Making music with voice

Distinguished lecture, CIRMMT Jan 2009,

MENU:

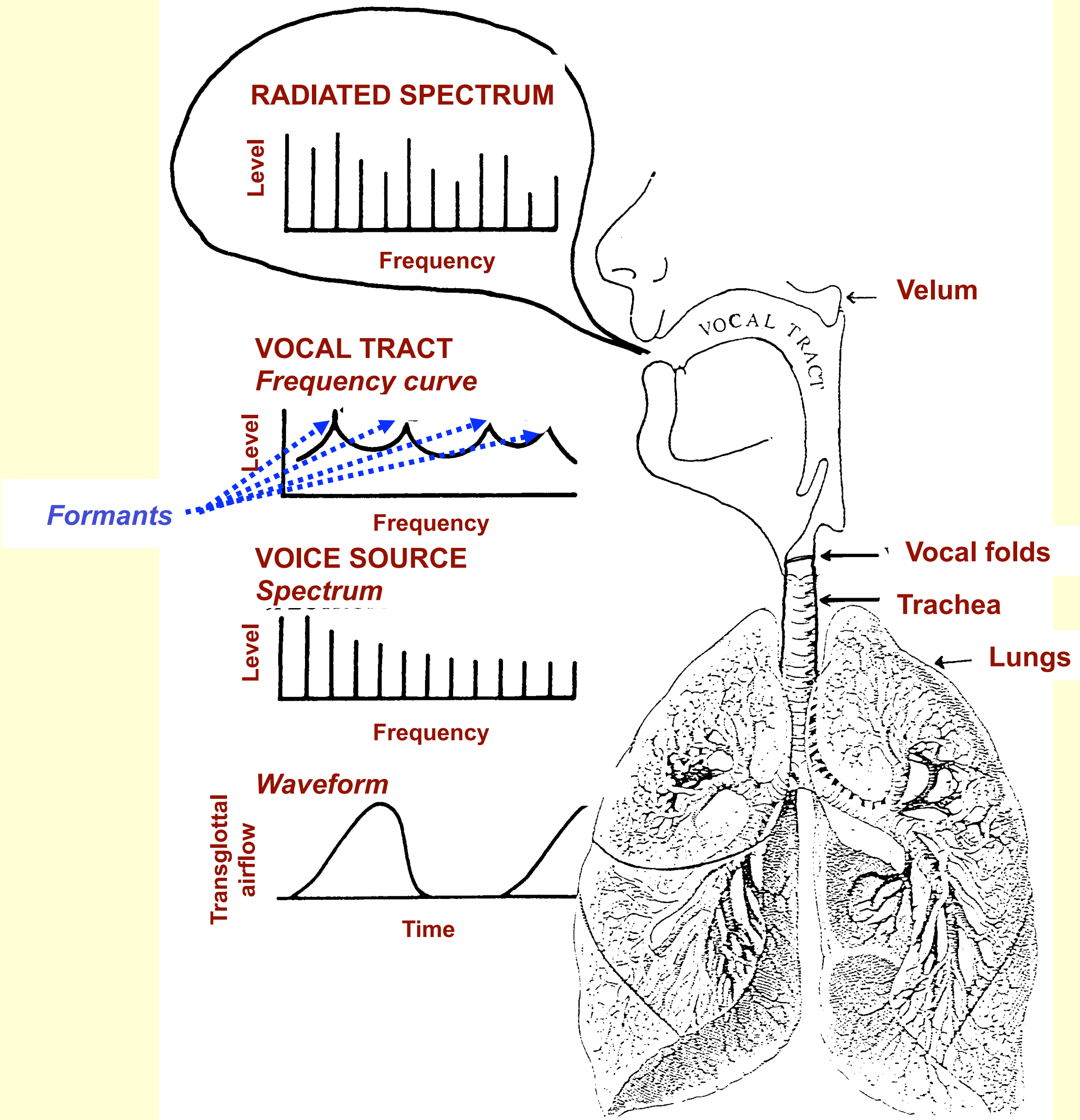
A: The instrument

B: Getting heard

C: Expressivity

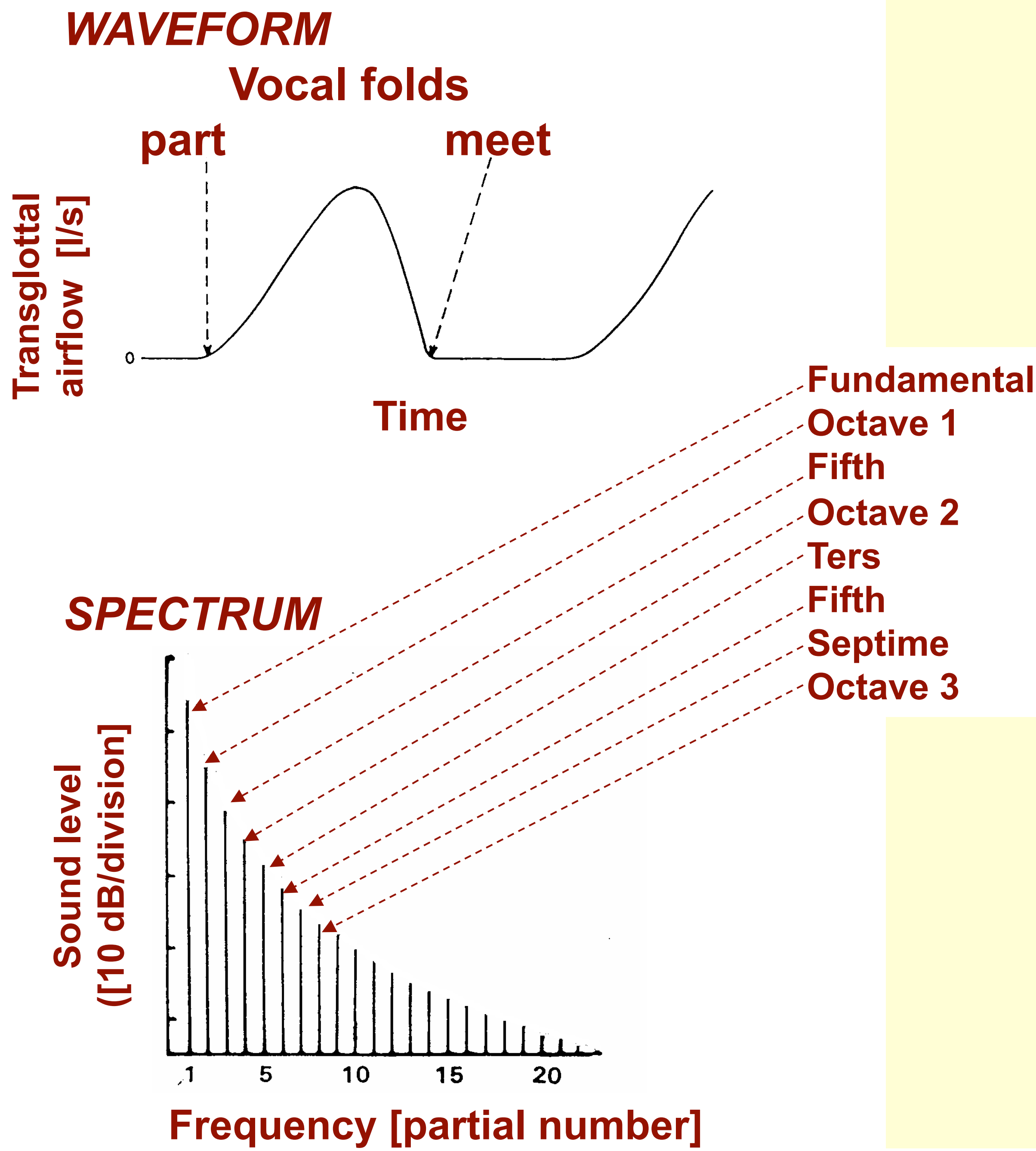
The instrument

Summary



RADIATED SPECTRUM
Level
Frequency
VOCAL TRACT
Frequency curve
Level
Frequency
Formants
VOICE SOURCE
Spectrum
Level
Frequency
Waveform
Transglottal airflow
Time
VOCAL TRACT
Velum
Vocal folds
Trachea
Lungs

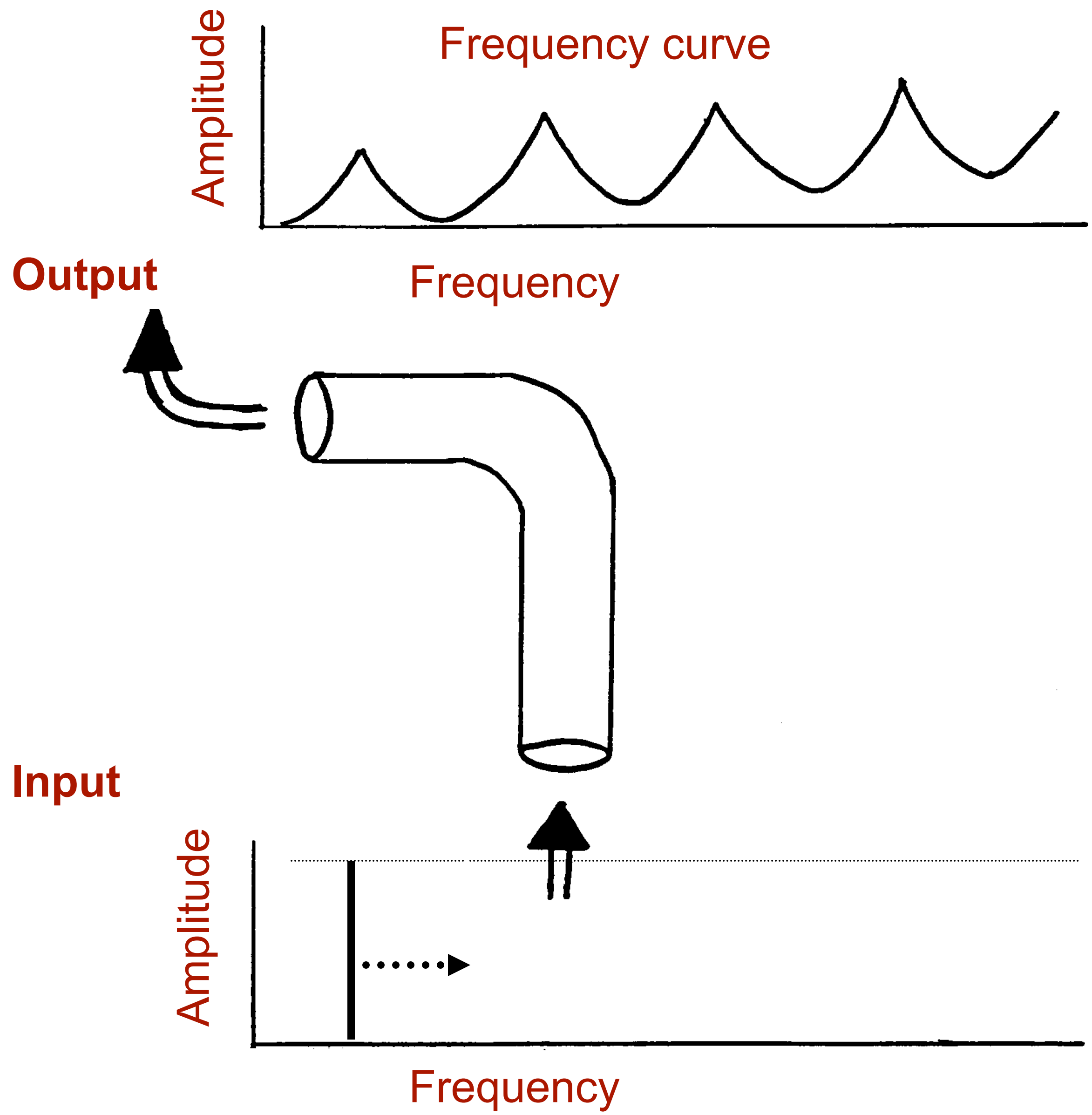
Voice Source



Demo

Variable sine wave traveling through a tube

RESONANCE


Amplitude
Frequency curve
Frequency
Output
Input
Amplitude
Frequency

Thus, spectrum peaks at formant frequencies

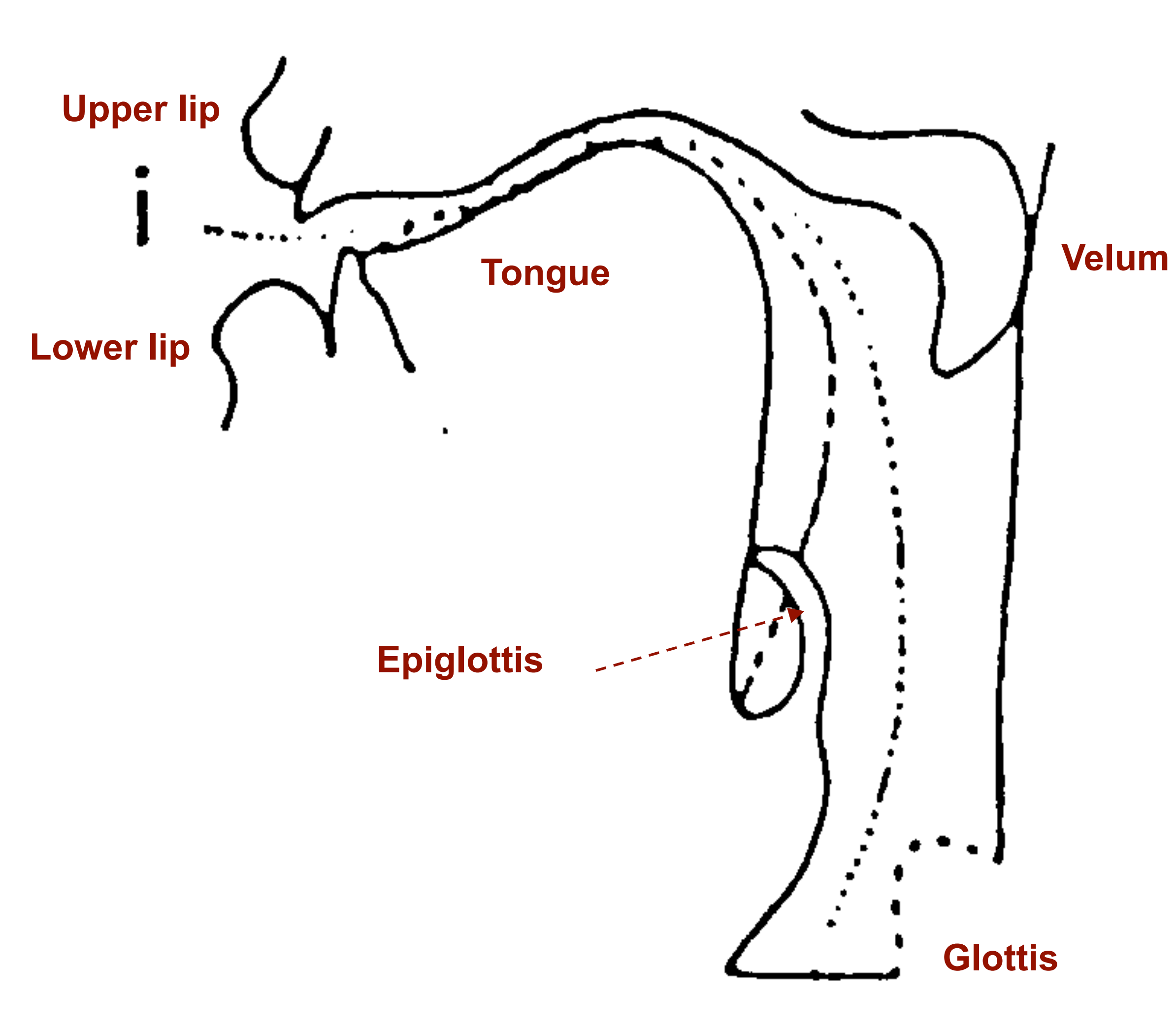
Demo

Pulsating airflow through tube

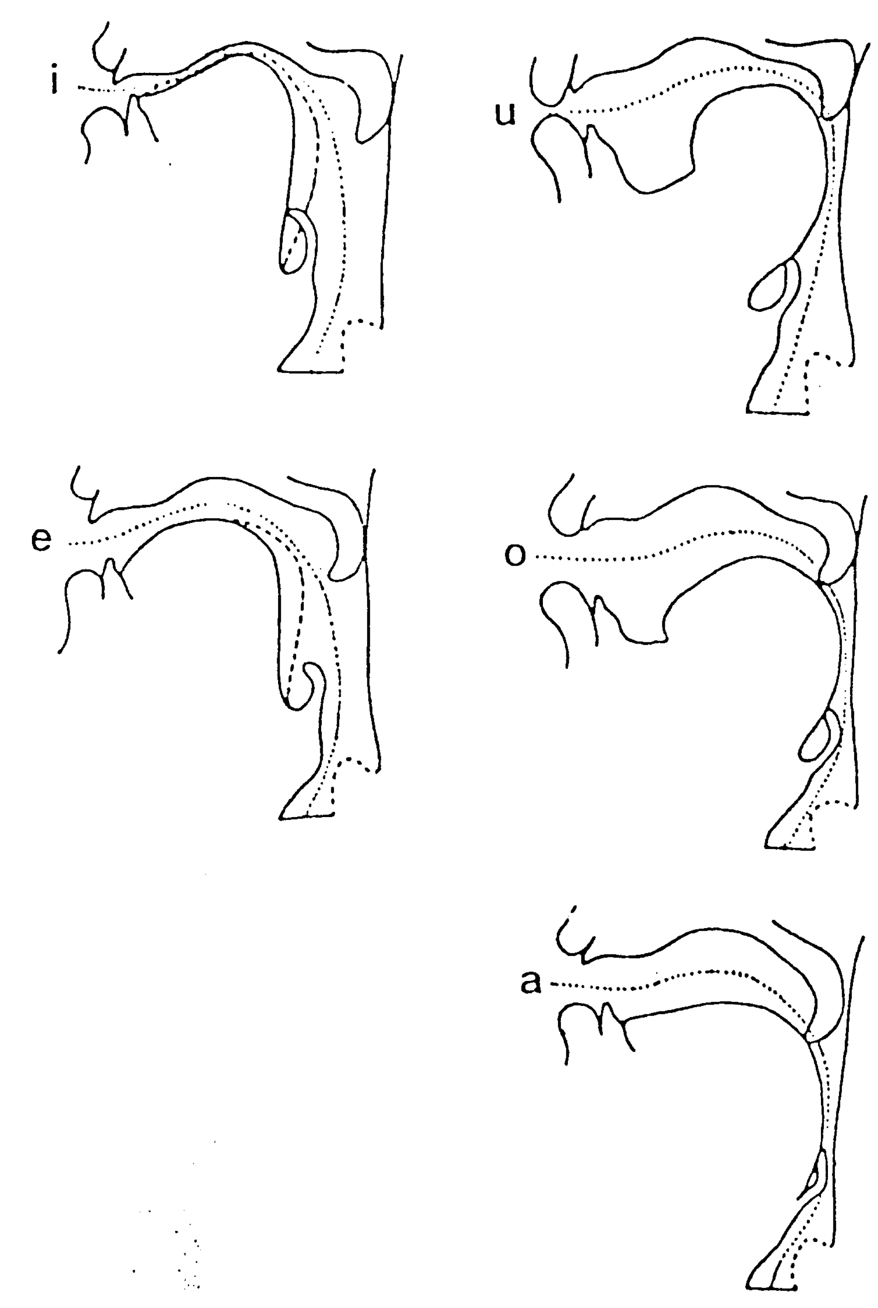
Result: vowel-like sound

Formant frequencies determined by vocal tract shape

Vocal tract shape of vowel /i/



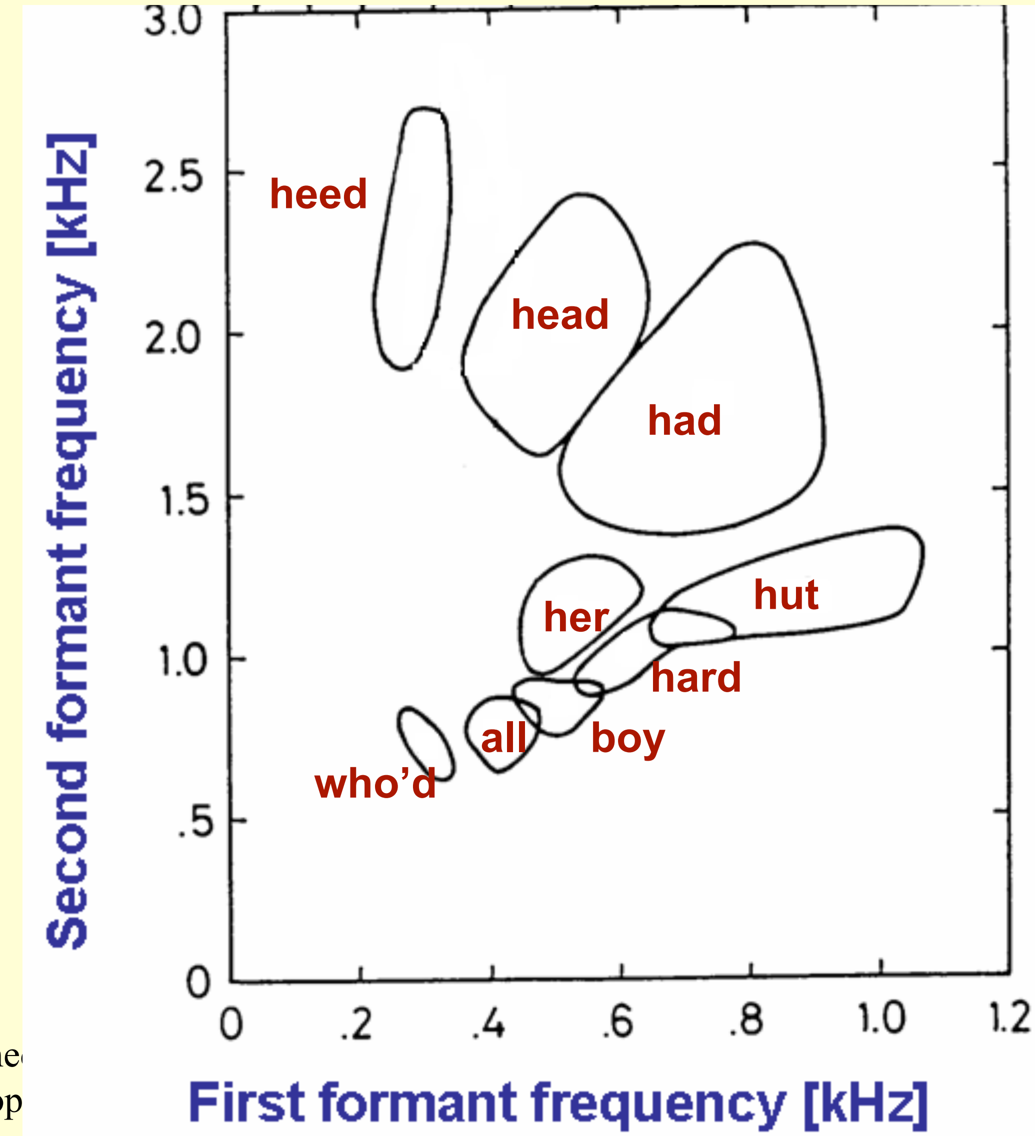
Vocal tract shape of vowels



Demo:

Pulsating airflow through pinched tube produces vowels

Formant frequencies of vowels



Demo:
Cruisade in the F_1 & F_2 archipelago

Result:
all vowels available by varying F_1 & F_2

Madde.exe

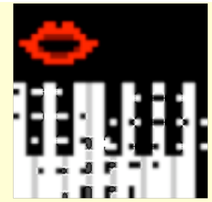
Articulatory tools:

- Jaw opening
- Lip opening
- Tongue body shape
- Tongue tip
- Larynx position

Vocal tract length is also important

Short vocal tracts have higher resonance frequencies than longer vocal tracts

Listen to voice timbre difference produced by different vocal tract lengths!



