
↓F2	velar region + <i>lip rounding</i>	↑F2	mid-palatal region + glottal region
↓F3	pharyngeal region + <i>bunching of the tongue,</i> <u><i>retroflexion</i></u> + <i>lip rounding and lip protrusion</i>	↑F3	apical and <u>prepalatal</u> regions + lip spreading + glottal region (<i>larynx lowering</i>)

Table 3: Tongue constriction position, lip configuration, tongue shape and F-pattern values: a summary.



2) For what concerns the vowels

a) Need for references vowels

b) The rôle of anatomical details

- the laryngeal cavity for the vowels

- rôle of pharyngeal volume, etc.

Role of anatomical details

What is a model?

Why modelling?

Which models?

What is a useful model?

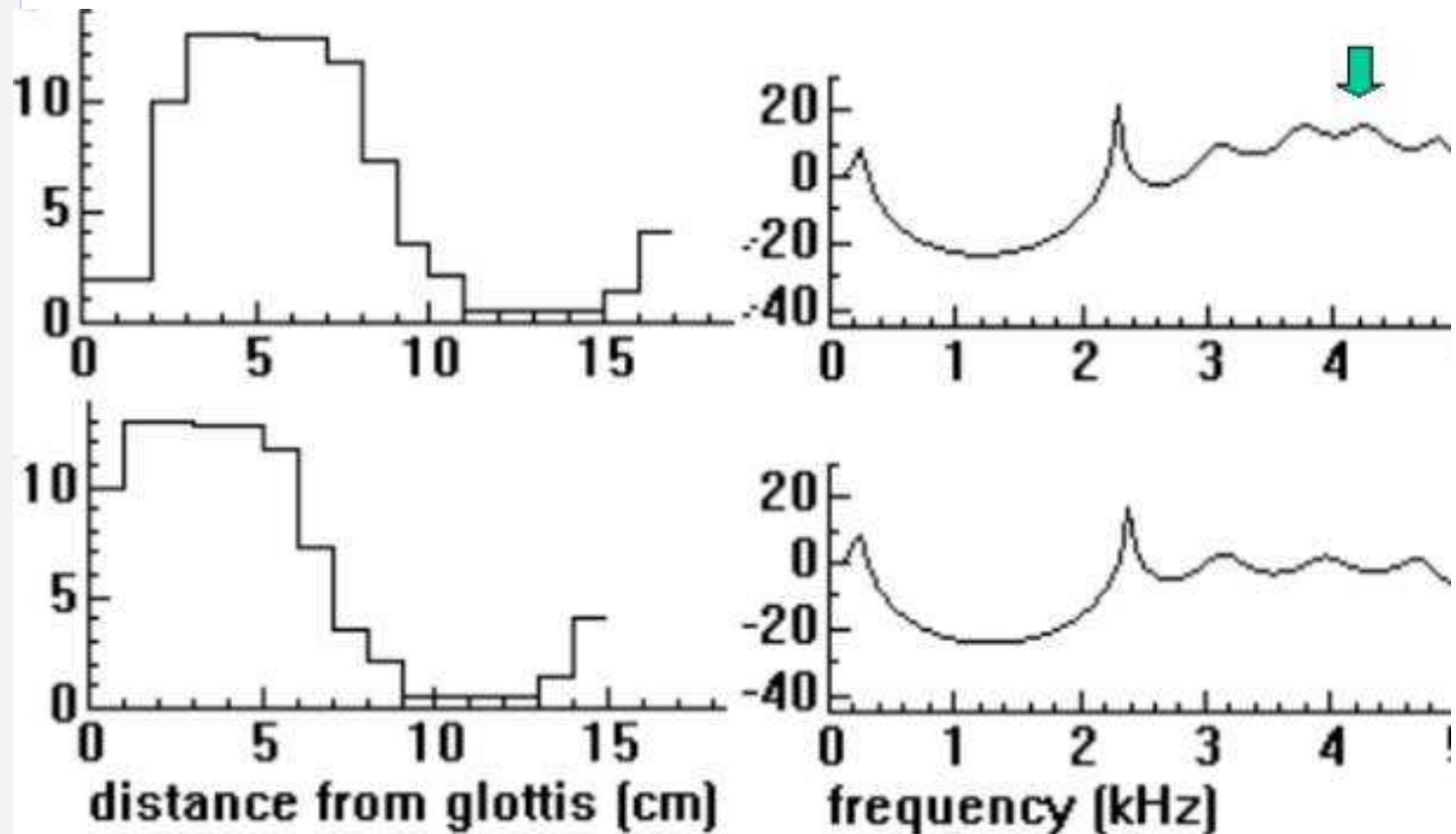
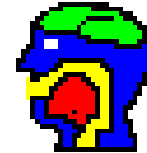
How done?

Demo

vowels
consonants

Other uses

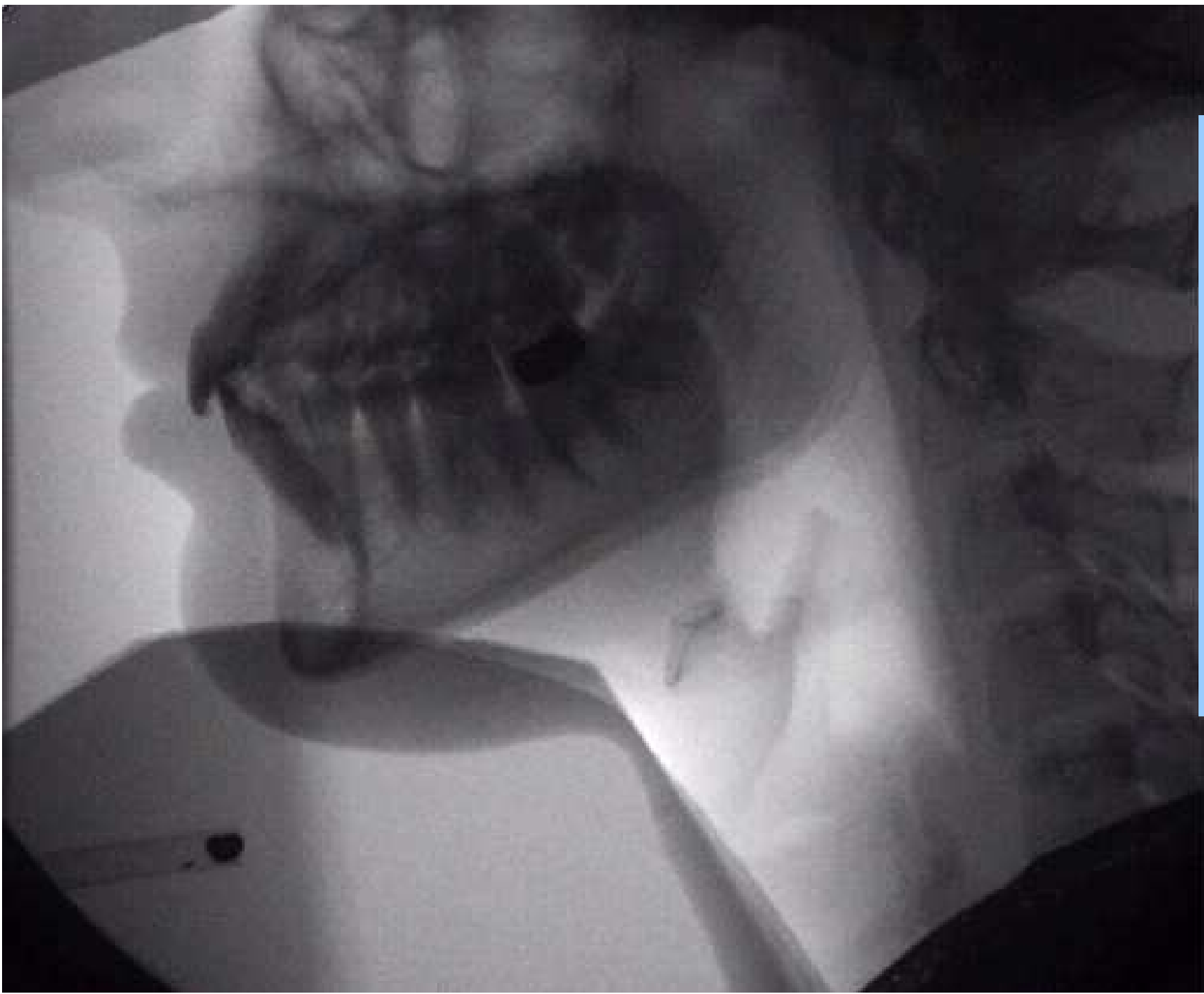
speaker anatomy
speaker strategy
singing formant
inversion
etc;



MODELSATION

02





Role of anatomical details

2) For what concerns the vowels

a) Need for references vowels

b) The rôle of anatomical details

*c) The acoustic properties largely
Prevail over articulation*

Perception prevails over articulation

What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

vowels

consonants

Other uses

speaker anatomy

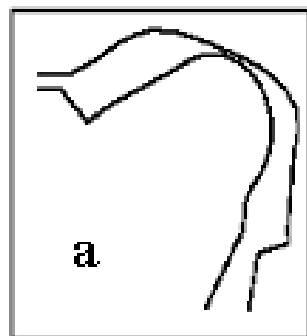
speaker strategy

singing formant

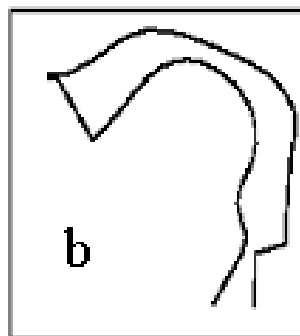
inversion

etc;

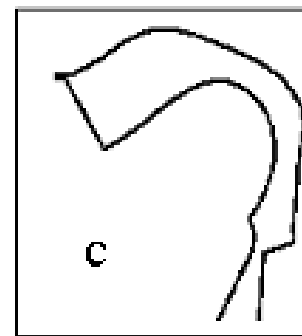
About the same sound (except the focal and extreme sounds can be obtained by Fairly different VT configuration



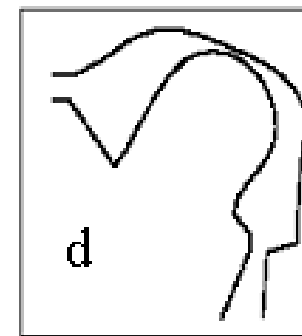
335 904 2150



341 986 2113



346 953 2118



352 949 2112



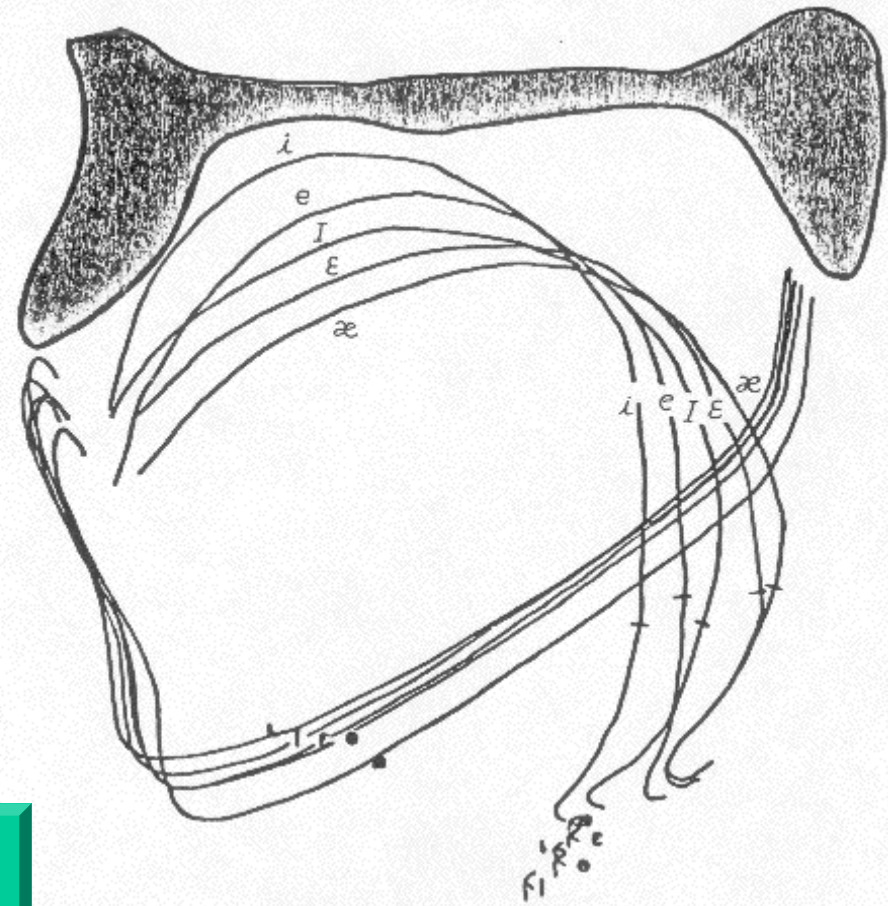
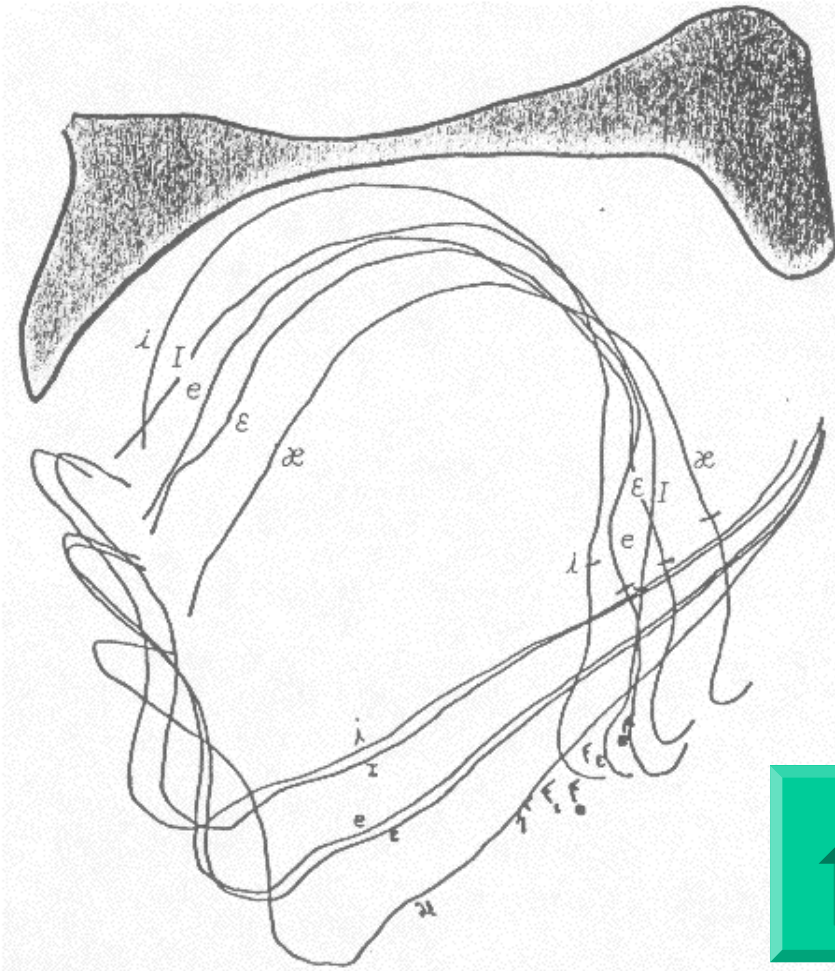
2) For what concerns the vowels