Madde.exe

Tuning formants

First formant:

Mostly jaw opening

Second formant :

Mostly tongue shape

Determine vowel

Third formant :

Cavity behind lower incisors

Higher formants :

Vocal tract length, Larynx position

CONCLUSIONS

Formants

- controlled by *vocal tract shape (articulation)*
- first two resonances determine *vowel quality*
- higher formants relevant to *personal voice quality*

MENU:

A: The instrument

B: Getting heard

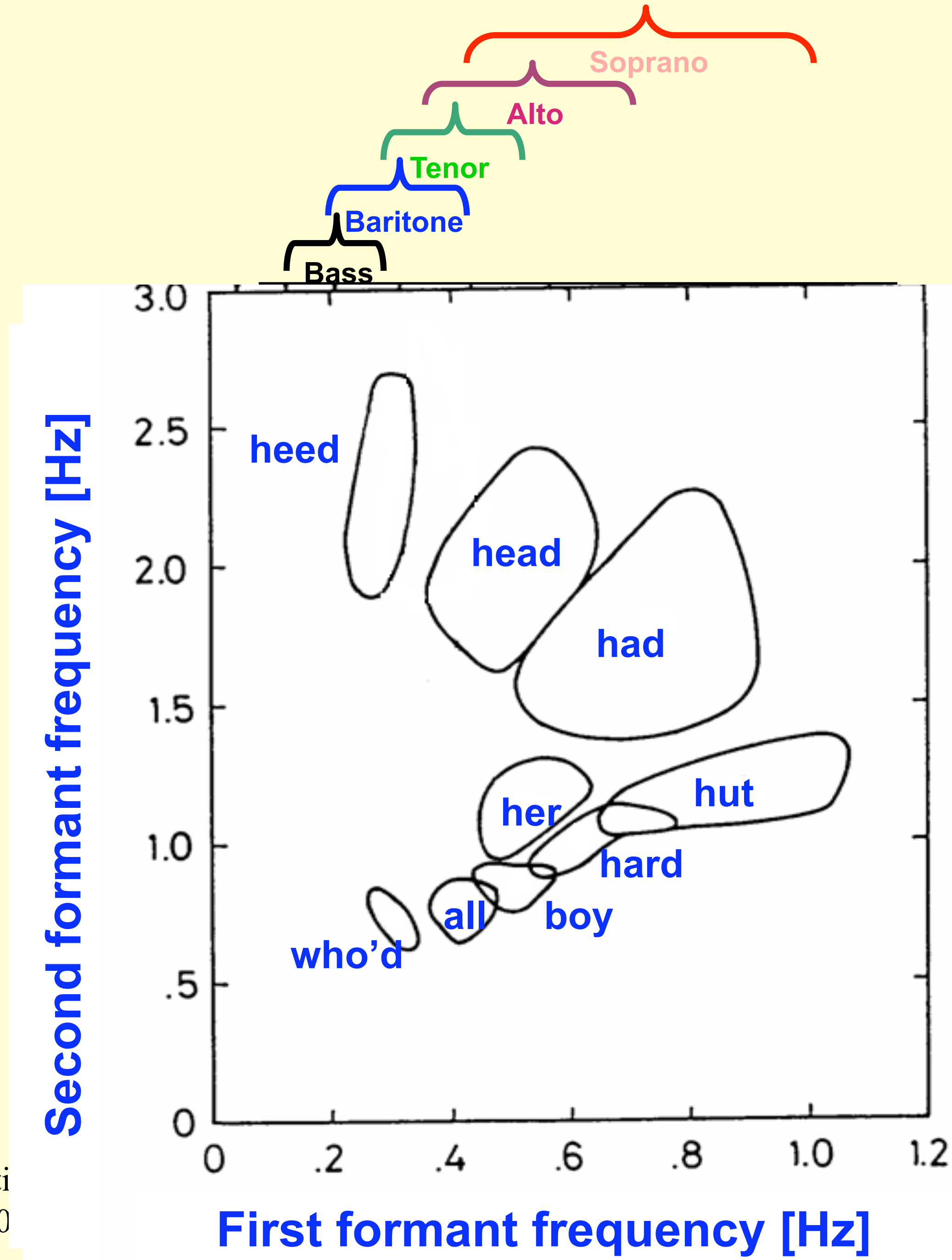
C: Expressivity

Getting heard

The high-pitch case

Question:

Where is the fundamental and where is the first formant?



Is fundamental allowed to pass the first formant?

Listen!

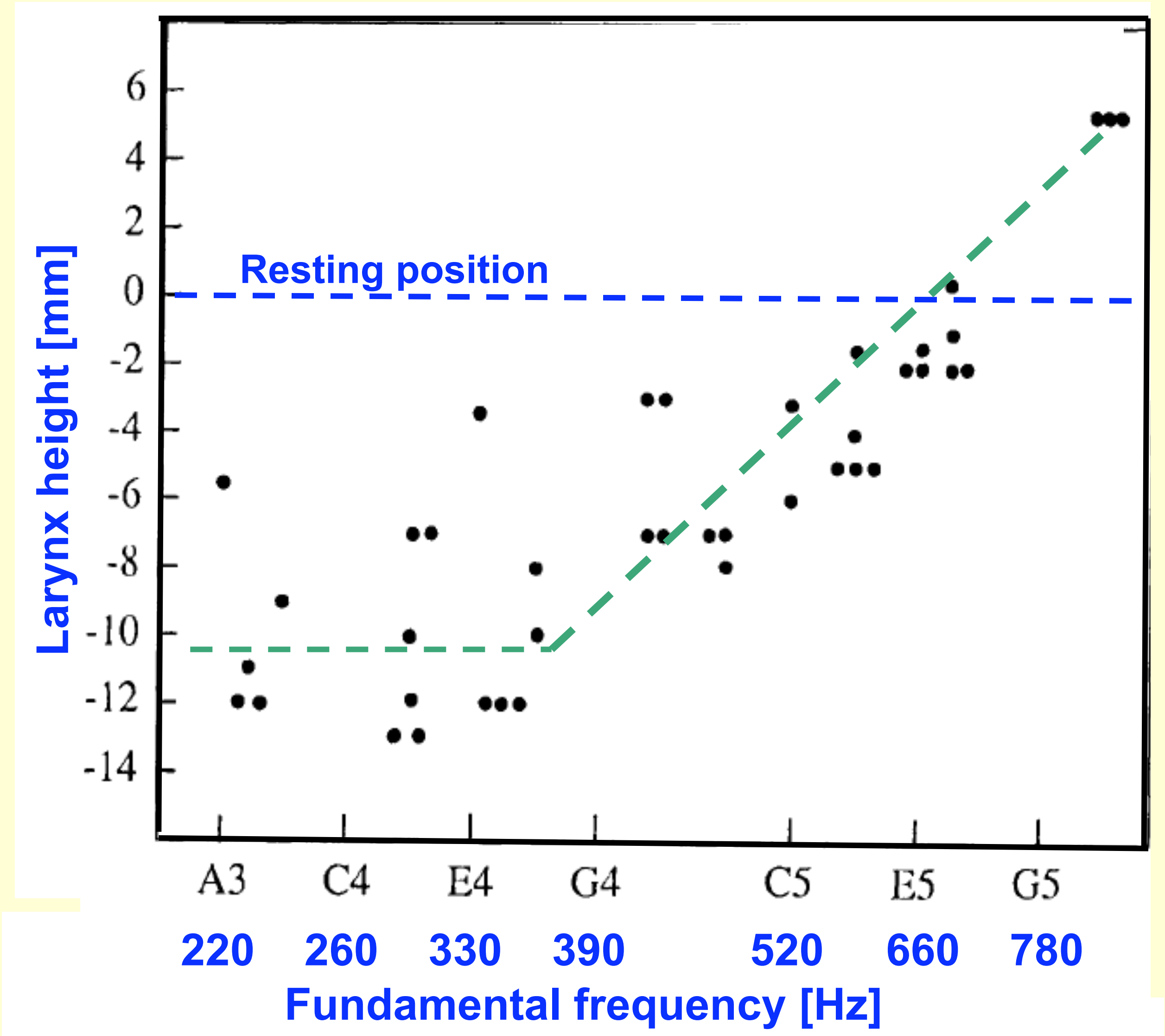
Jaw opening is particularly efficient tool for raising first formant

Female singers tend to widen the jaw opening at high pitches!

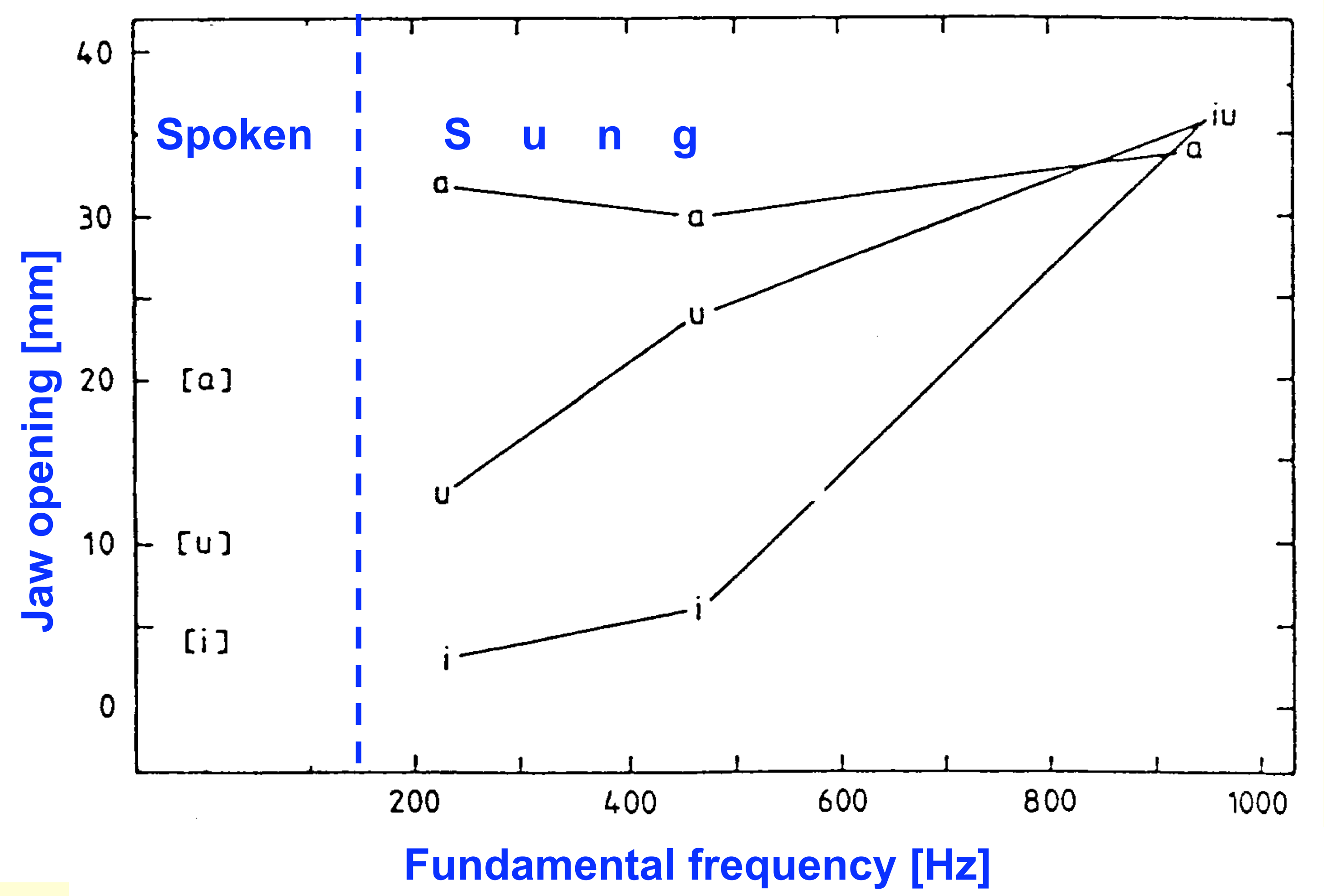
Vowel [i]

Vowel [u]

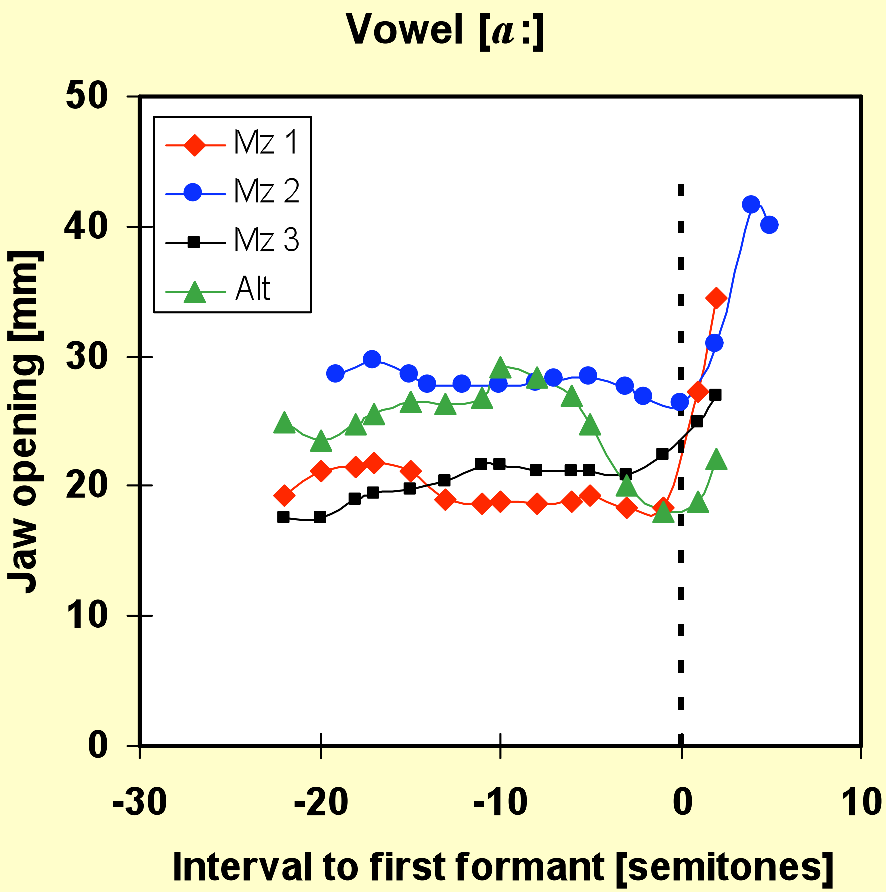
Larynx height strategy in professional soprano

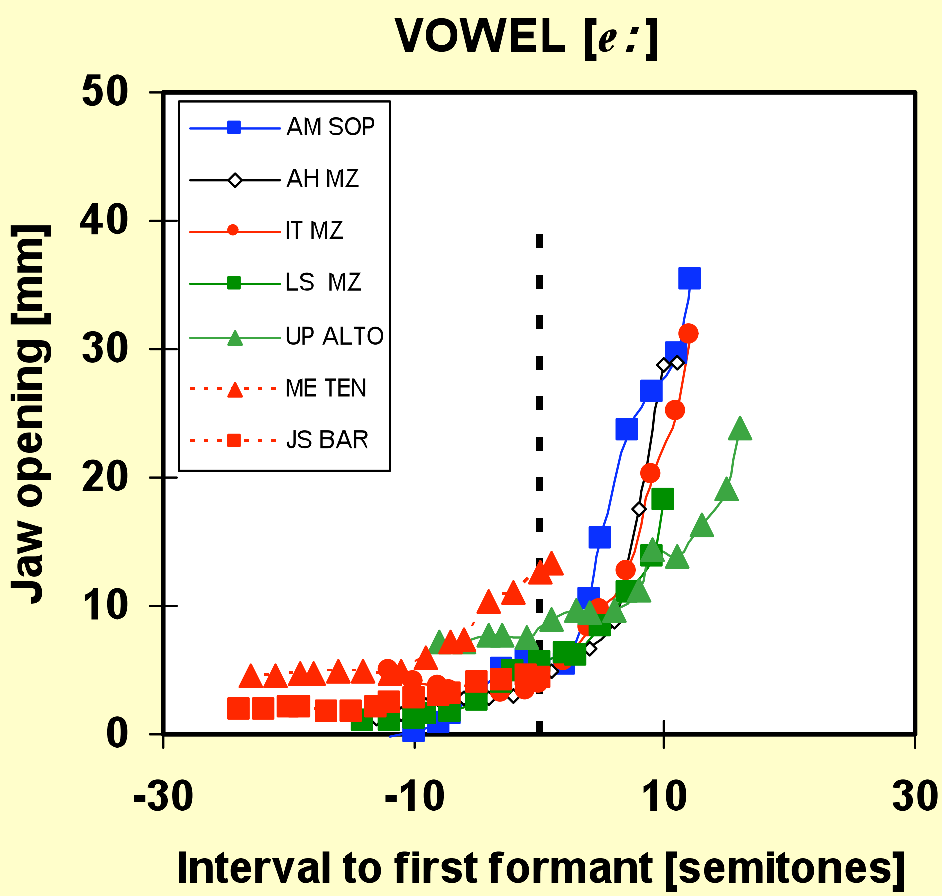


Jaw opening strategy in professional soprano



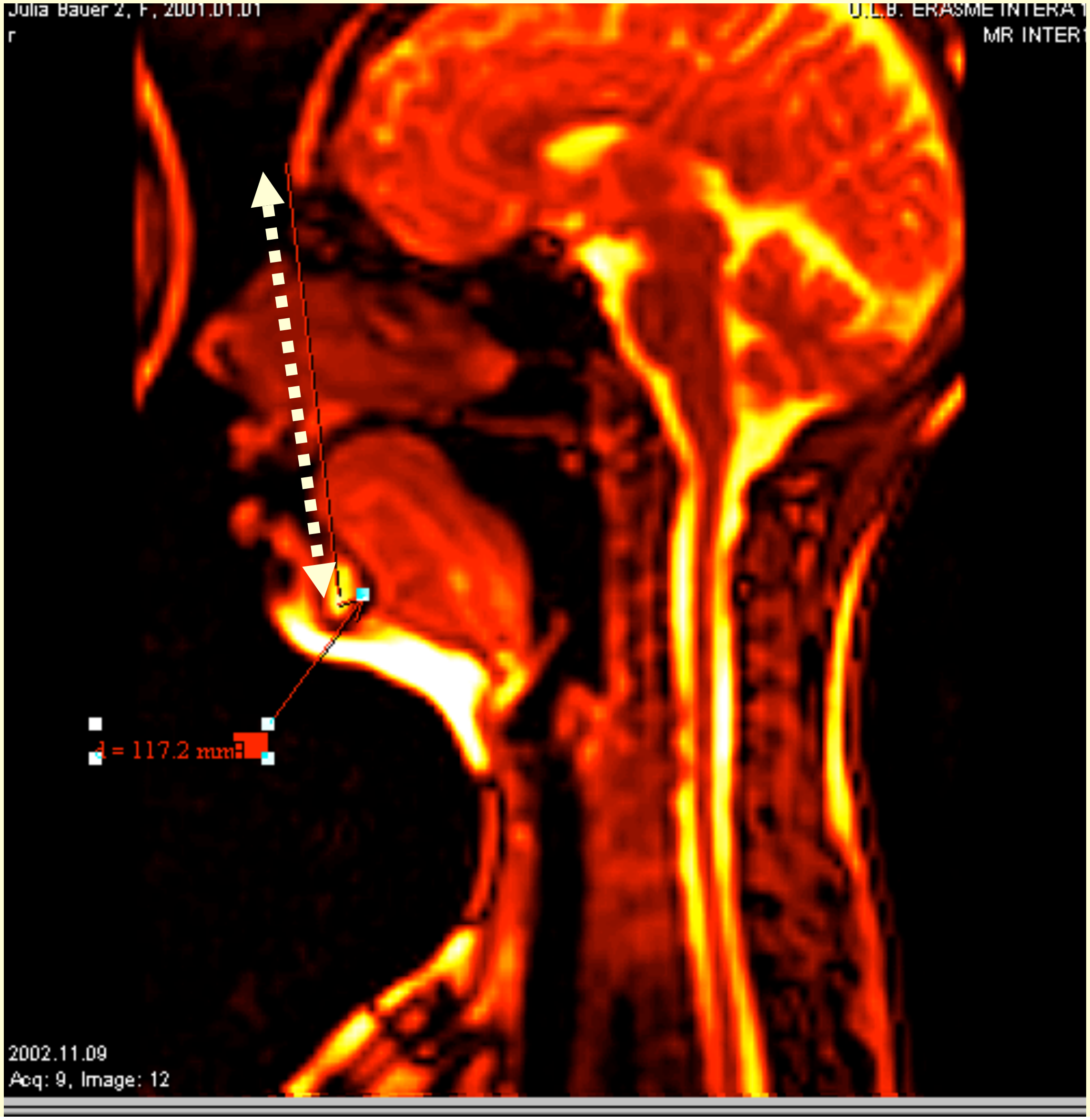
In [ɑ:] the jaw opening is widened when pitch freuqency approaches first formant, but in [e:] some semitones higher