a) Need for reference vowels

b) The rôle of anatomical details

*c) The acoustic properties largely
Prevail over articulation*

d) Different strategies can be modelled



inversion

Speaker different strategies



2) For what concerns the consonants

a) Simple concatenation works better than expected

2) For what concerns the consonants

a) Simple concatenation work than expected

b) The rôle of anatomical details: sublingual cavity

What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;

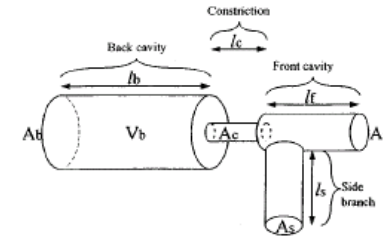
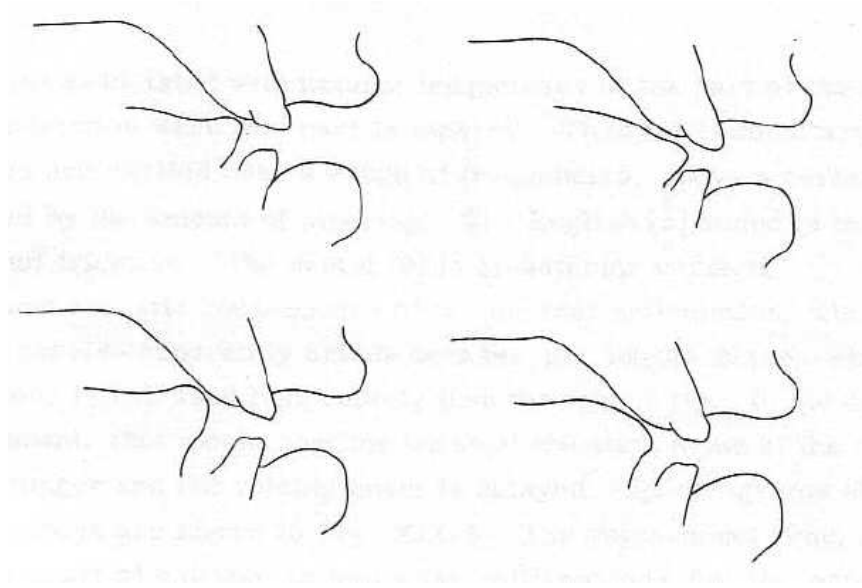
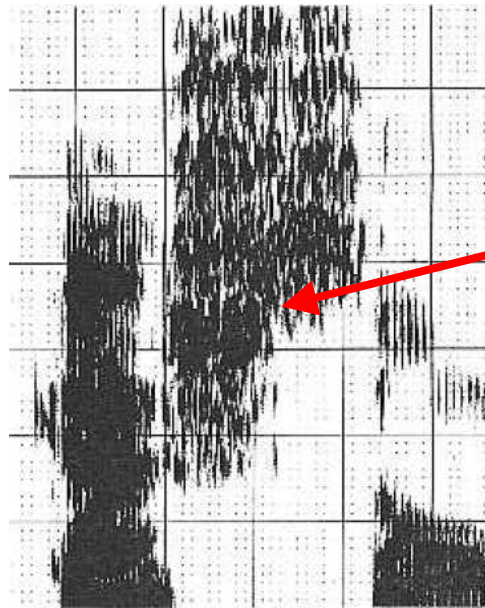


FIG. 5. The tube configuration simulated in the "weakly coupled" models.



sublingual cavity
Necessary
To recreate existing
Acoustic discontinuity

Modelisation



2) For what concerns the consonants

a) Simple concatenation work than expected

b) The rôle of anatomical details: sublingual cavity

*c) The acoustic properties largely
Prevail over articulation: the velar*

2) For what concerns the consonants

a) Simple concatenation work than expected

b) The rôle of anatomical details: sublingual cavity

*c) The acoustic properties largely
Prevail over articulation: the velars*

d) Exotic consonants may be easy to model

Non French consonants

What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

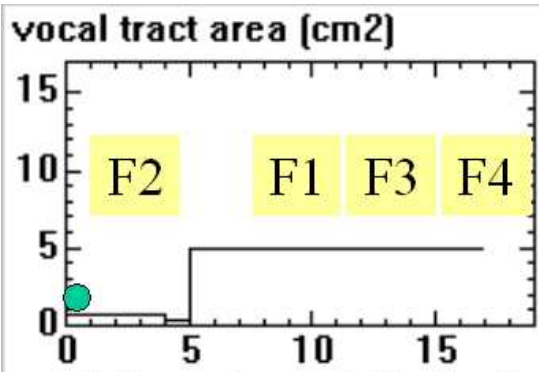
vowels
consonants

Other uses

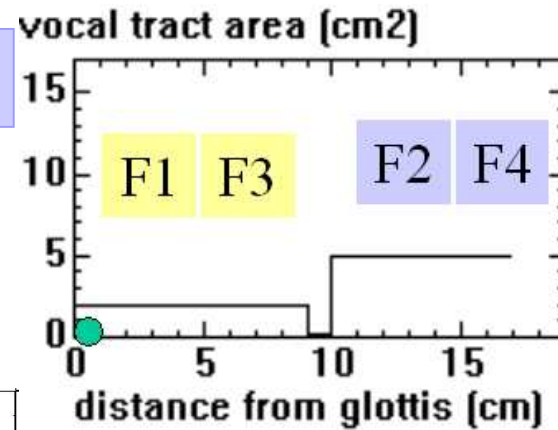
speaker anatomy
speaker strategy
singing formant
inversion
etc;

- Start from articulatory model for the flanking vowels
- Tube or area function for the consonant
- Examples: posterior arabic consonants
- (Mohamed Yeou's thesis)





95%, 69*



100%, 76

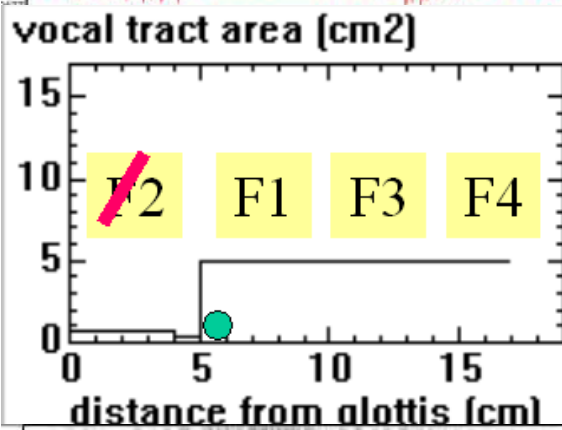


0.35

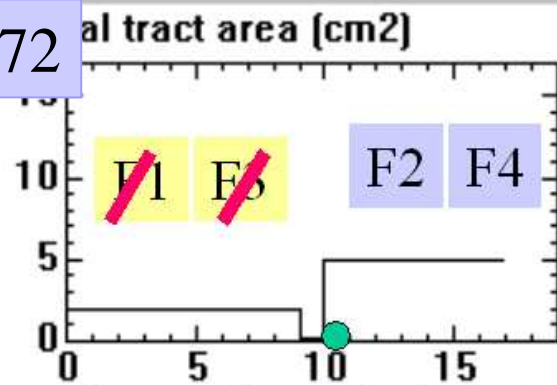
Glottis more open?