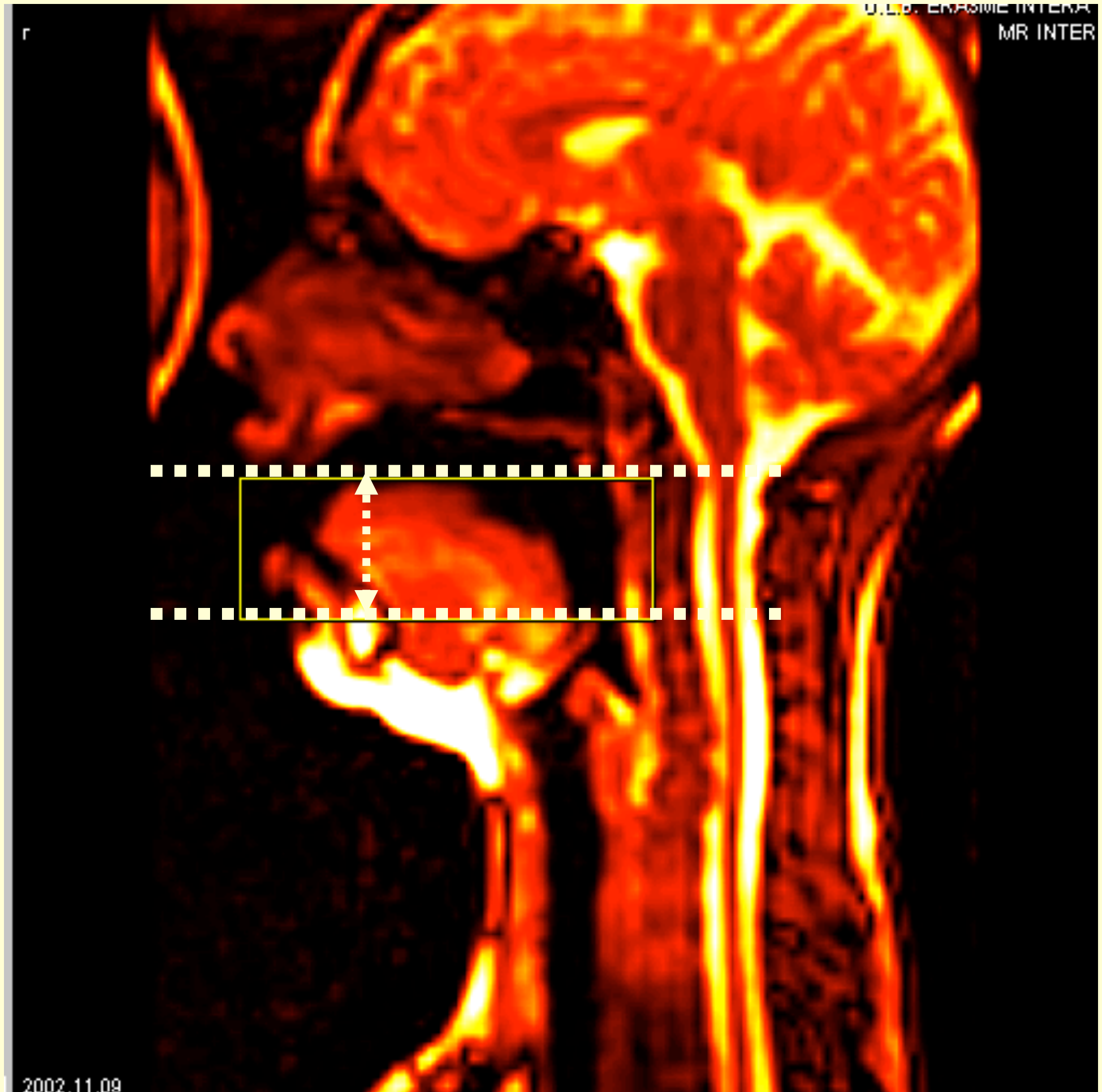


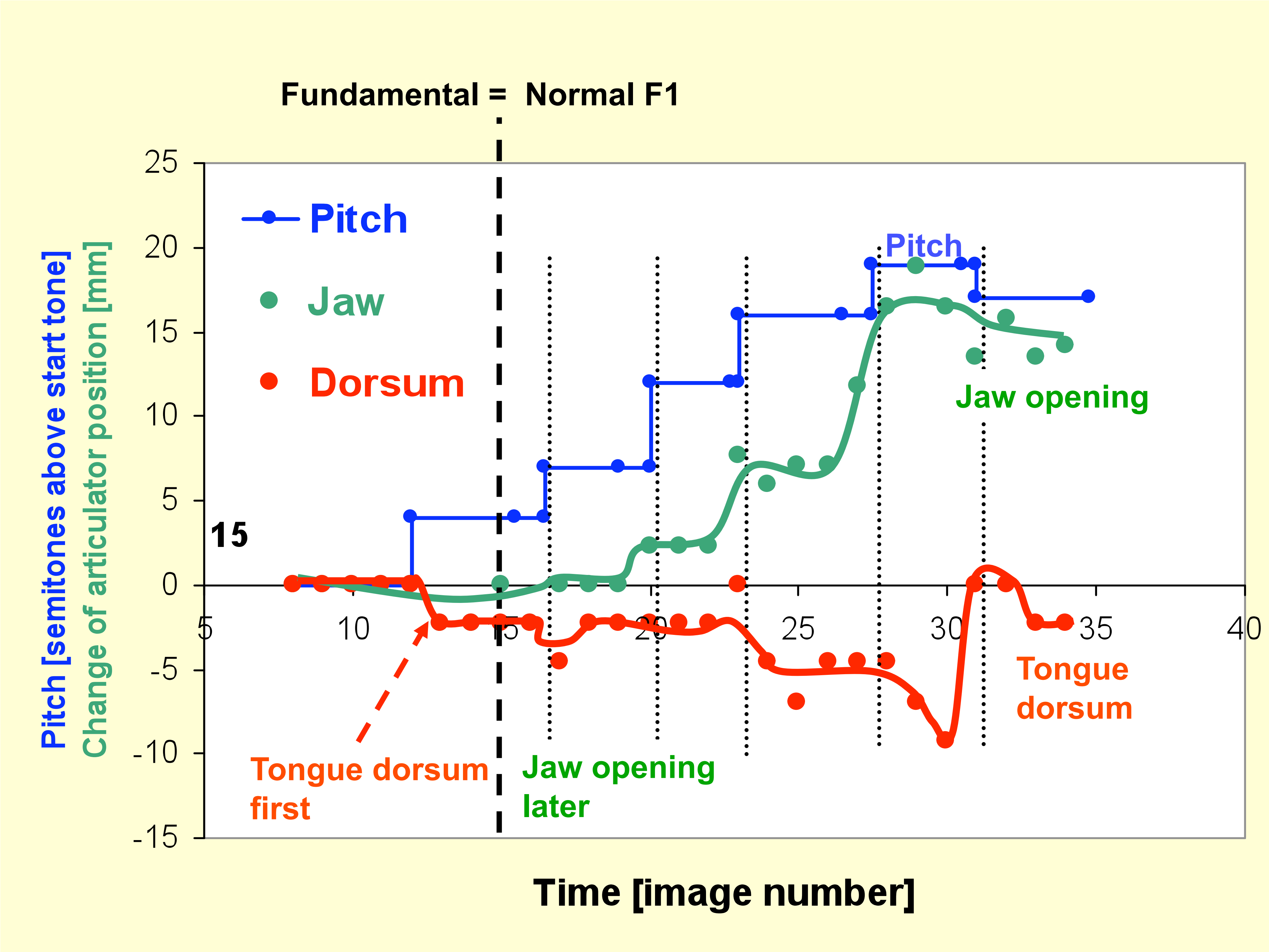
Experiment
MRI analysis of professional soprano singing different vowels on a triad pattern covering her range

Measuring jaw opening



Measuring tongue dorsum height

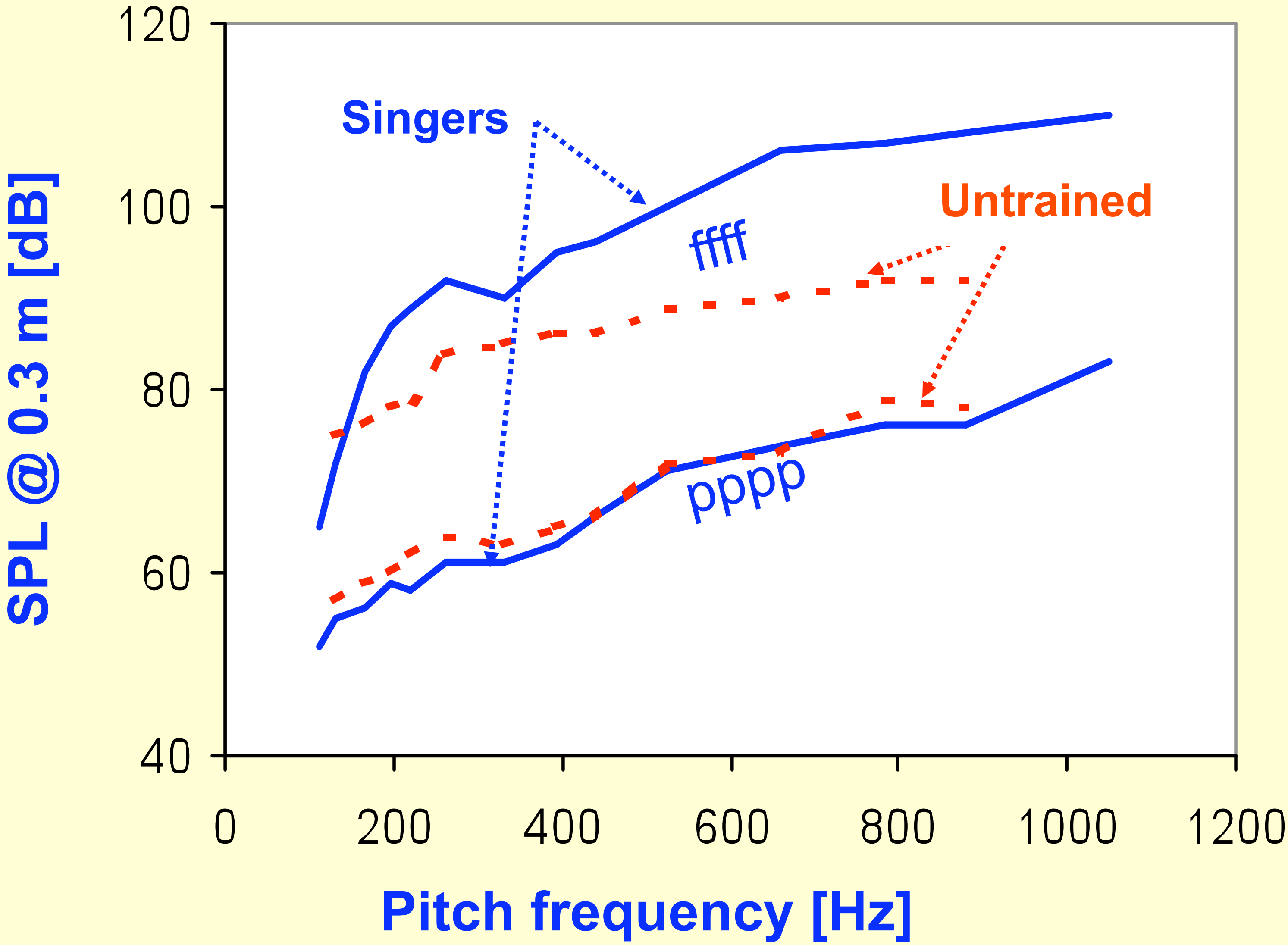




Fundamental = Normal F1
Pitch
Jaw
Dorsum
Pitch
Jaw opening
15
Tongue dorsum
Tongue dorsum first
Jaw opening later
Pitch [semitones above start tone]
Change of articulator position [mm]
Time [image number]
25
20
15
10
5
0
-5
-10
-15
5
10
15
20
25
30
35
40

So why not reduce tongue bulging also in /a/?
APEX, please

This formant strategy expands the dynamic range

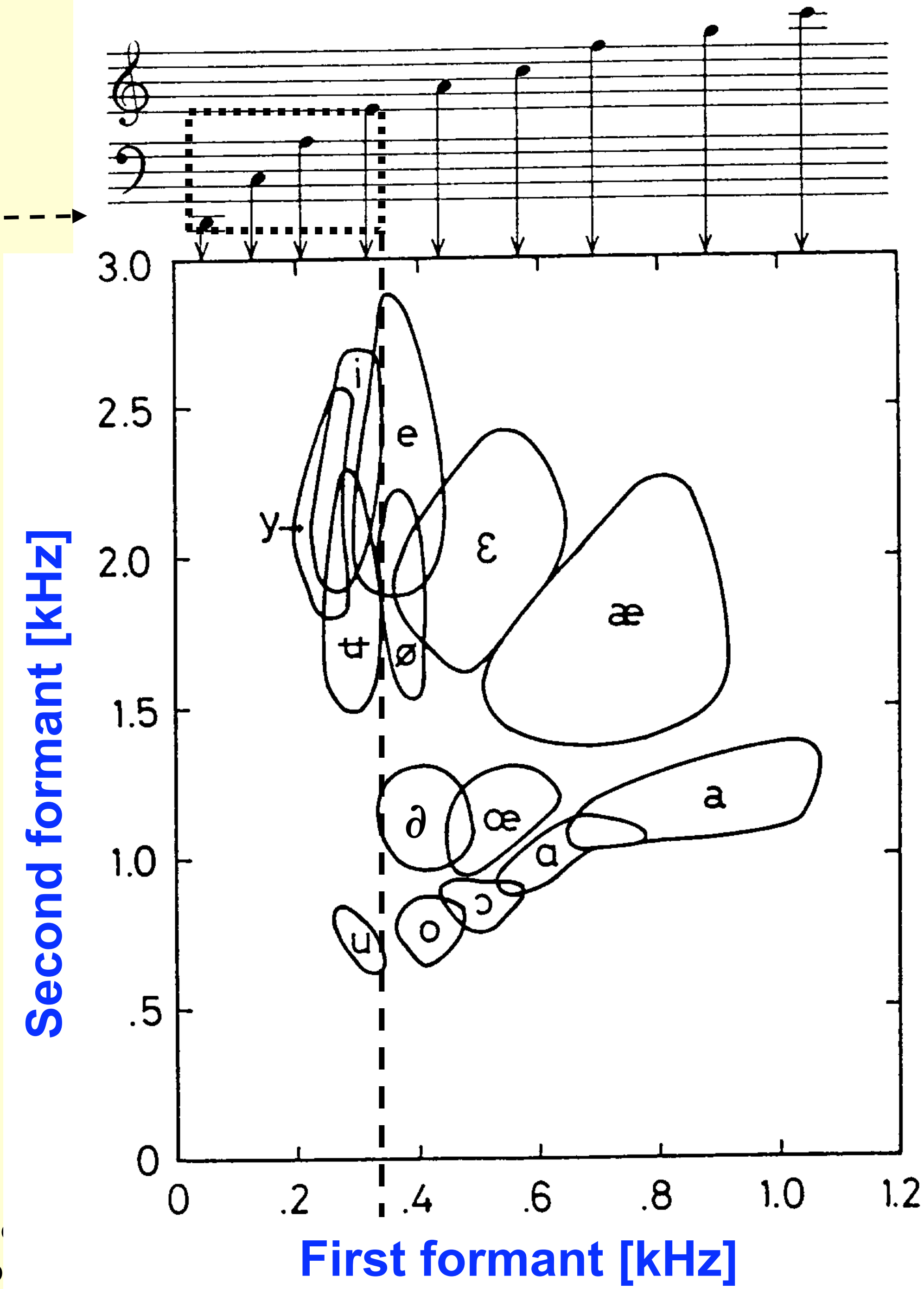


Considerable sound level gain:
Loud tones at low cost,
Vocal economy!

Which singers can profit from this strategy?

Classification

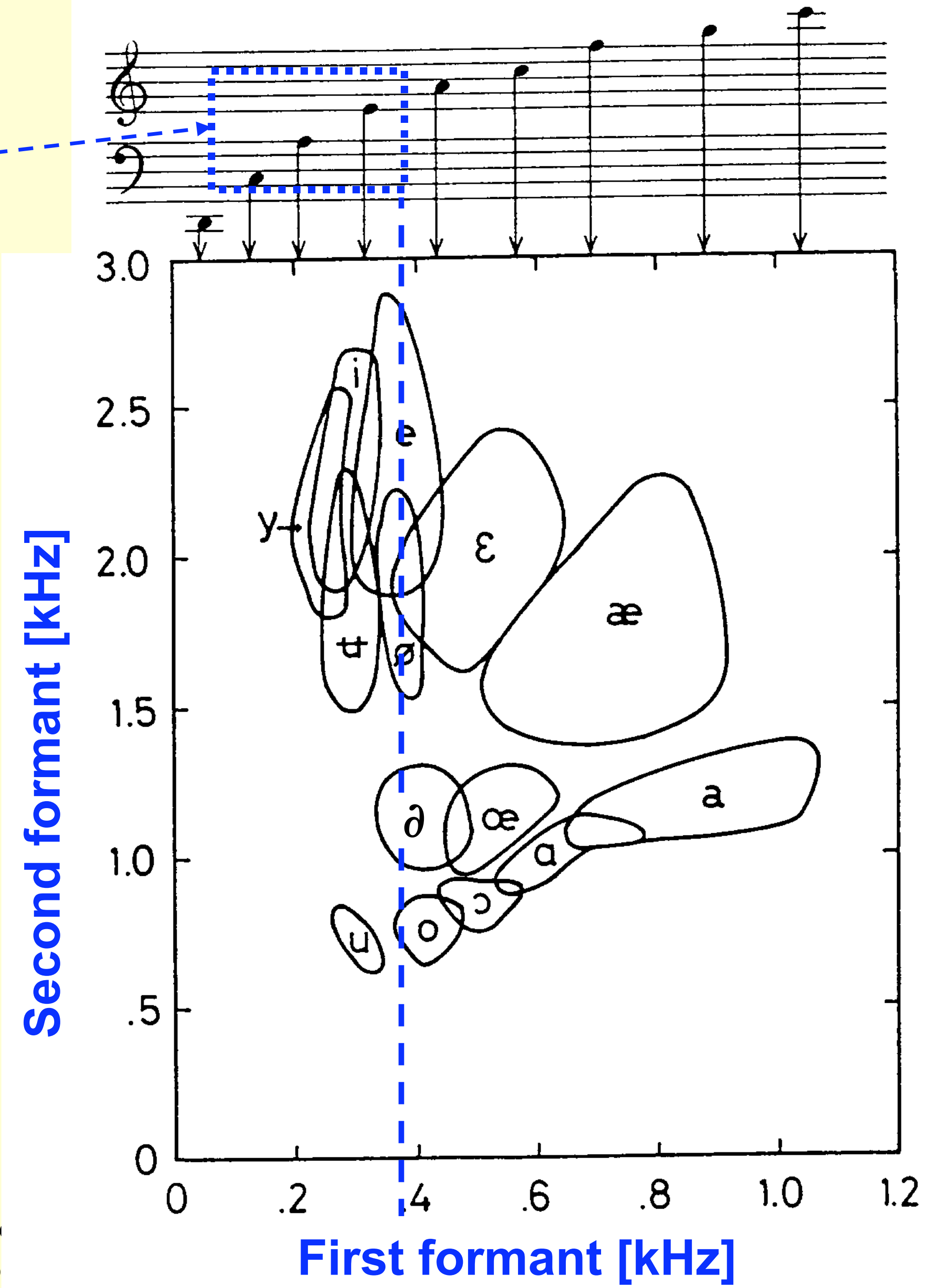
Formant frequencies for vowels



Classification

Baritone

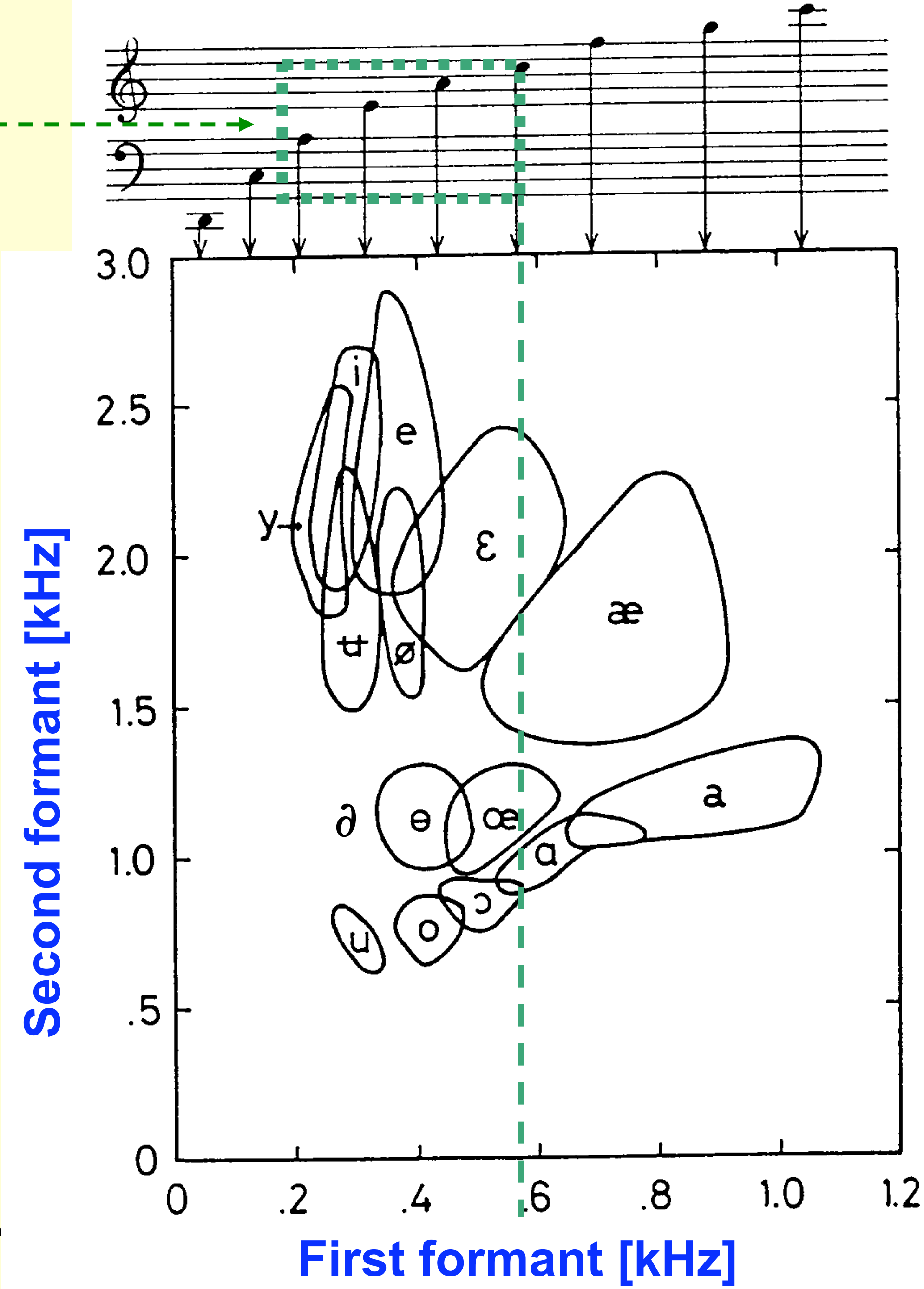
Formant frequencies for vowels



Classification

Formant frequencies for vowels

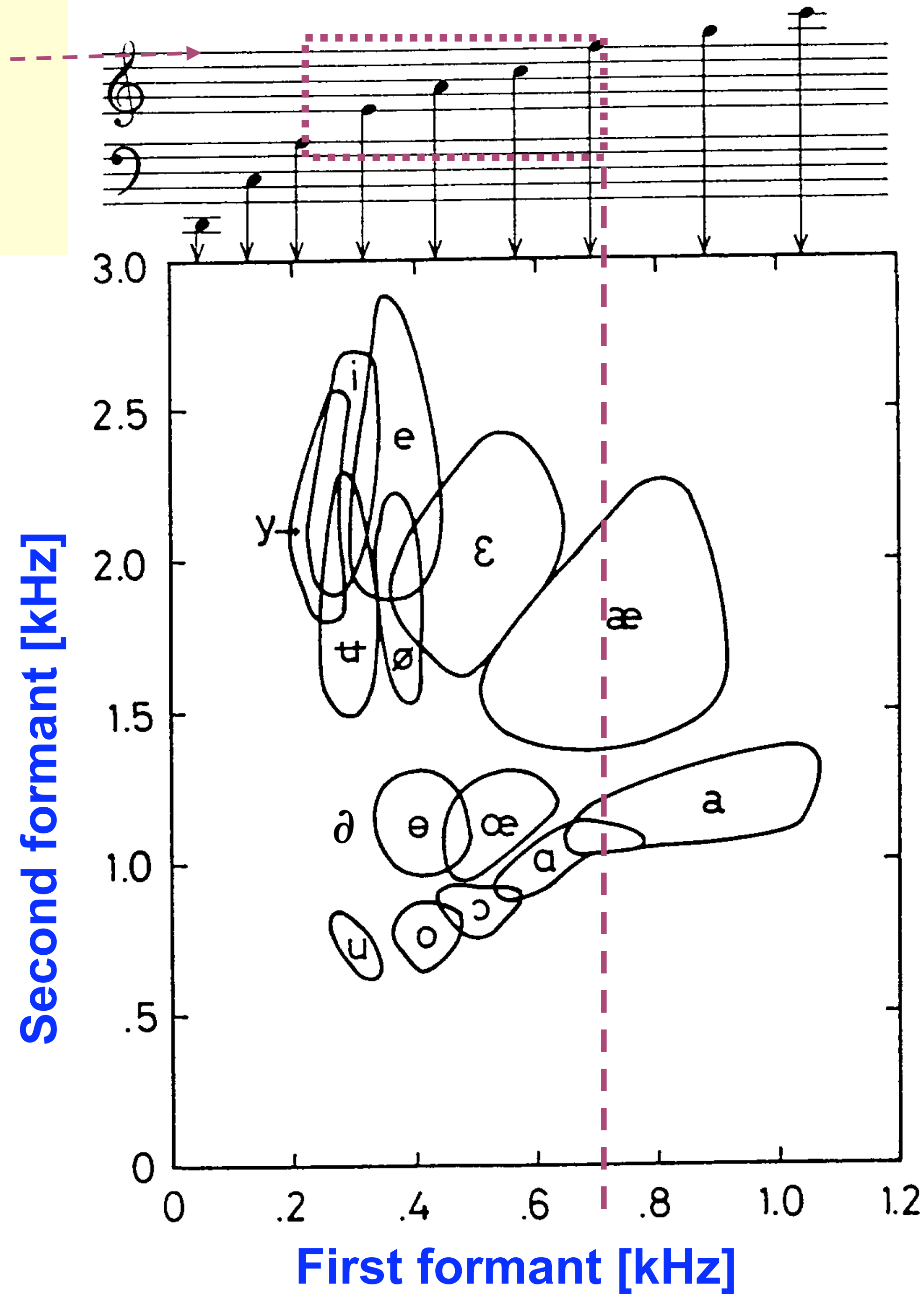
Tenor



Distinguishe
2009, Cop

Classification

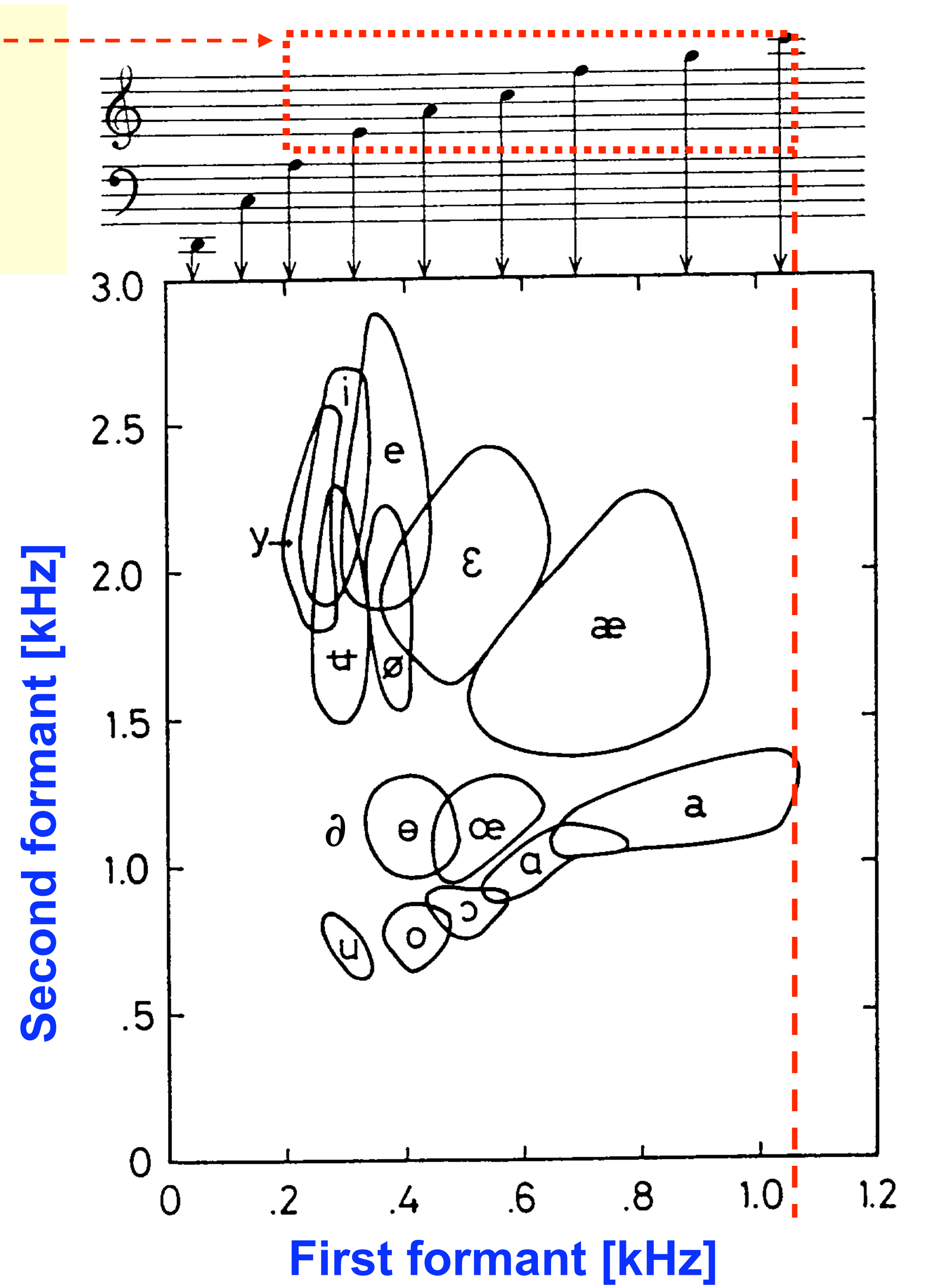
Formant frequencies for vowels



Distinguishe
2009, Cop

Classification

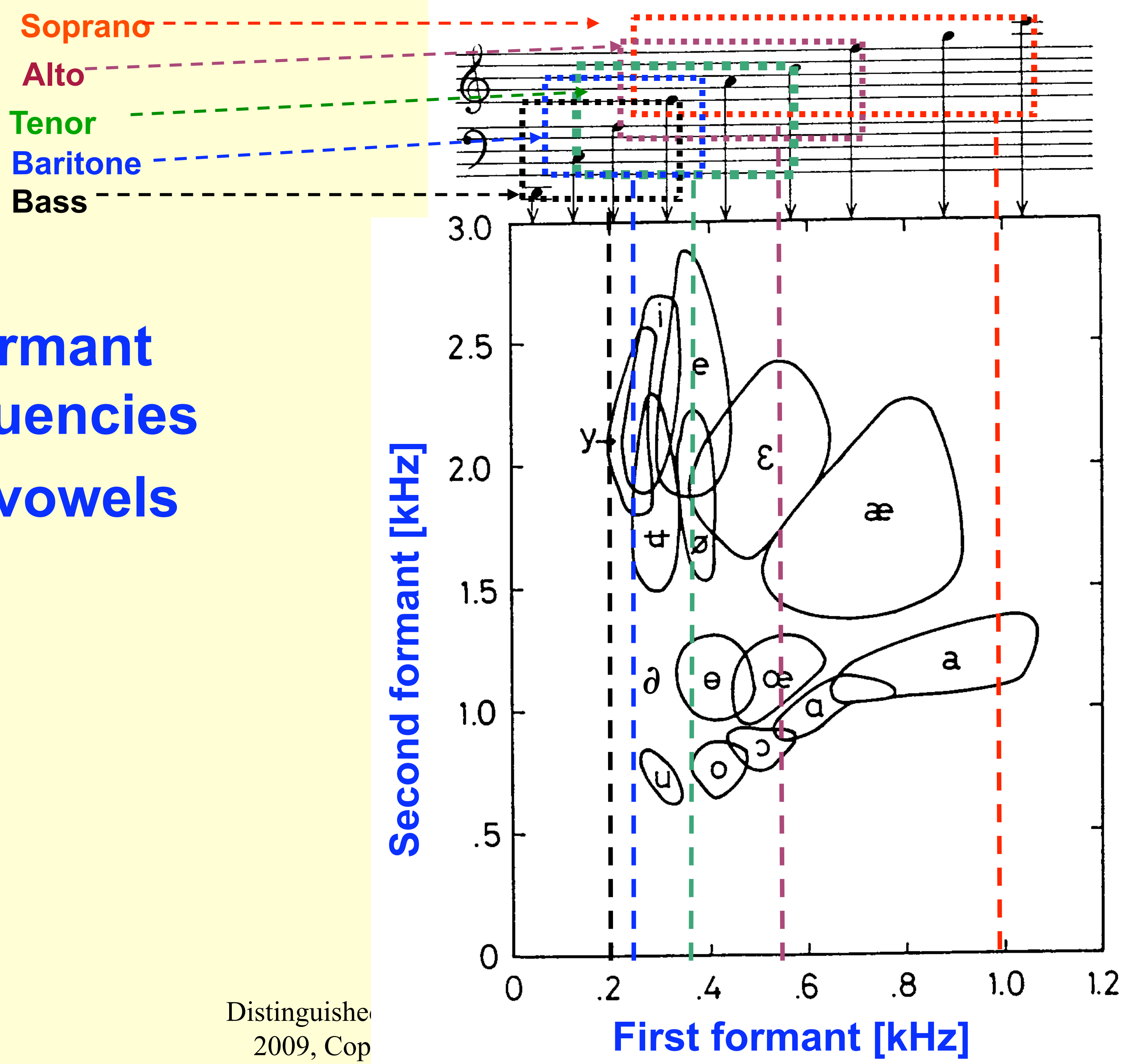
Formant frequencies for vowels



Distinguishe
2009, Cop

Classification

Formant frequencies for vowels



Singers singing in pitch ranges above normal value of first formant need to learn a pitch-dependent vowel articulation!!!!!!!

Don't allow pitch frequency to pass the first formant!

Trick:
- reduce articulatory constriction
- widen jaw opening

Result:
- loud sound at minimum effort/vocal economy

Getting heard

The male case

Singer’s formant cluster

Also called singer’s spectrum peak

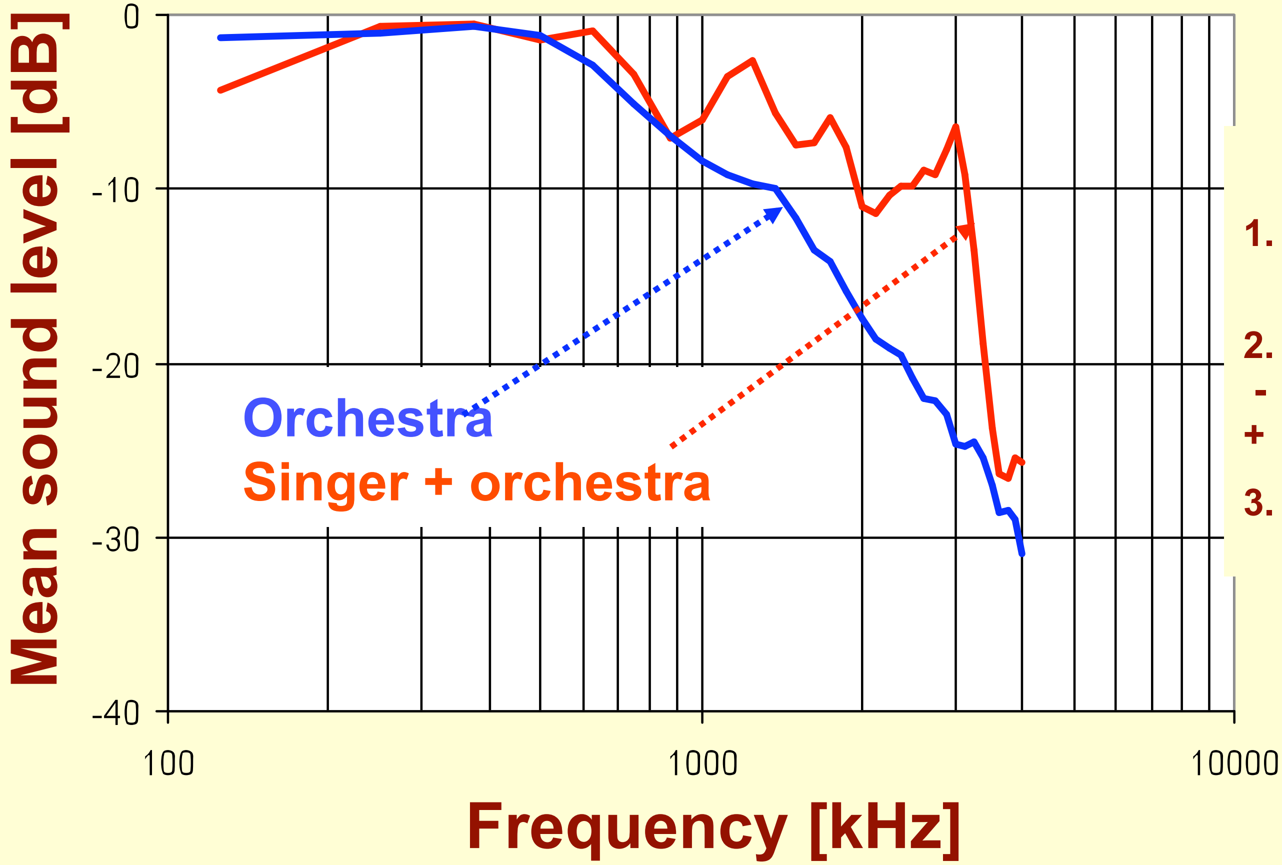
The fine art of clustering resonances; Performed by male classically trained

- tenors
- baritones
- basses

Check spectrum

Singer's formant cluster

Long-term-average spectrum of orchestra ± singer



Sound example

1. Noise corresponding to orchestral sound
2. Singer
   - Singers' formant cluster
   + Singers' formant cluster
3. Examples 1. & 2. together

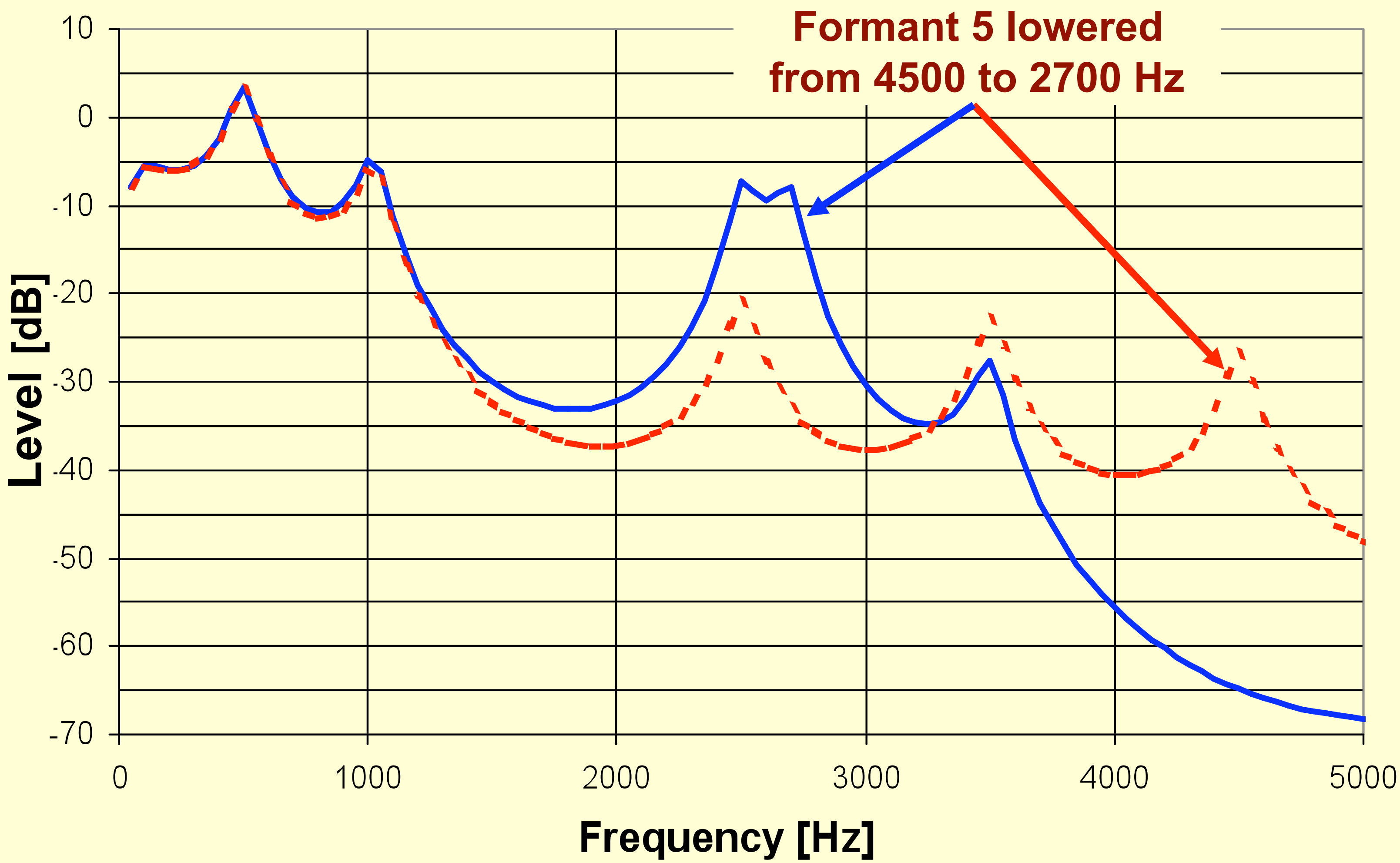
Production of singer's formant cluster

Good voice source
Wide pharynx/Low larynx
Clustering of formants 3, 4, 5

Formants generate spectrum peaks
Their levels determined by their frequencies

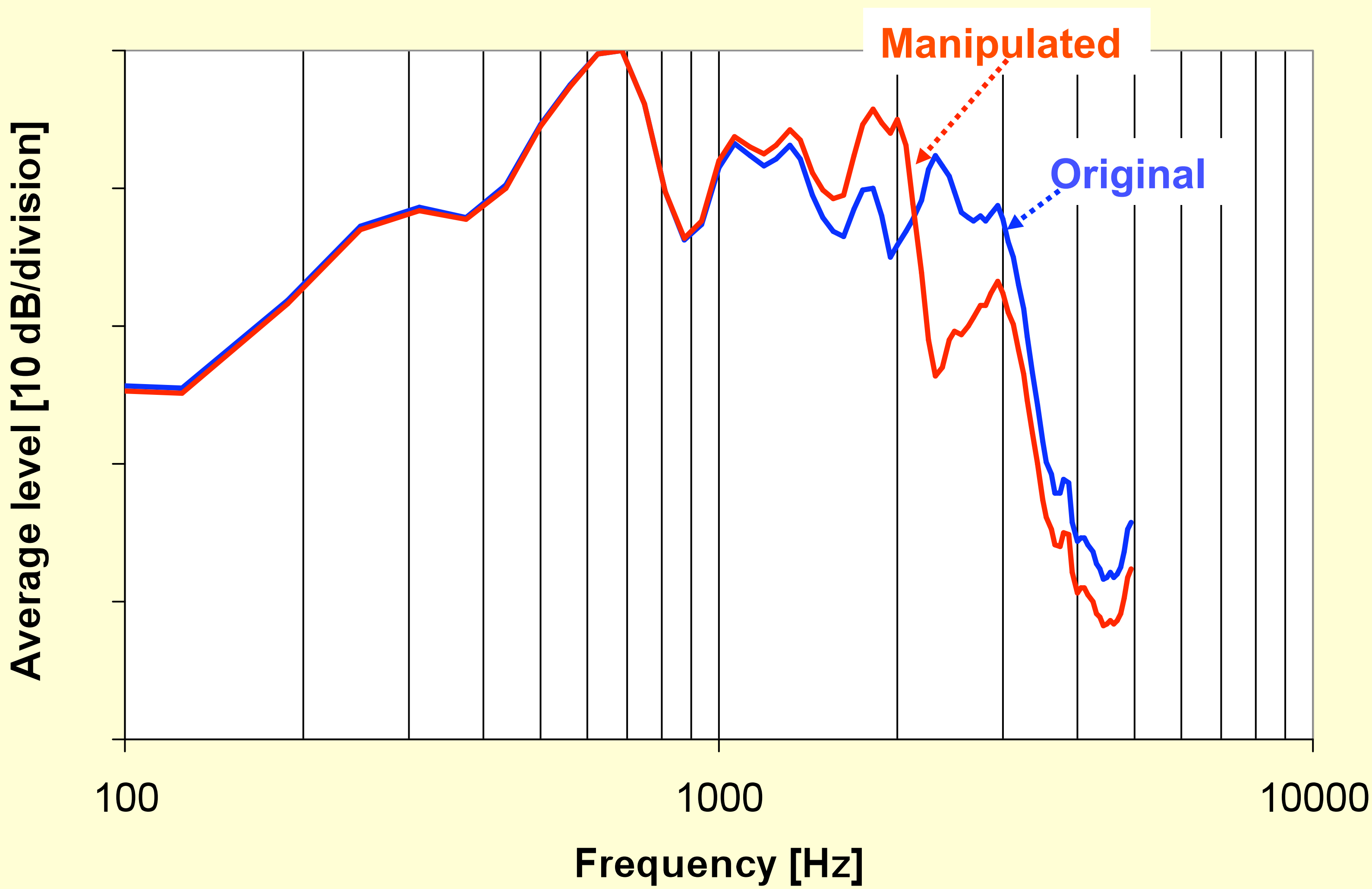
(Resonances are like good friends, proximity strengthens)