χ k



100%, 72



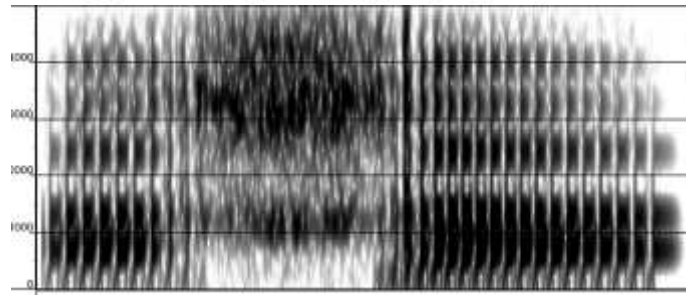
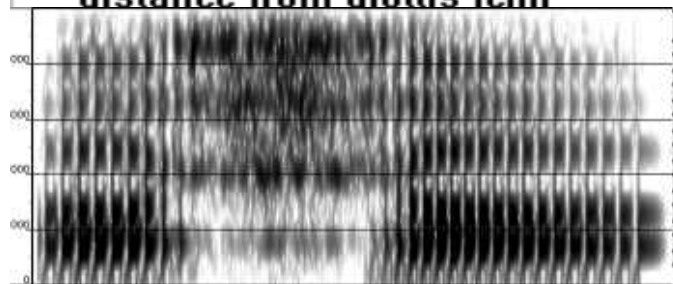
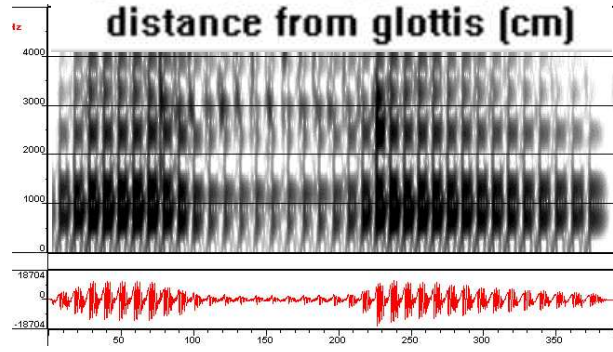
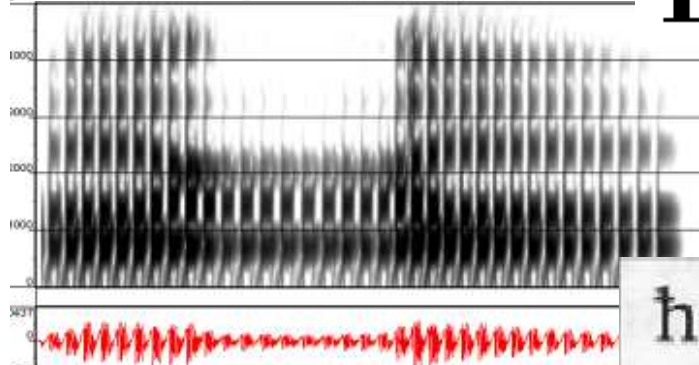
100%, 79



0.20

10 listeners
10 repetitions

*Alwan, 1989  74



Beans on a string synthesis

W	• Pharyngeal sourde		
h	• 16.5	0.7 0.7 0.7 0.7 0.30	5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0
W	• Pharyngeale sonore		
ʕ	• 16.5	0.7 0.7 0.7 0.7 0.35	5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0
H	• [uvulaire sourde]		
χ	• 17	2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 0.2	5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0
	• [uvulaire sonore]		
B	• 17	2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 0.35	5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0
	• [uvulaire sourde]		

Ag = 0 cm2

Ag = 0.20-0.25 cm2

+ timing



2) For what concerns the consonants

a) Simple concatenation work than expected

b) The rôle of anatomical details: sublingual cavity

*c) The acoustic properties largely
Prevail over articulation: the velars*

d) Exotic consonants may be easy to model

e) Lenition and fortition not difficult to model

lenition

What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

Demo

vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;

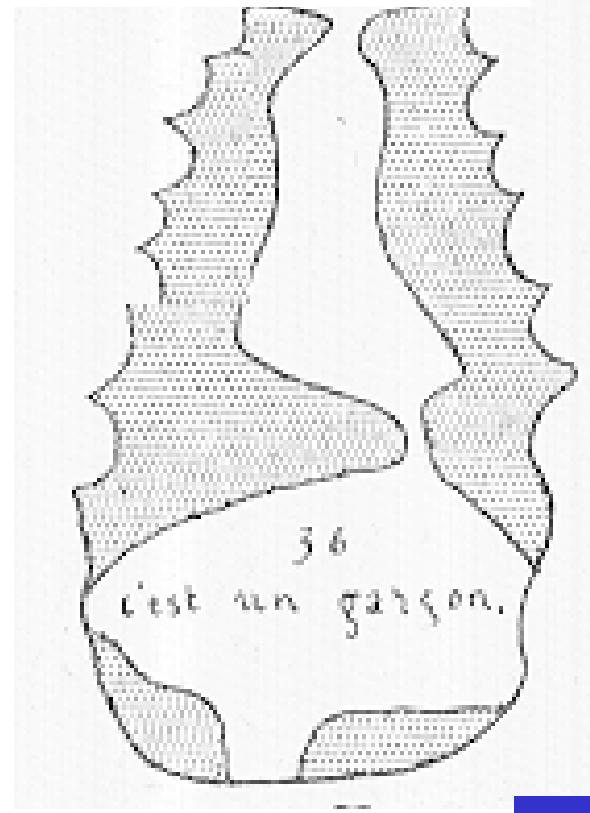
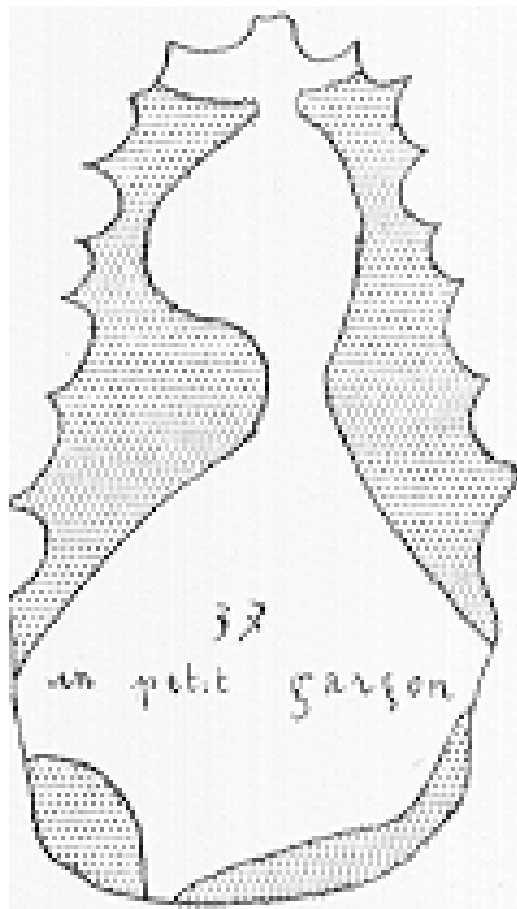
- **Less strong constriction**
- **More close glottis**



- Ration between the two areas may change, and to the category of the consonant
- But the underlying F-pattern is the same



Marguerite Durand



speaker anatomy
speaker strategy
singing formant
inversion
etc;

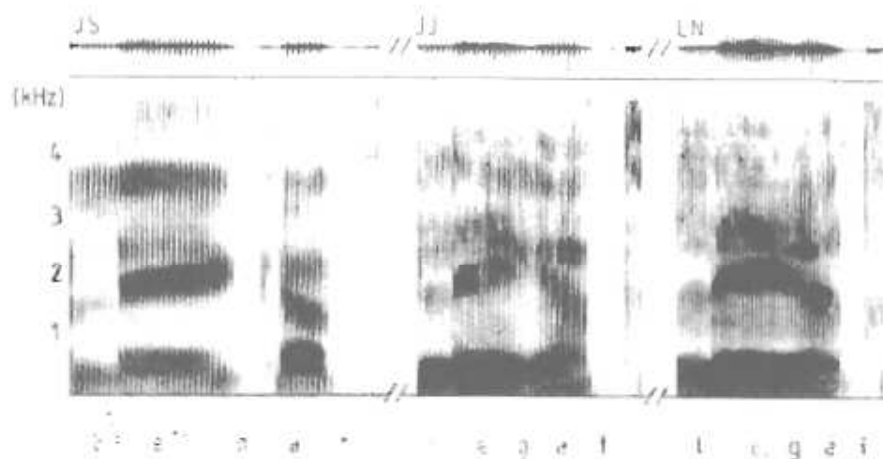


Figure 4.4.2. Normal and two degrees of target undershoot of a voiced stop.



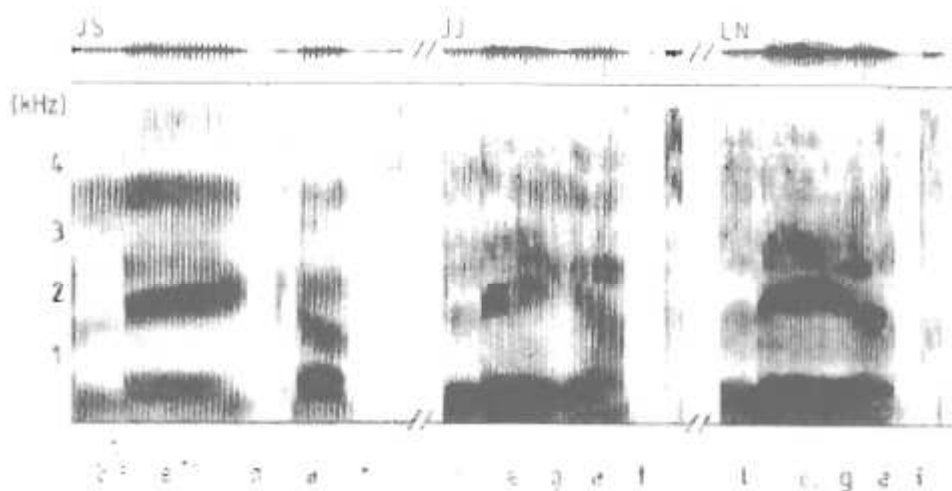
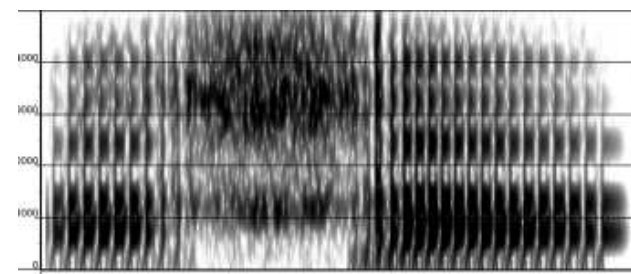
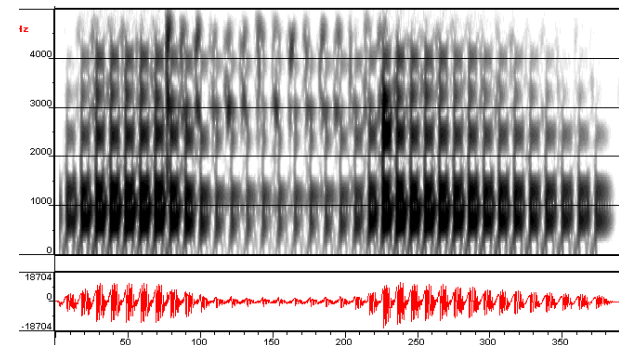


Figure 4.4.2. Normal and two degrees of target undershoot of a voiced stop.



Vt more close than vf

Less vf opening

Voiceless > voiced

Noise created at the narrowest

How done?

Demo

vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;

Less strong closure
in the middle

Stops > fricatives
> sonantes



2) For what concerns the consonants

a) Simple concatenation work than expected

b) The rôle of anatomical details: sublingual cavity

*c) The acoustic properties largely
Prevail over articulation: the velars*

d) Exotic consonants may be easy to model

e) Lenition and fortition not difficult to model

*f) Shape of the tongue counts
more than exact place of constriction*

What is a model?

Why model?

Which model?

What is a useful model?

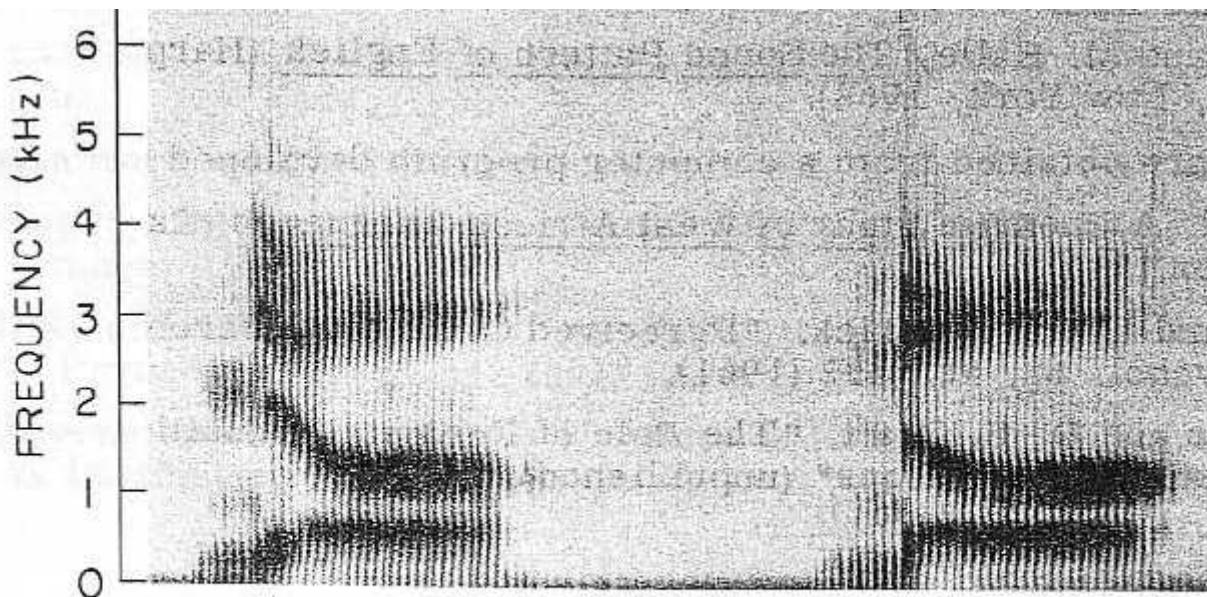
How does it work?