Creating singer's formant cluster produced by clustering formants



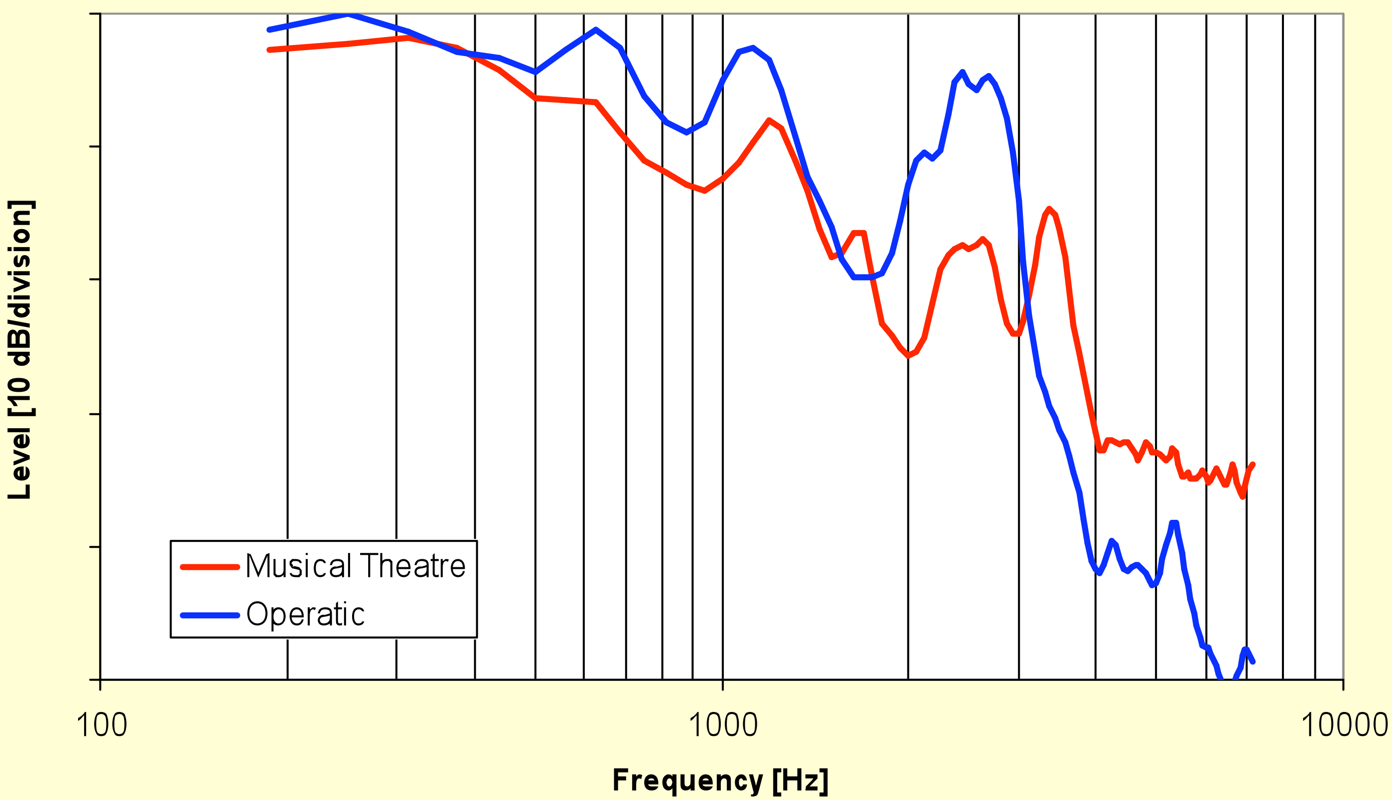
Center frequency of singer's formant cluster is perceptually relevant

Lowering third formant by 300 Hz

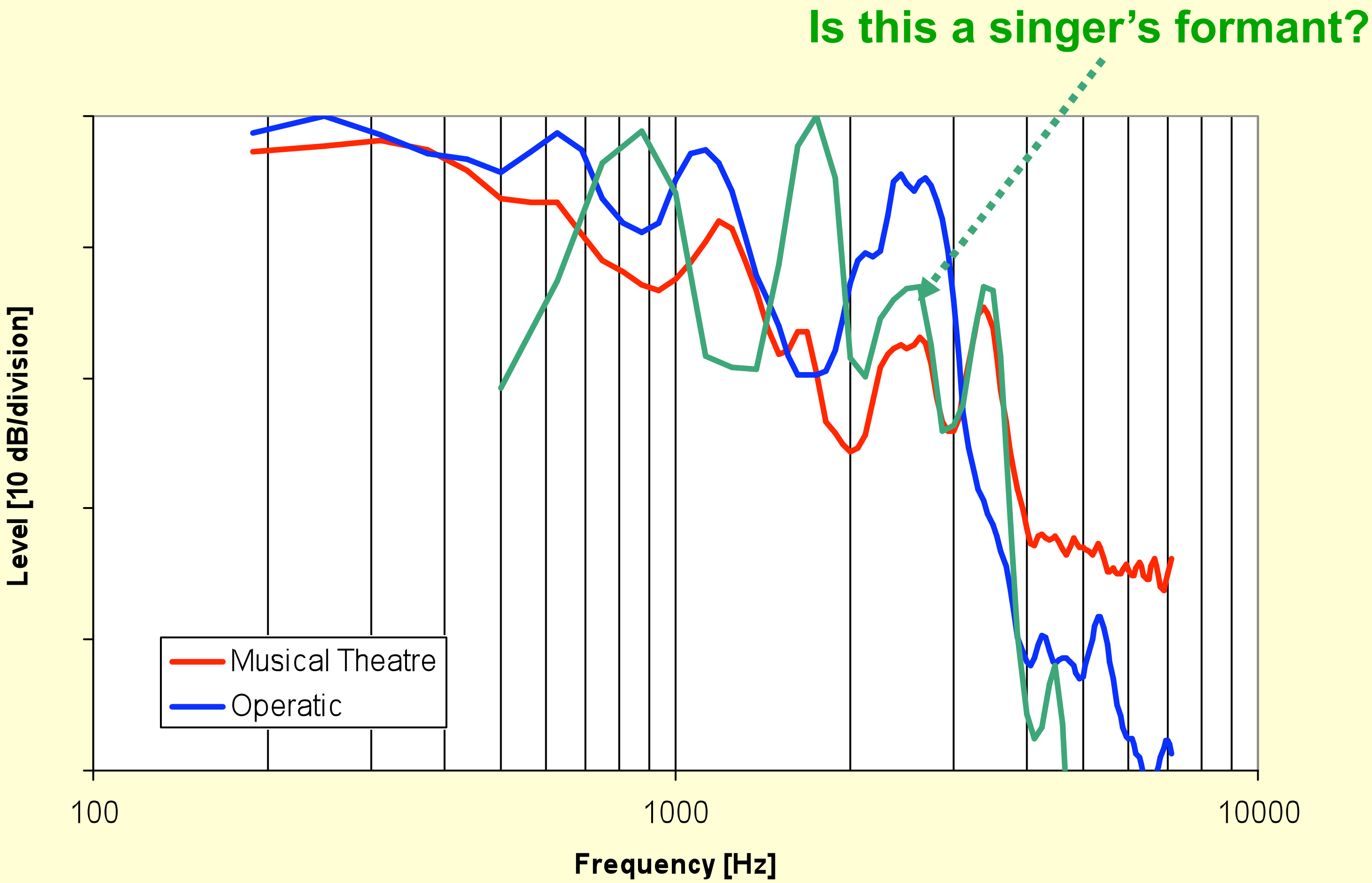


Who possesses a singer's formant cluster?

LTAS


Level [10 dB/division]
100
1000
10000
Frequency [Hz]
Musical Theatre
Operatic

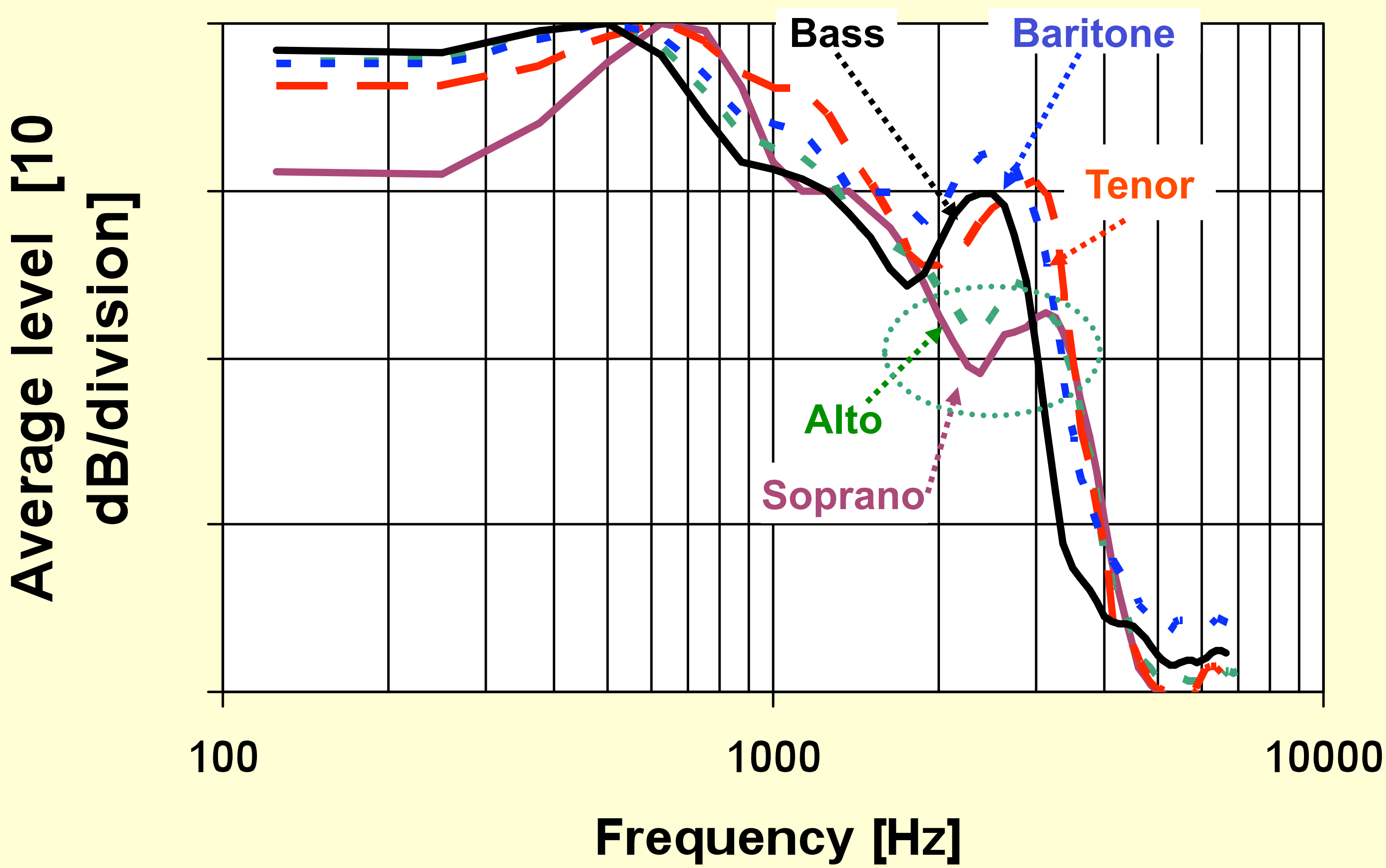
LTAS



Is this a singer's formant?
Level [10 dB/division]
Musical Theatre
Operatic
100
1000
10000
Frequency [Hz]

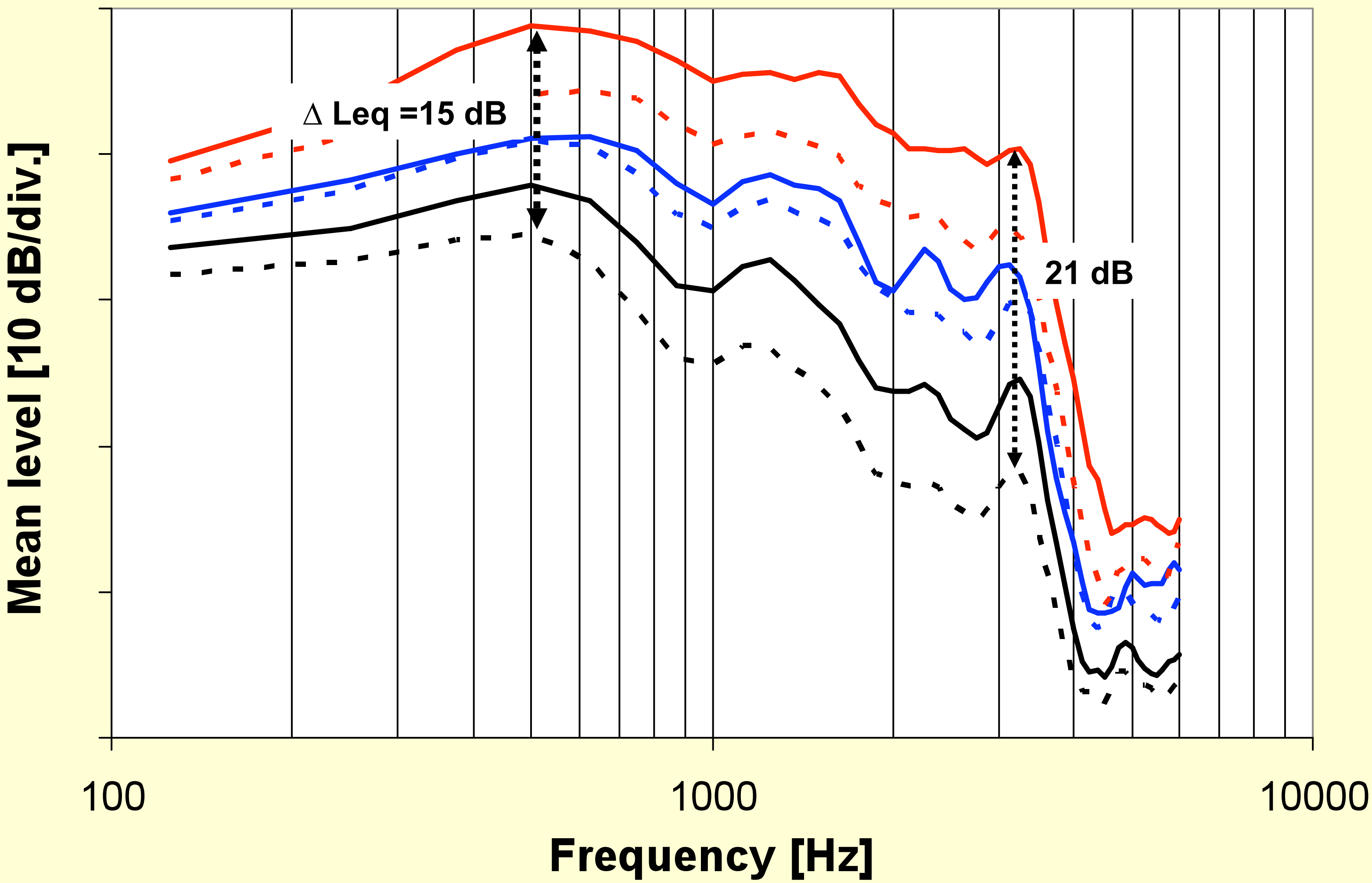
Any peak at high frequency is not a singer's formant cluster

Female singers don't have a singer's formant cluster



Vocal loudness and spectrum tilt

Nordenberg & Sundberg, J. Acoust. Soc. Am. 120, 453-457 (2006)



Effect of vocal loudness on spectrum slope,

Check spectrum, when loudness is increased!

High overtones gain more than low, so singer's formant cluster becomes more dominant, if vocal loudness is increased!

A bad strategy for achieving singer's spectrum peak!

Summary

Singer’s formant cluster

- occurs near 3000 Hz in tenor, baritone, and bass voices
- center frequency varies with voice classification
- generated by clustering formants 3, 4, & 5
- can be achieved by a wide pharynx/lowered larynx
- helps male solo singer’s voice to cut through loud accompaniment

Another case of vocal economy

MENU:

A: The instrument

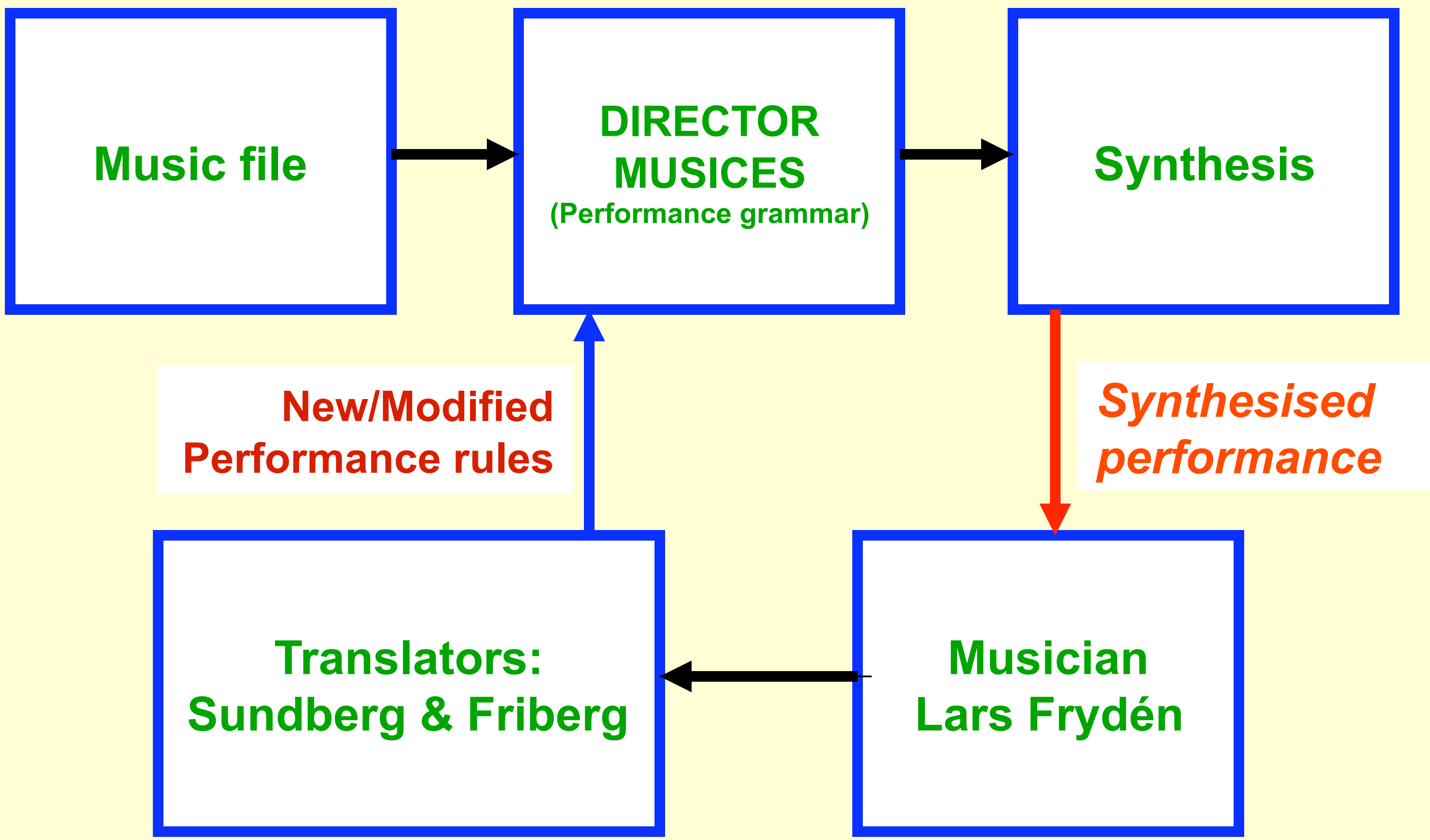
B: Getting heard

C: Expressivity

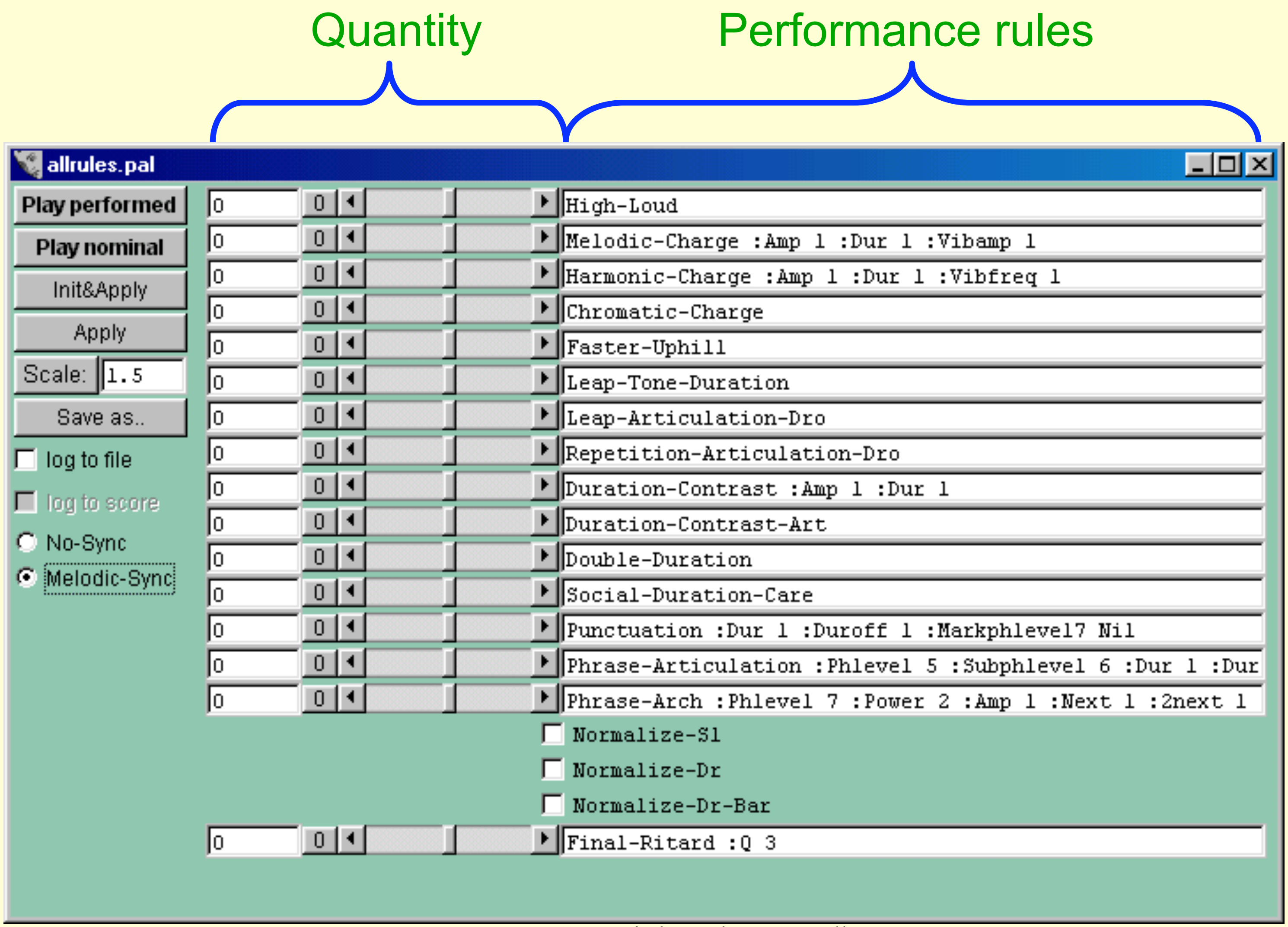
Expressivity

What is the code?
Where did we learn it?

The Analysis-by-Synthesis strategy



DIRECTOR MUSICES interface



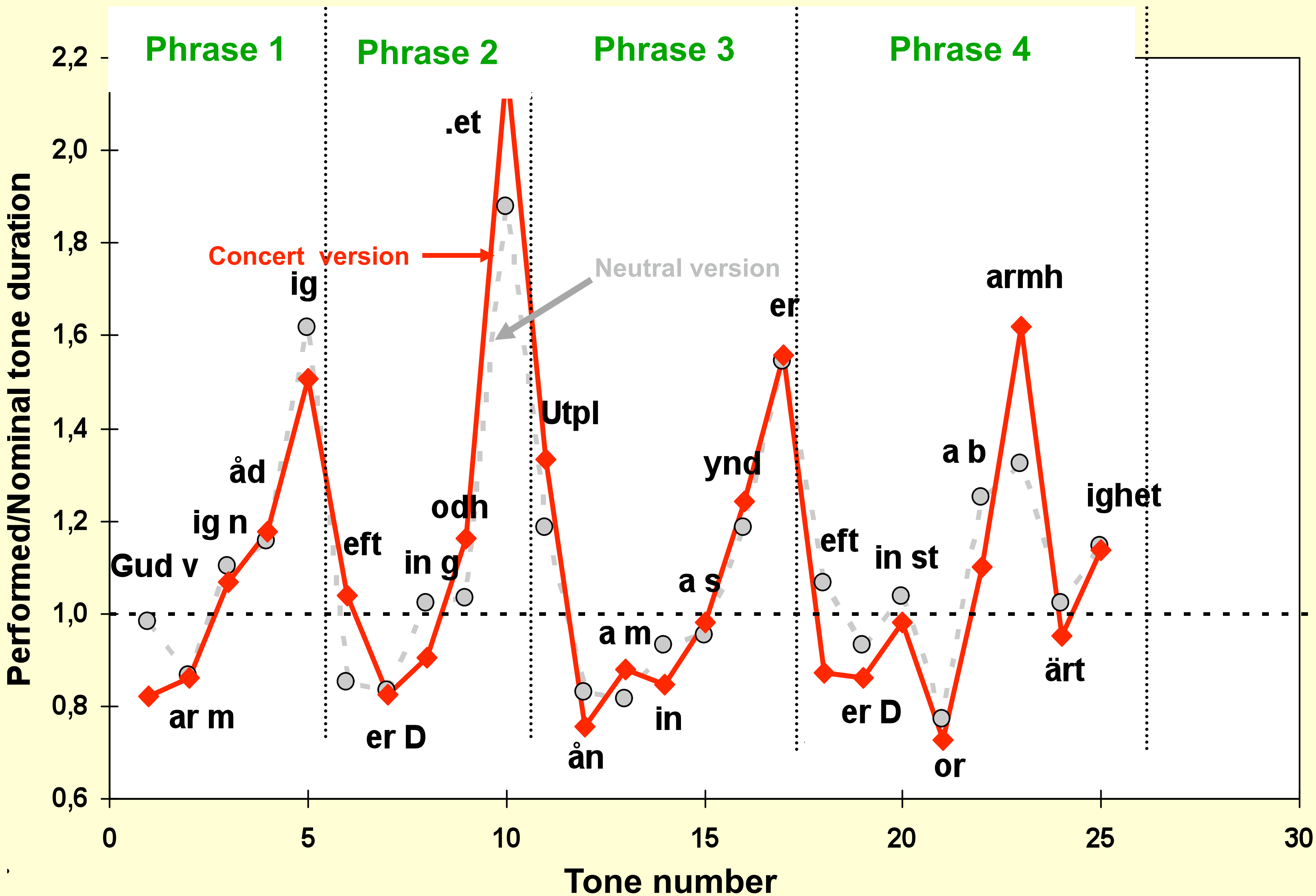
Three performance principles:

1. Marking the structure
2. Sharpening contrasts
3. Emphasising important notes

Principle 1:

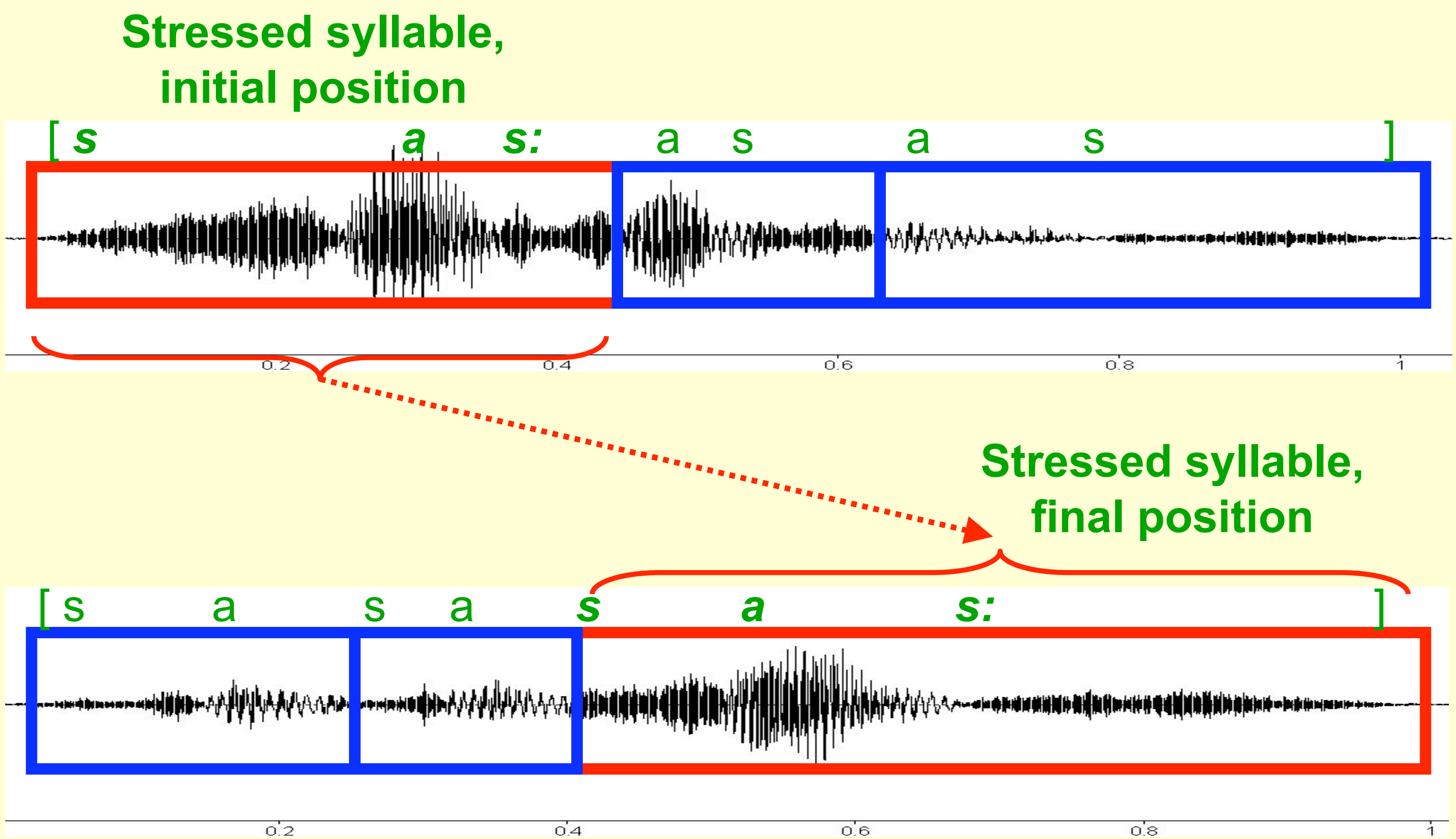
Mark the structure!

Phrase marking: Phrase Arch



Tempo change is an *expressor*
Similar expressor used in speech

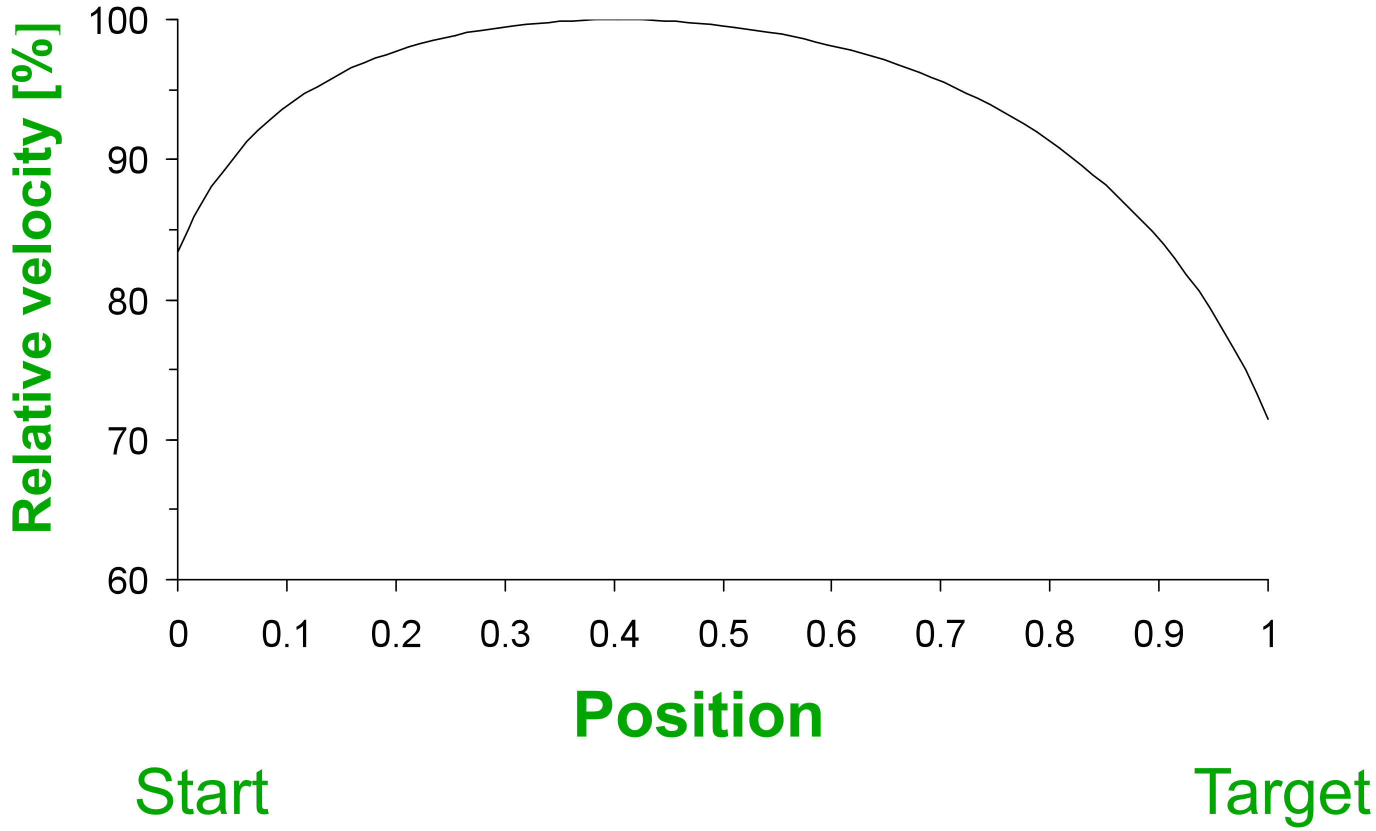
Final lengthening in speech



Origin of this expressor?

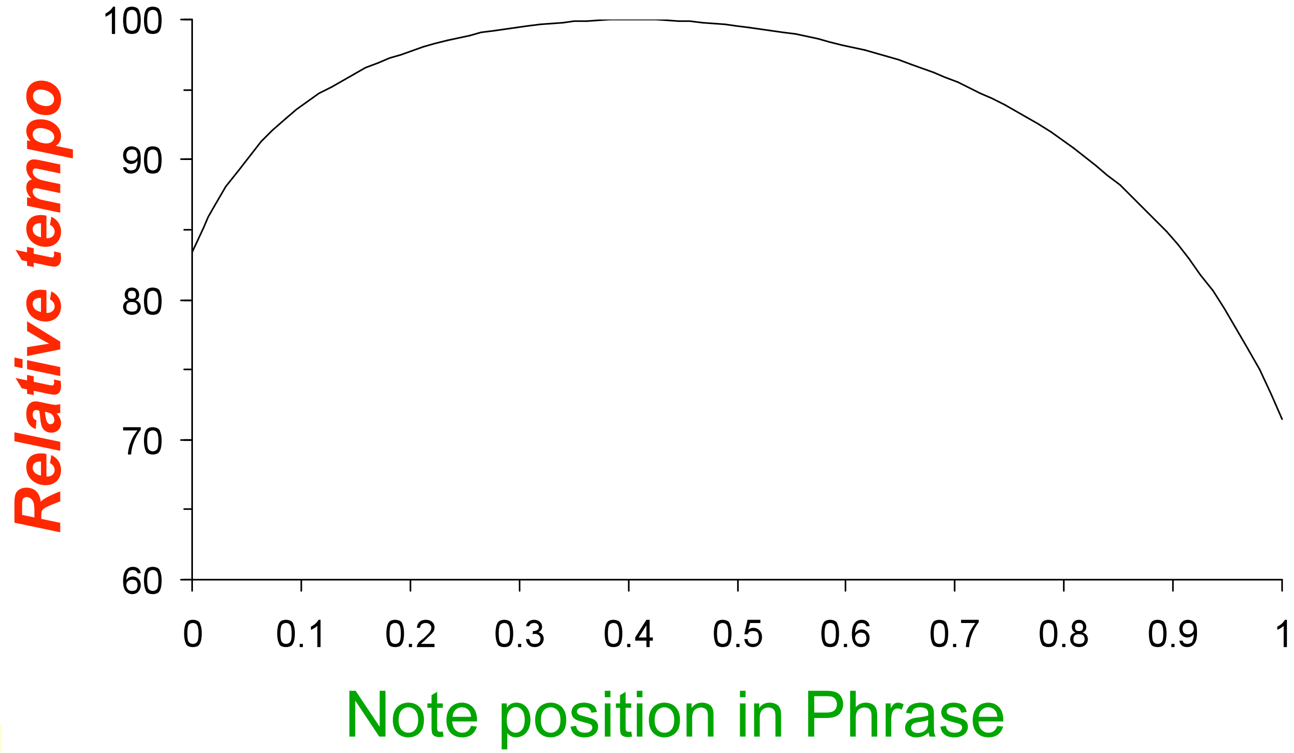
Velocity of hand movement

Change of hand position along straight line



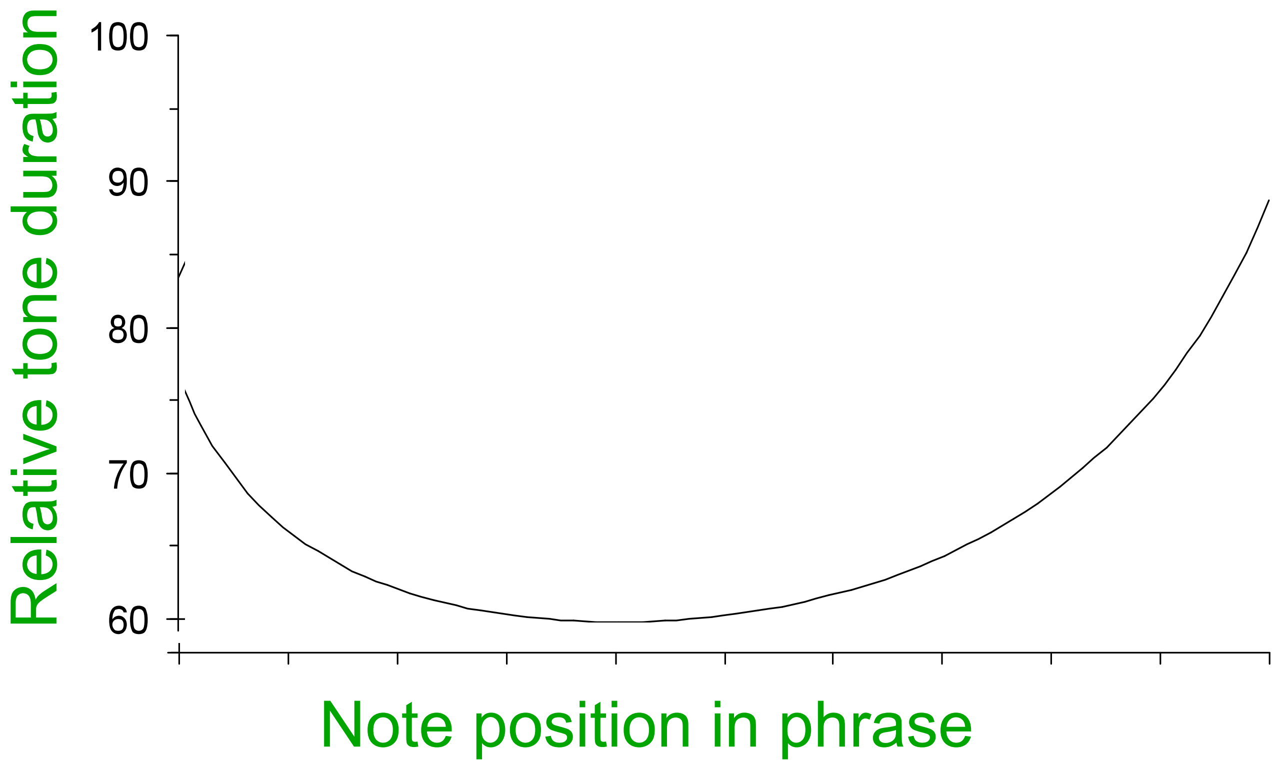
(according to Juslin, Friberg and Bresin, forthcoming)

Velocity of hand movement translated to tempo



(according to Juslin, Friberg and Bresin, forthcoming)

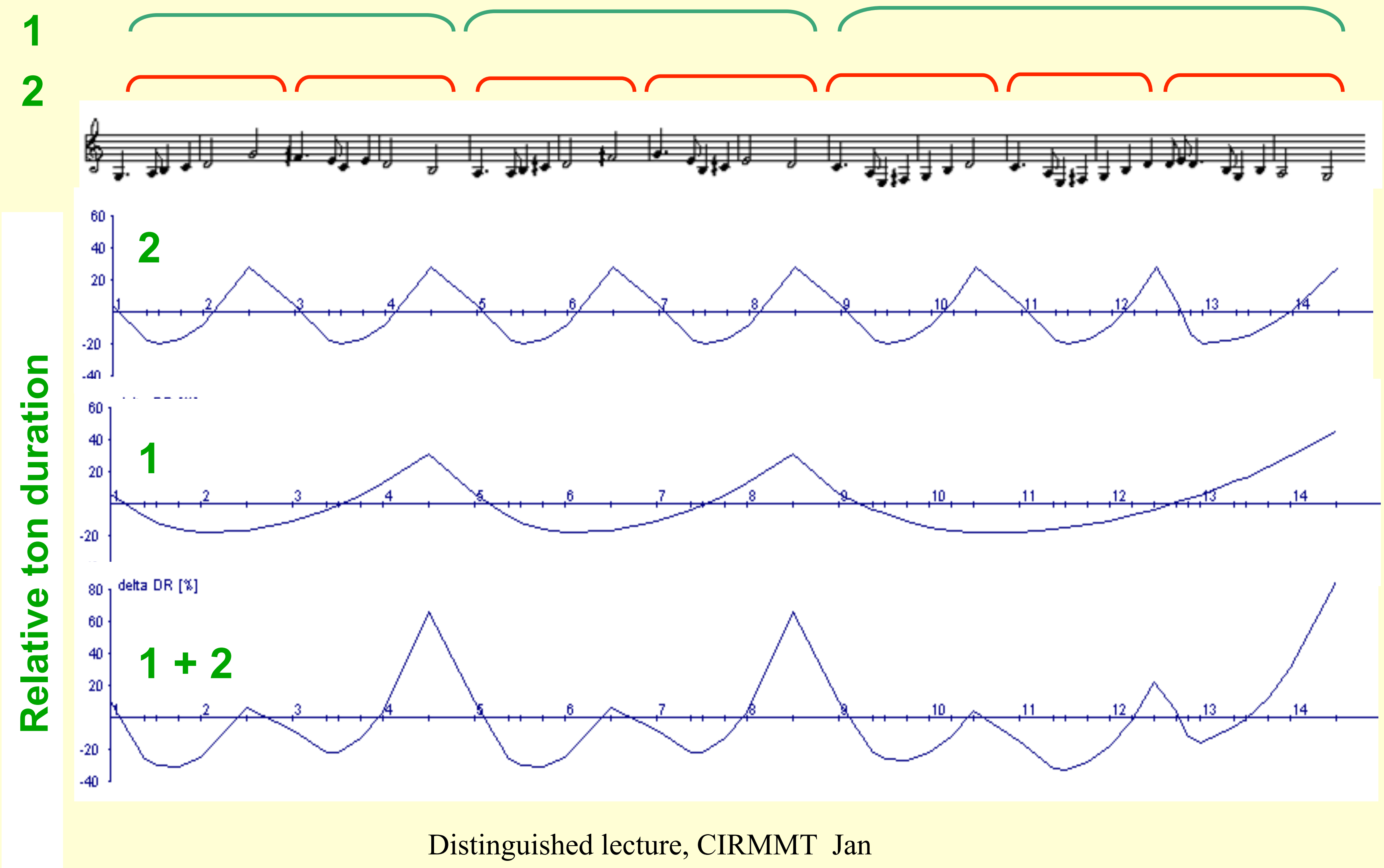
Hand movement pattern translated to tone duration



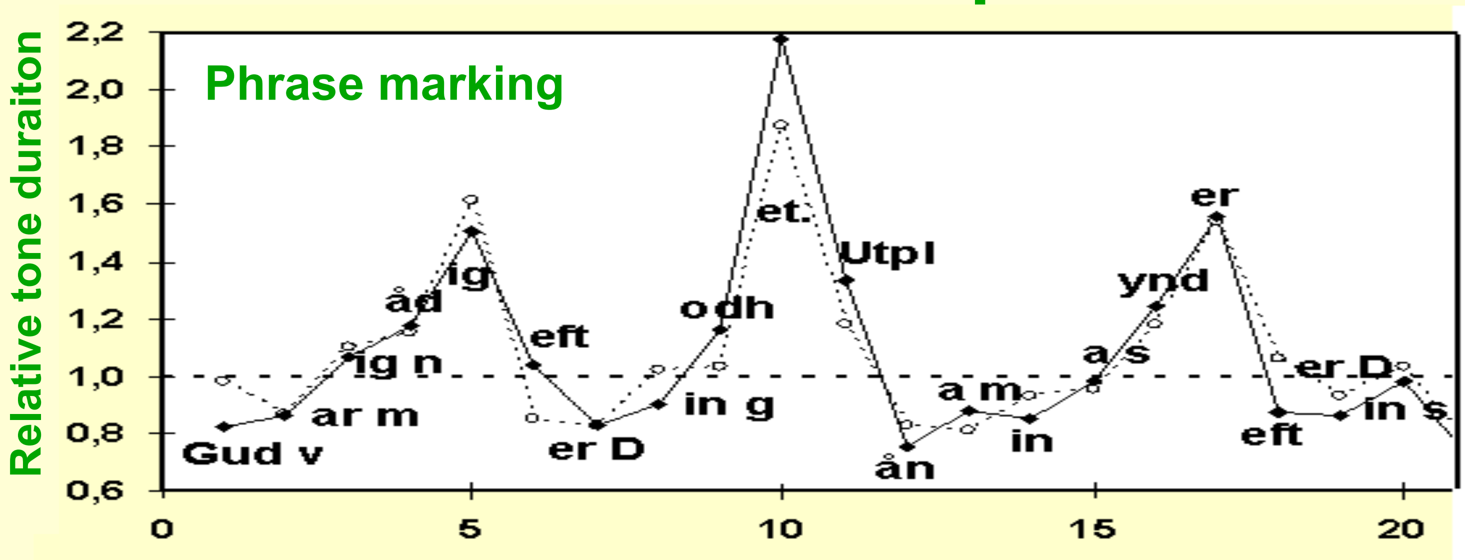
(according to Juslin, Friberg and Bresin, forthcoming)