Demo

vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;



laminal

apical

F2

And shape of the tongue is influenced by the vowels



2) For what concerns the consonants

a) Simple concatenation work than expected

b) The rôle of anatomical details: sublingual cavity

*c) The acoustic properties largely
Prevail over articulation: the velars*

d) Exotic consonants may be easy to model

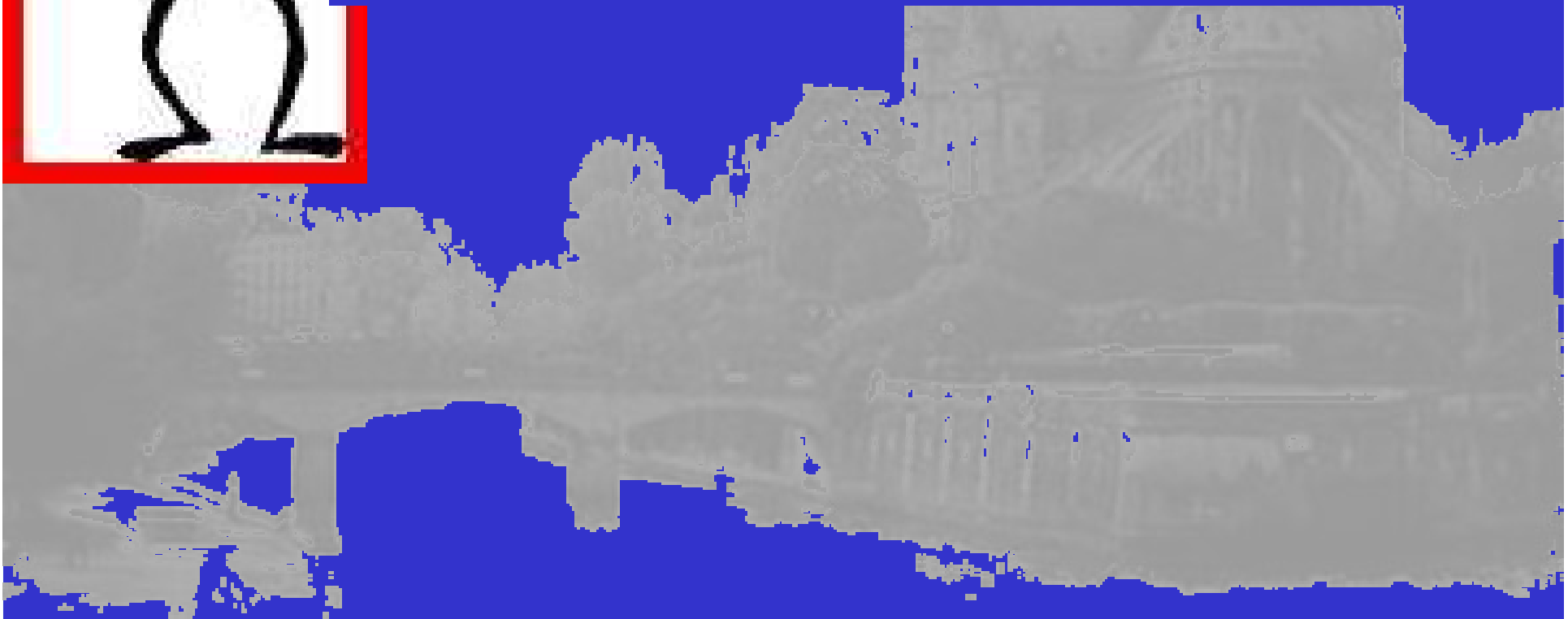
e) Lenition and fortition not difficult to model

*f) Shape of the tongue counts
more than exact place of constriction*

*g) Suppressing the coarticulation effect allows
to distangle the perceptual effects C to V and V to V*



Speaker adaptation .



VLAM (Maeda, 1994)

Variable Linear Articulatory Model

lip, jaw, tongue, larynx

What is a model?

Why modelling?

Which models?

What is a useful model?

How done?

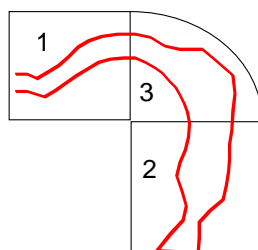
Demo

vowels

consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc:



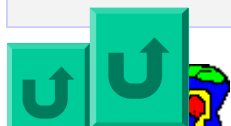
The Larynx Height Index variation is introduced by modifying the longitudinal dimension of the vocal-tract according to 2 scaling factors and 3 zones:

- (1) for the anterior part of the vocal-tract
- (2) for the pharynx
- (3) interpolating the zone in-between

See the work at ICP Grenoble (web)

Modelisation

→ Babies
Neanderthal
monkey

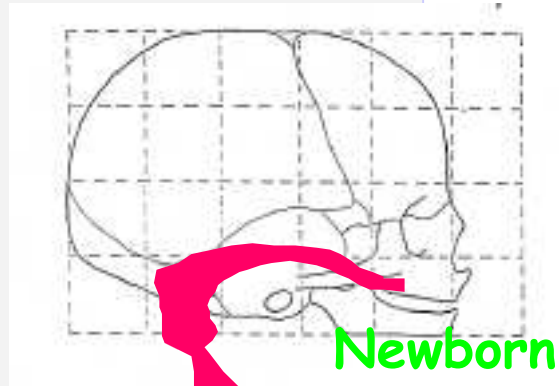


Vowel prototypes for ontogenesis



Which models?

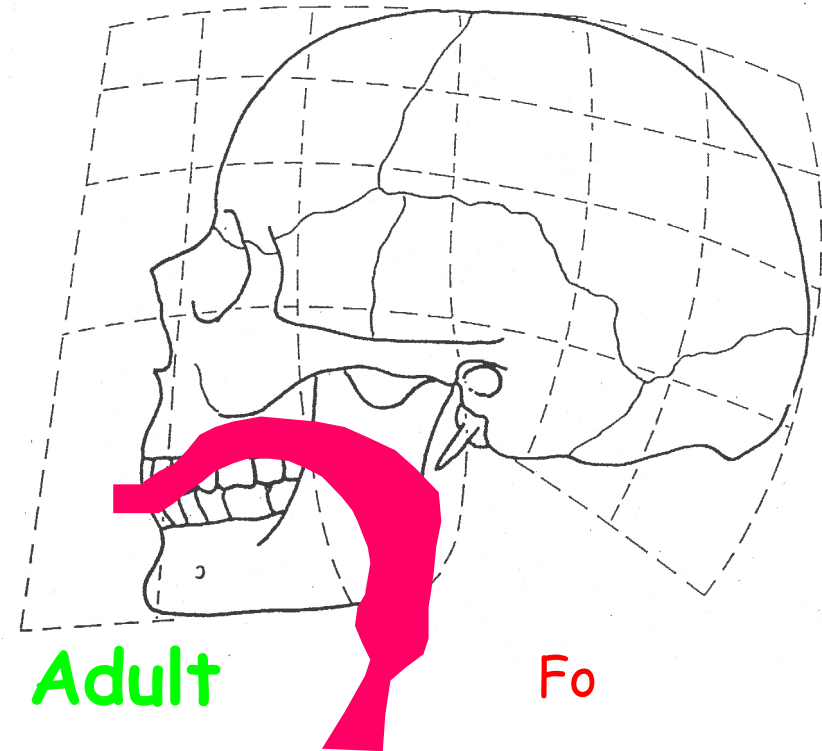
What is a useful model?



speaker anatomy
speaker strategy
singling formant
inversion
etc;

F₀

Ontogenesis



Adult

F₀

Larynx

See the work at ICP Grenoble (web) with Maeda

Babies
Neanderthal
monkey





Larynx Height Index

What is a model?

Why modelling?

Which models?

What is a useful model?

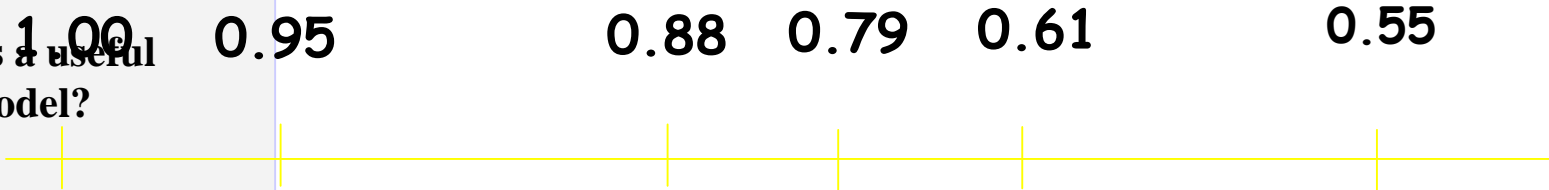
How done?

Demo

Vowels
consonants

Other uses

speaker anatomy
speaker strategy
singing formant
inversion
etc;



Man Woman Child (10y 4y) Newborn

Ape
Newborn Adult

Neandertal

La Ferrassie La Chapelle-aux-Saints

See the work at ICP Grenoble (web), Boé, etc.
with Maeda

Babies
Neanderthal
monkey





Vowel prototypes (adult man)

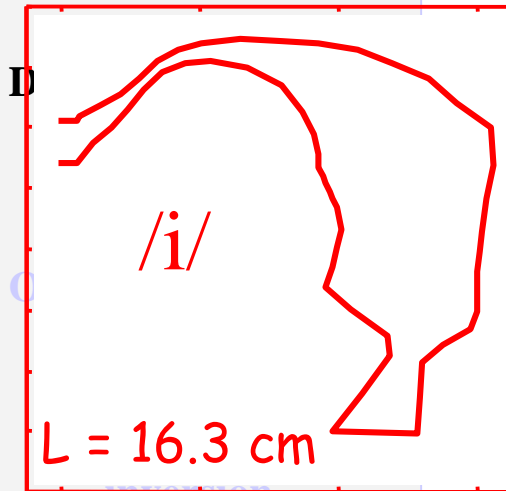
What is a model?

Why modelling?

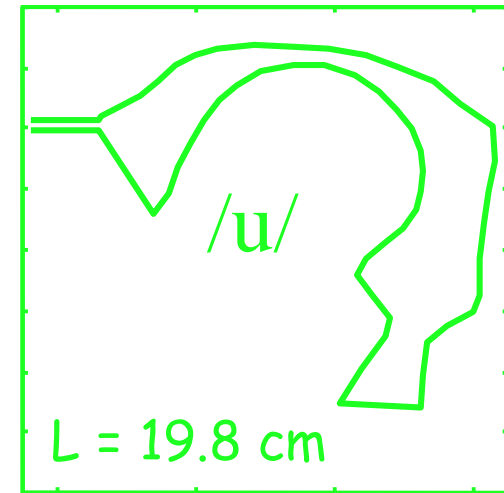
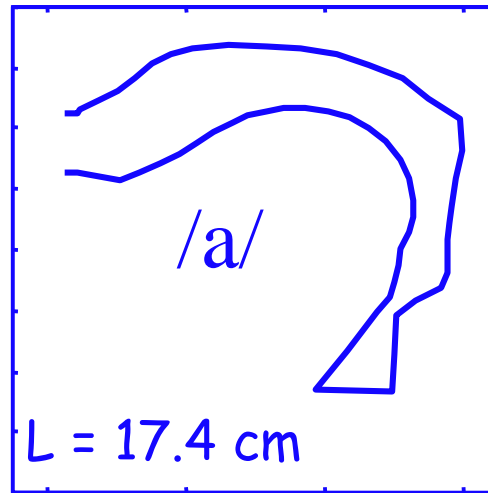
Which models?

What is a useful model?

How done?



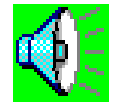
inversion
etc;



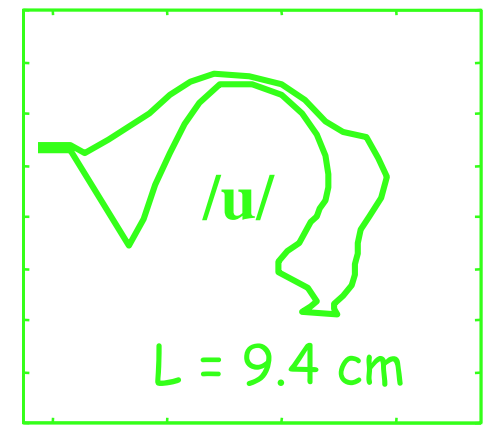
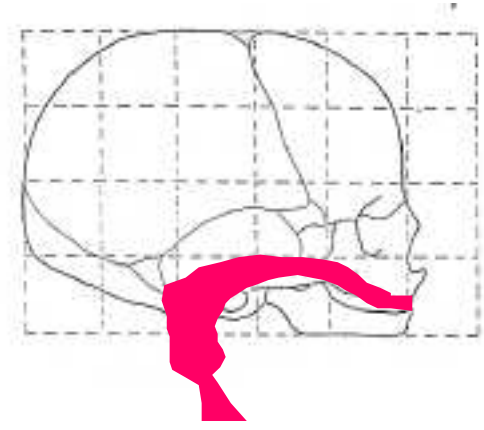
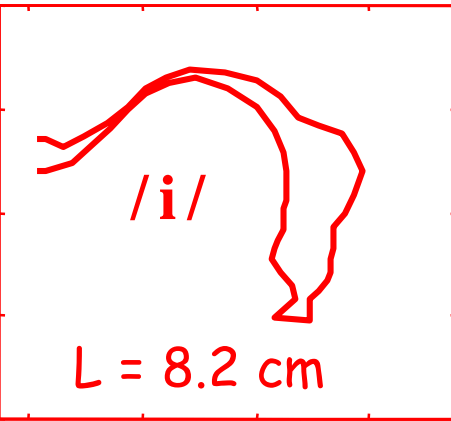
See the work at ICP Grenoble (web) with Maeda

Babies
Neanderthal
monkey





Why i
Which
What



model?

How done?