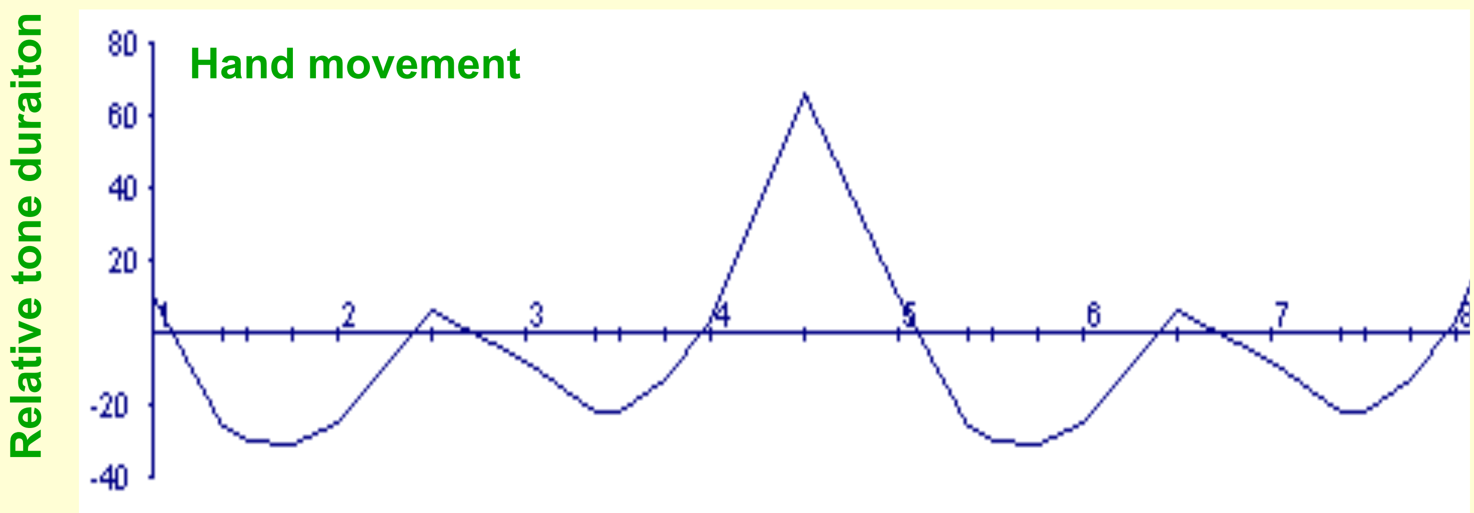
Phrase marking

Phrase level



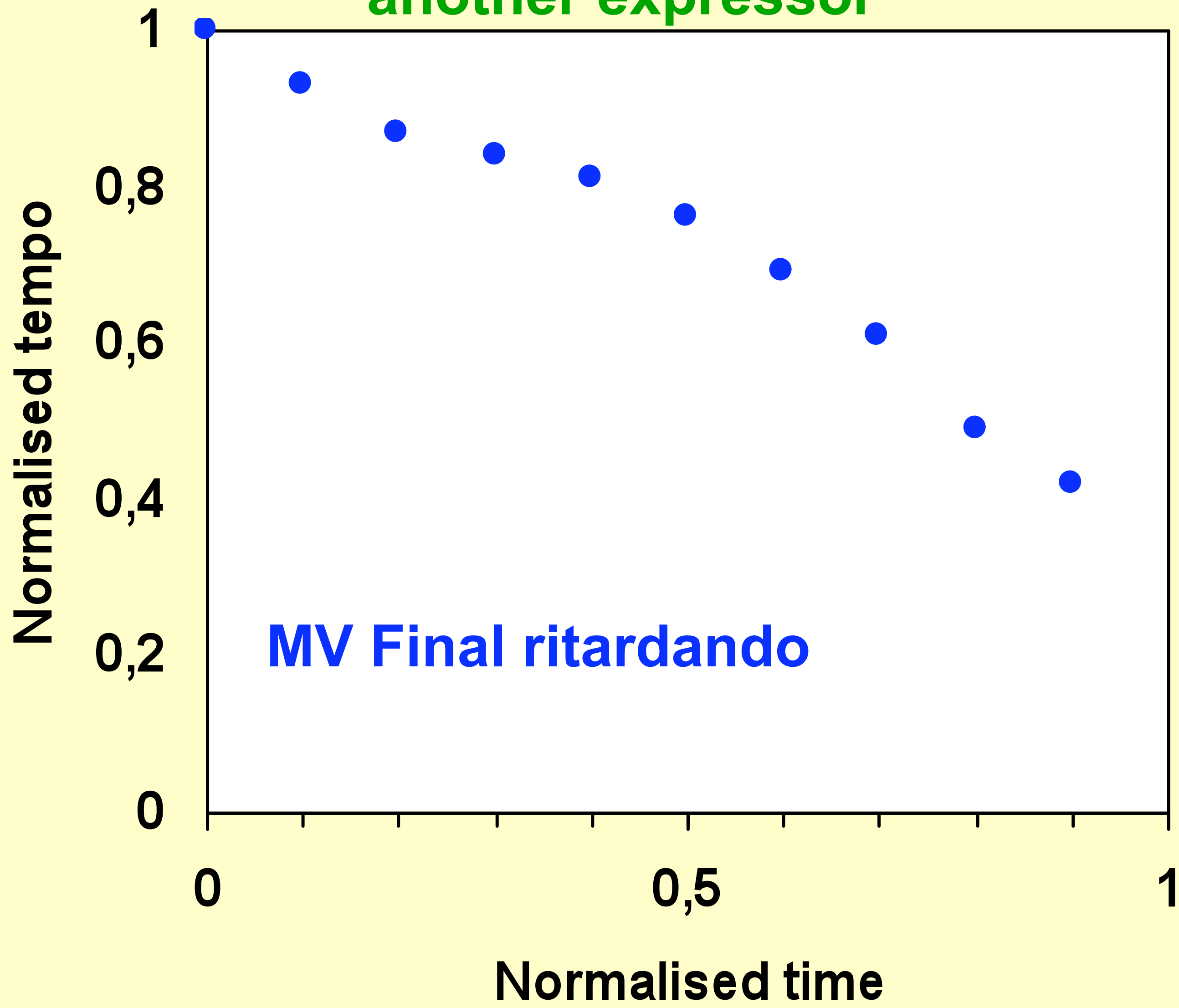
Modelling Hagegård's phrase marking with hand movement pattern



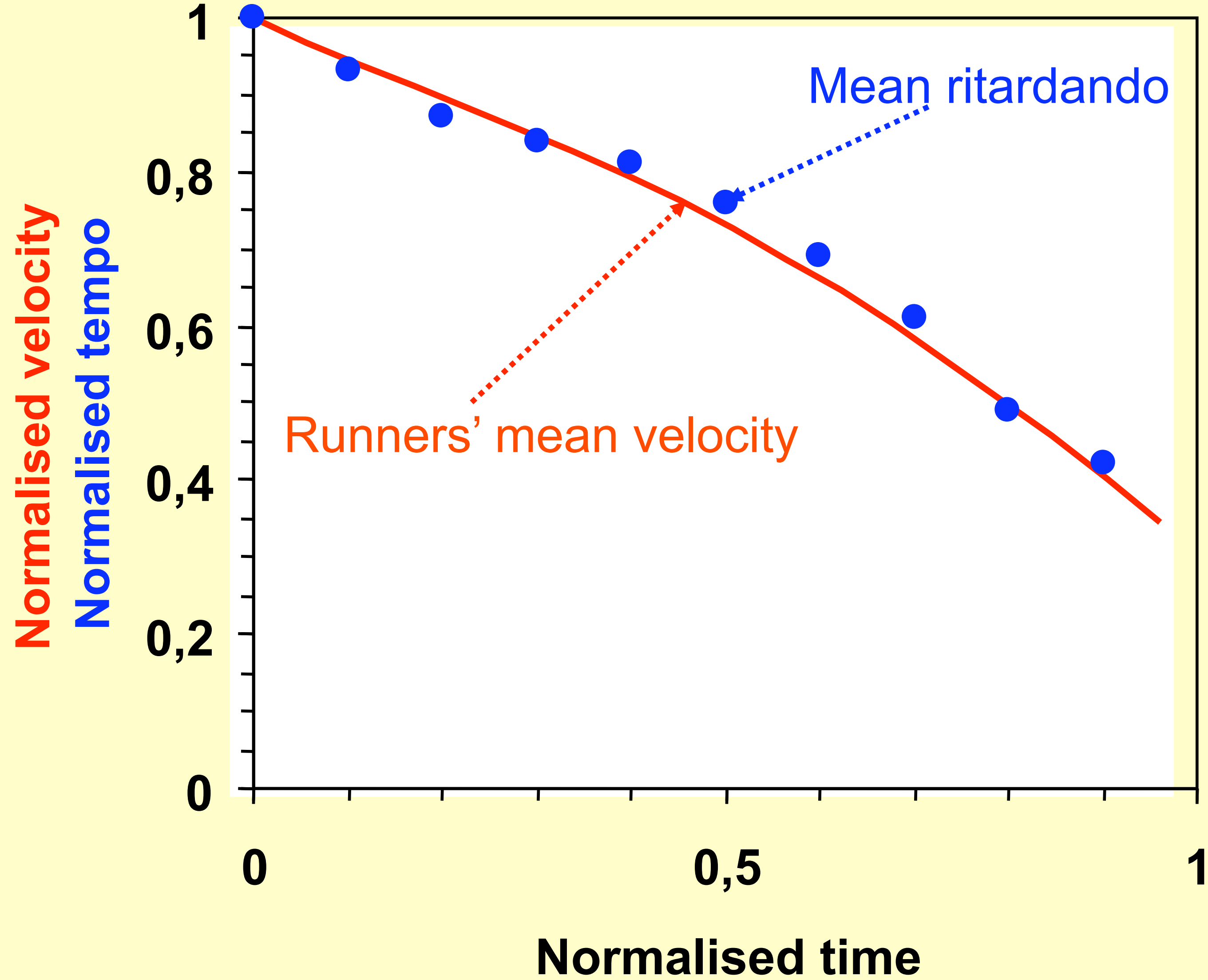


Distinguished lecture, CIRMMT Jan 2009, Copyright Johan Sundberg

Final ritardando,
another expressor



Final ritardando & stopping running



Do we understand tempo change expressors because they allude to experience of movement?

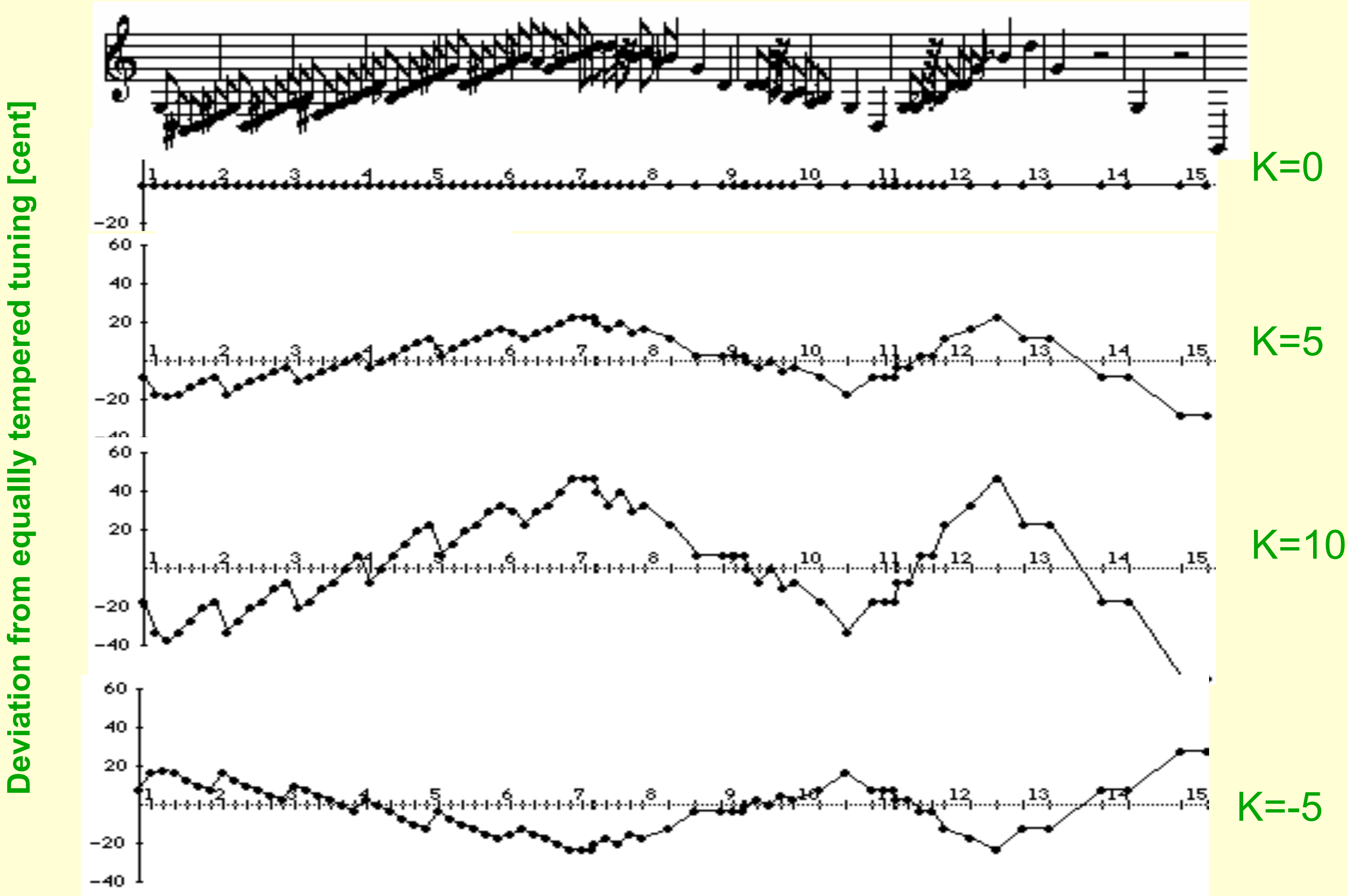
Principle 2:

Sharpen contrasts!

The case of pitch

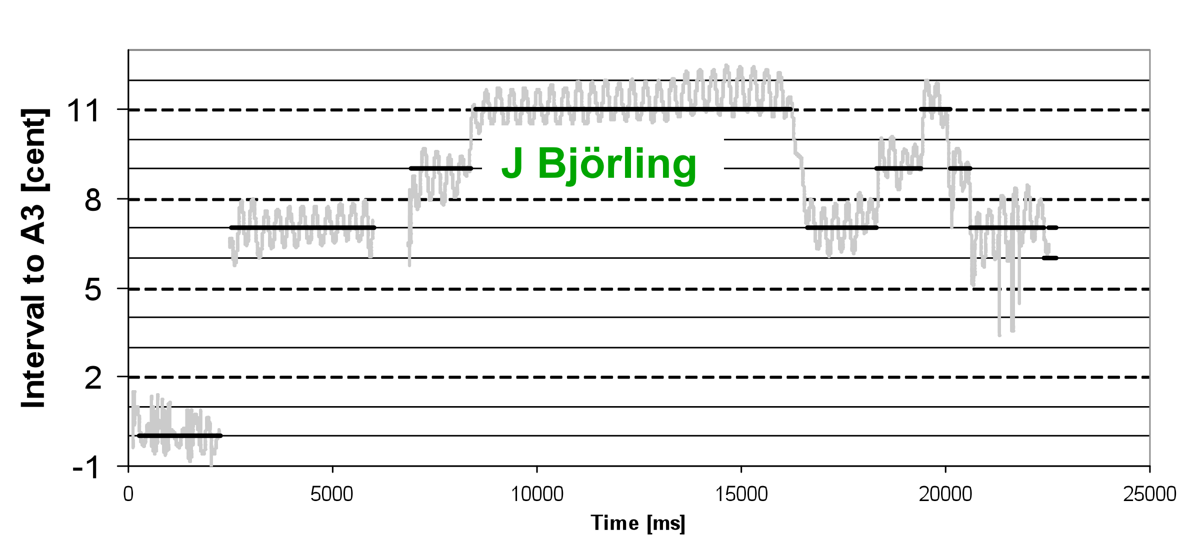
Director musices example

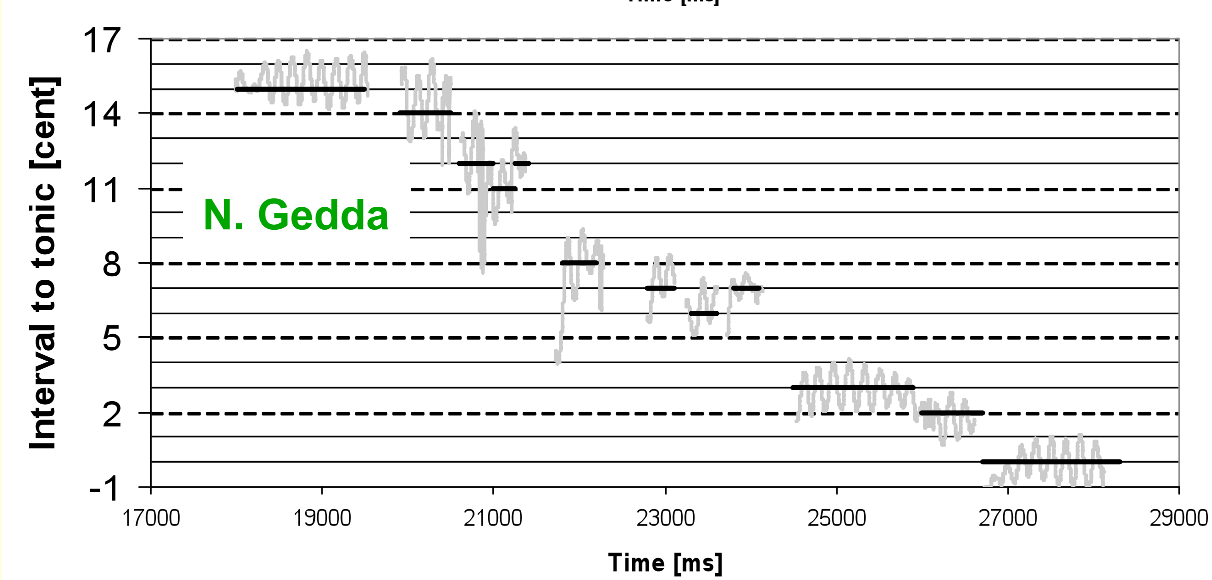
Felix Mendelssohn Bartholdy: *Scherzo* from *Ein Sommernachtstraum,* op 61