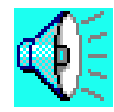
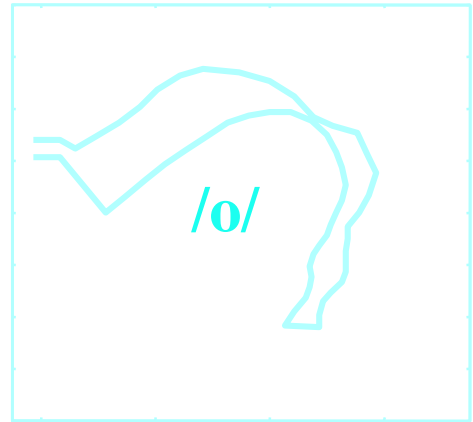
Demo



vowels
consonants



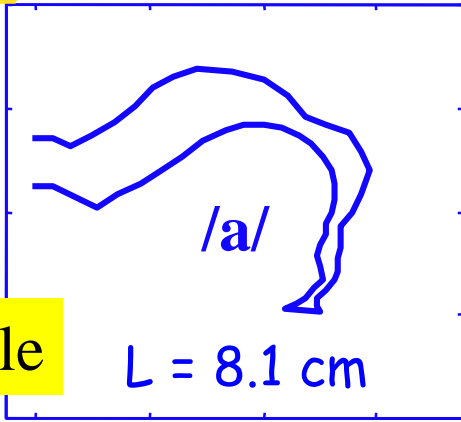
4 months



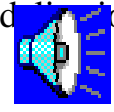
Other uses

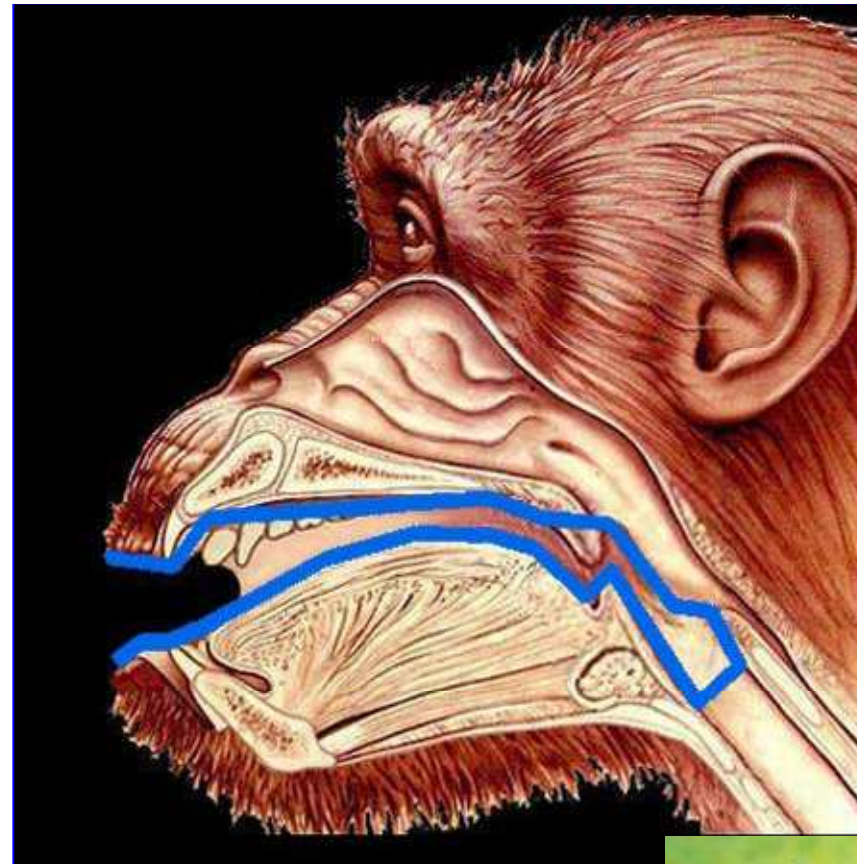
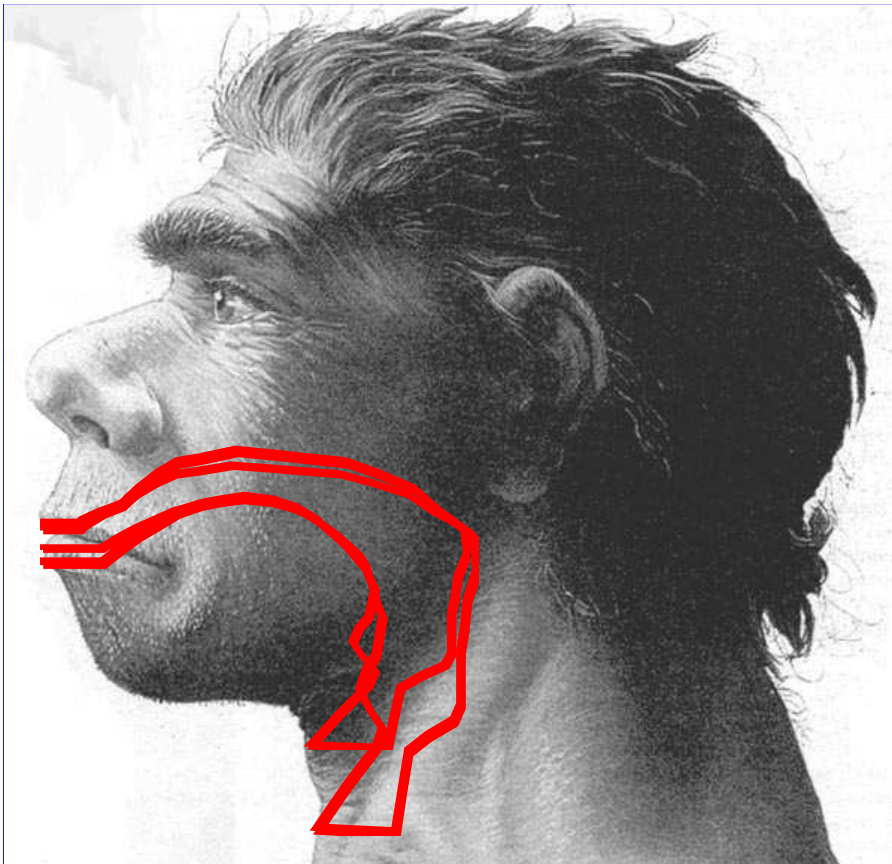
- speaker anatomy
- speaker strategy
- singing formant
- inversion
- etc;

Maeda + ICP-Grenoble



Model on





Other uses

- speaker anatomy
- speaker strategy
- singing formant
- investigative
- etc;

Contra Lieberman & Crelin

Modelisation of the differences suggests that the neandertals were no more vocally handicapped than children at birth are

Babies
Neanderthal
monkey

Maeda + ICP-Grenoble

Modelisation



Conclusions?



What

Why

Which models?

What is a useful model?

How done?

Demo

vowels

consonants

Other uses

speaker anatom

speaker strategy

singing forma

inversion

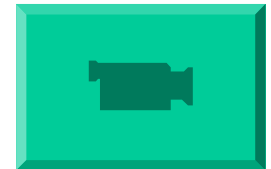
etc;

- AM is a very useful research and teaching tool
 - Essential as a platform for discussions between phoneticians and engineers

- As a complement of other instrumentations such as EMMA, echograph, IRM, etc.

- Still in progress (a third cavity)

- New thesis coming in fricatives in different languages (Toda/Maeda), MRI, ATR



Conclusions?



What

Why

Which models?

What is a useful model?

How done?

Demo

vowels

consonants

Other uses

speaker anatom

speaker strategy

singing forma

inversion

etc;

- **limits**
 1. /l/ and many other sounds not yet done (as presented in this congress)
 1. Register/Phonation types/laryngeal region area and Fo/quality interaction not included (could replace the actual 3 parameters)
 2. Aerodynamic constrains increase when VT very close
 3. mid-saggital profile conversion to area function not straightful process (3D)
 4. New X-ray difficult to obtain (MRI and new instrumentation)



What is a model?

Why modelling?

Which models?

What

- The corresponding paper with references are available.

How

Demo

Other



Bon anniversaire !