Distinguished lecture, CIRMMT Jan 2009, Copyright Johan Sundberg

Other examples

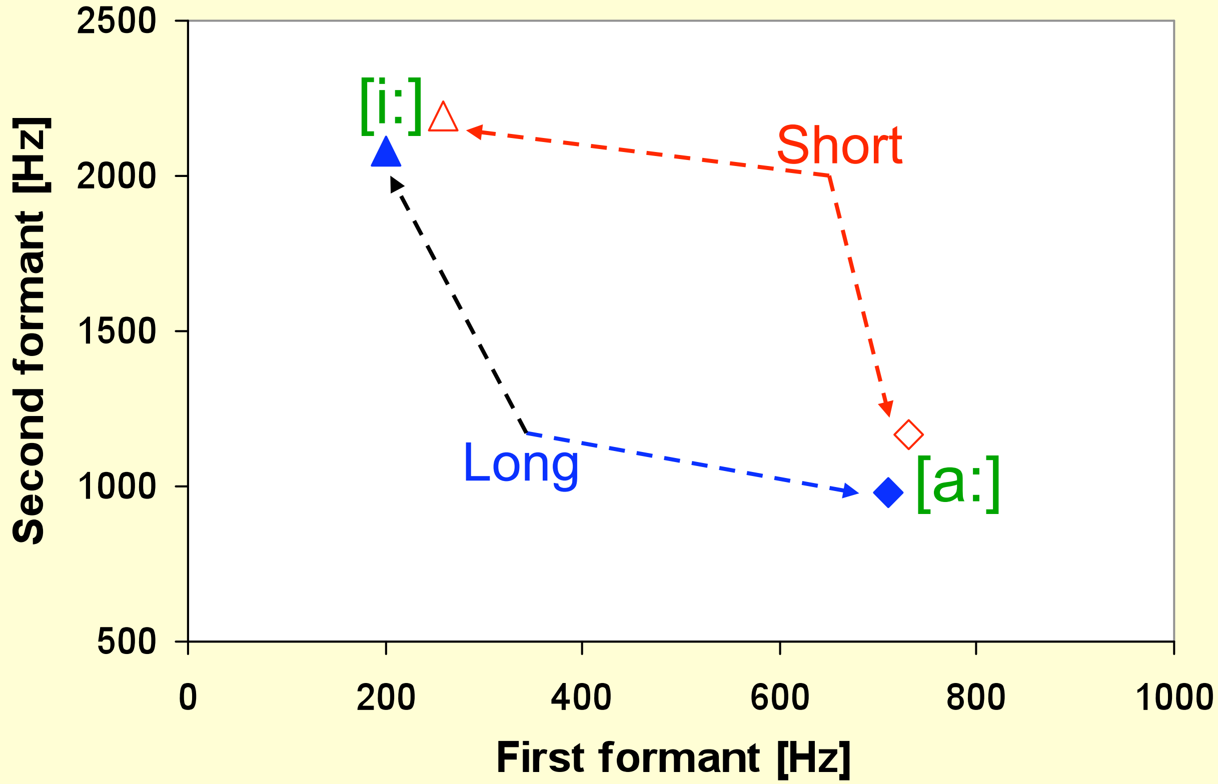




Sharpening contrasts in speech

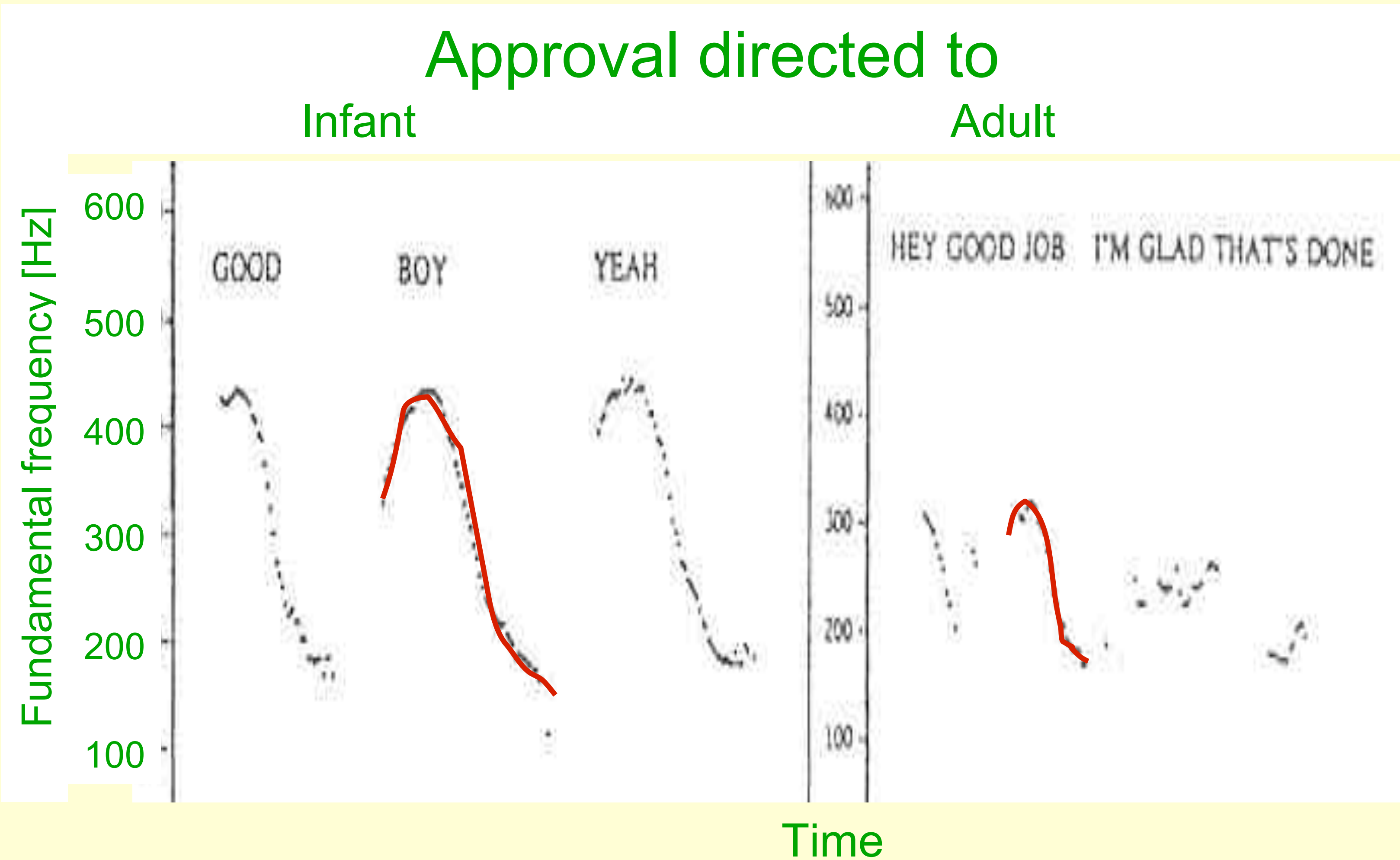
Swedish example:

Long and short vowels : (ha:t = hatred; hatt: = hat)



Vowel duration contrast enhanced by formant frequency differences

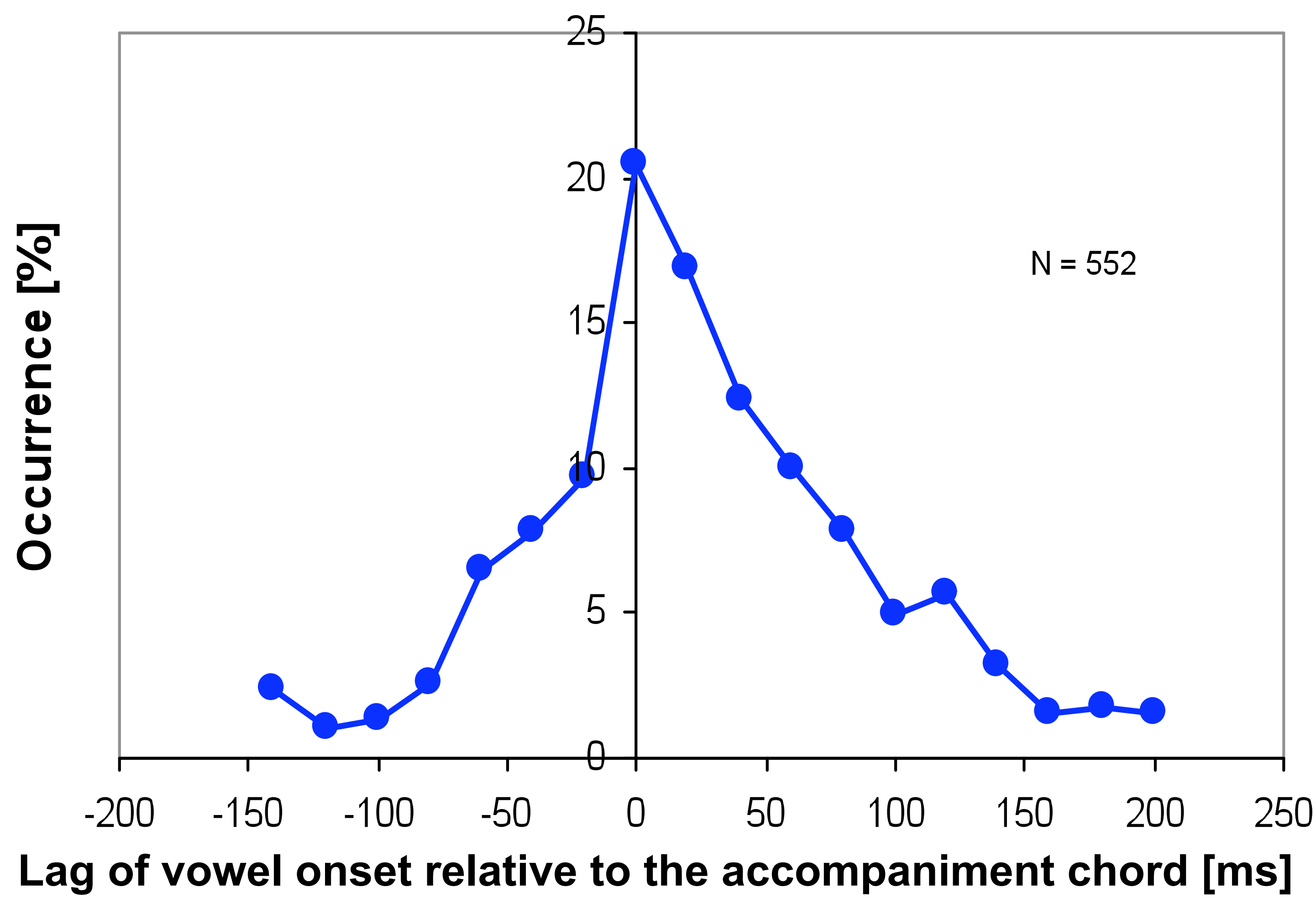
Sharpening contrasts in speech



Principle 3:

Emphasise important events

Tone onset and vowel onset

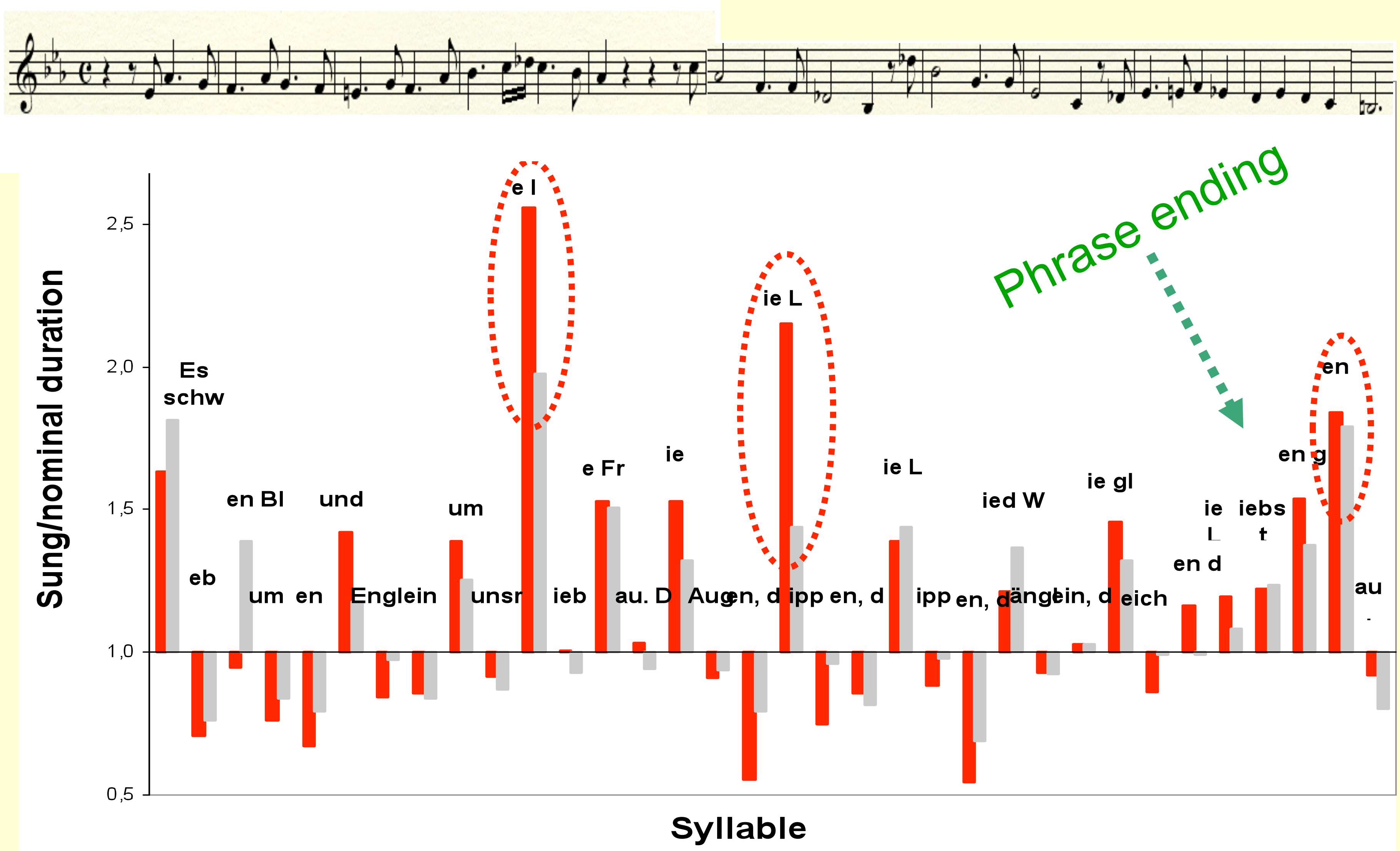


Thus, sung tone start at the vowel onset

Expressor in singing:

Timing of tone onset/Tone duration

Tone durations in Hagegård's material



Distinguished lecture, CIRMMT Jan 2009, Copyright Johan Sundberg

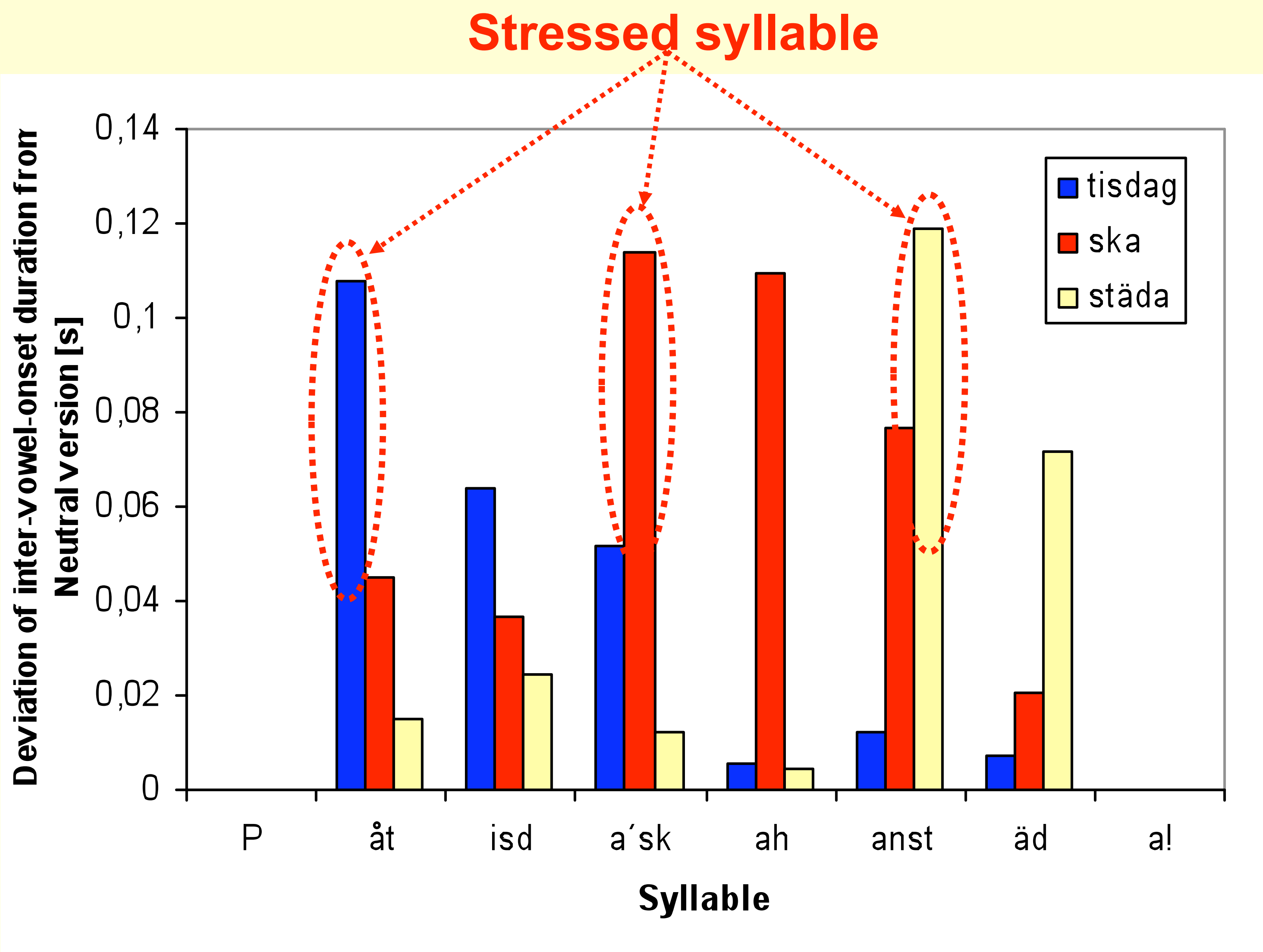
Expressor in singing:

Emphasis by delayed arrival

Expressor in speech:

Syllable duration

Syllable duration in actor's speech



Expressor in speech:

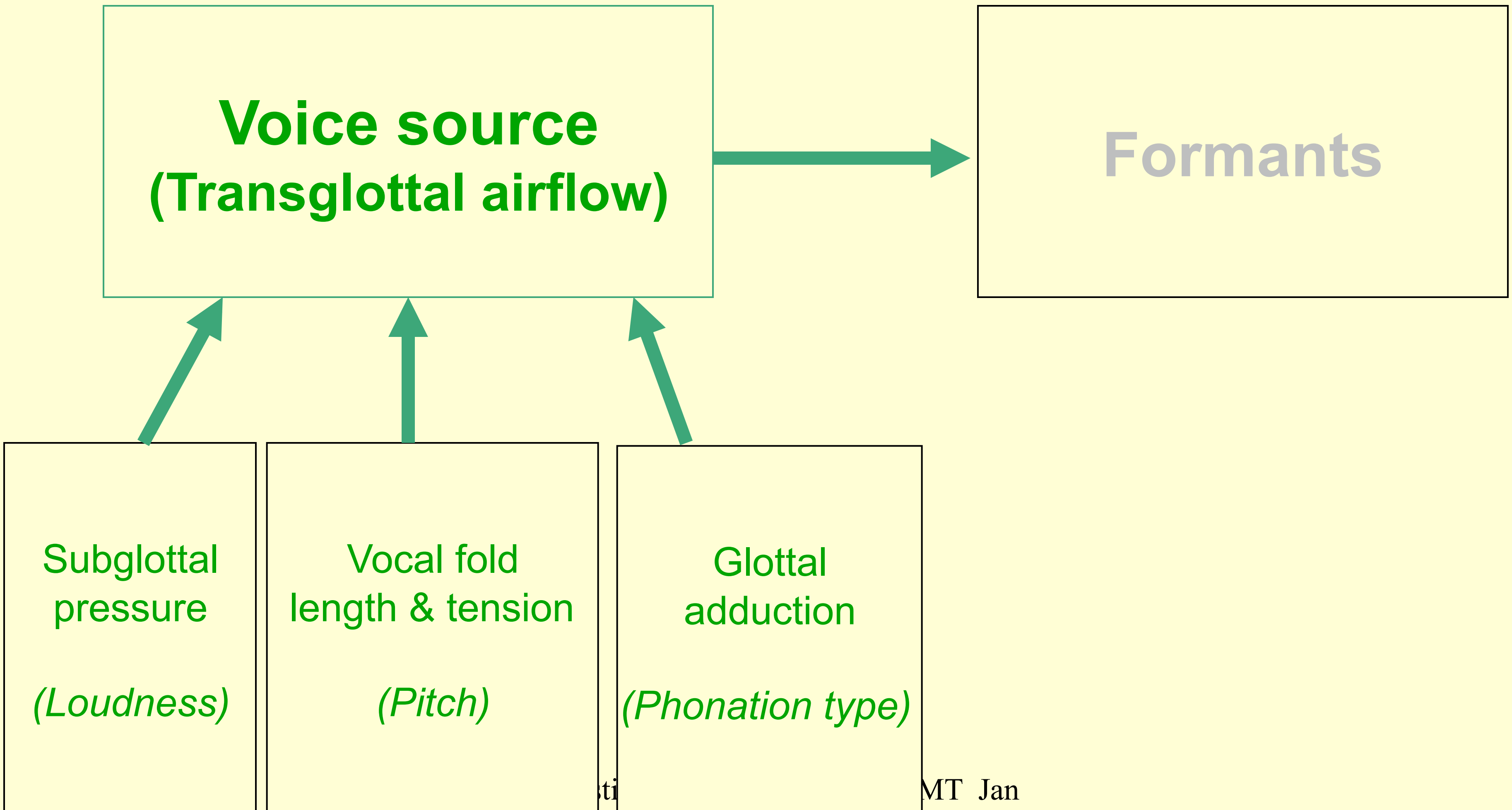
Emphasis by delayed arrival

Expressor in singing:

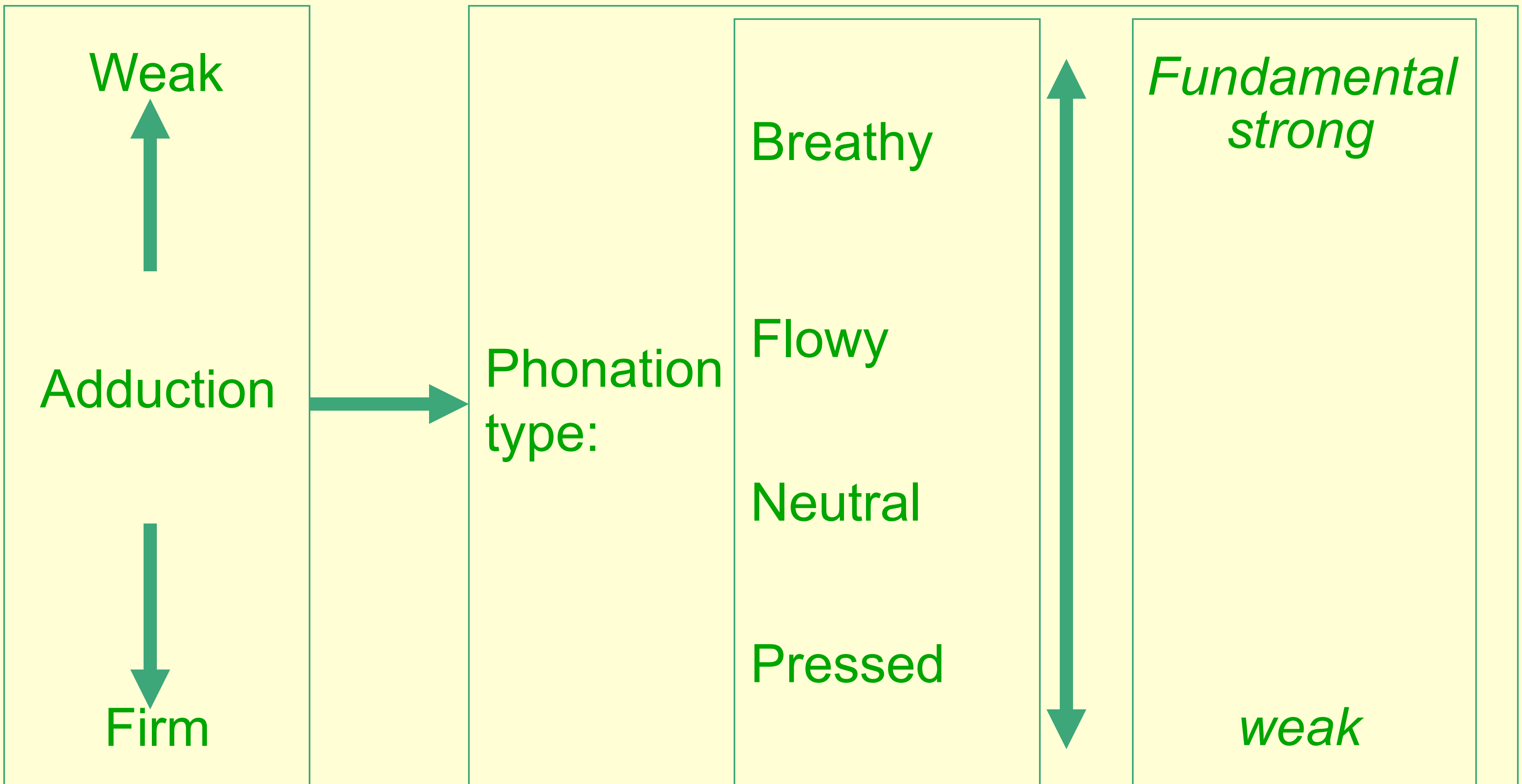
Amplitude of fundamental

How does it sound?

Physiological factors affecting voice timbre

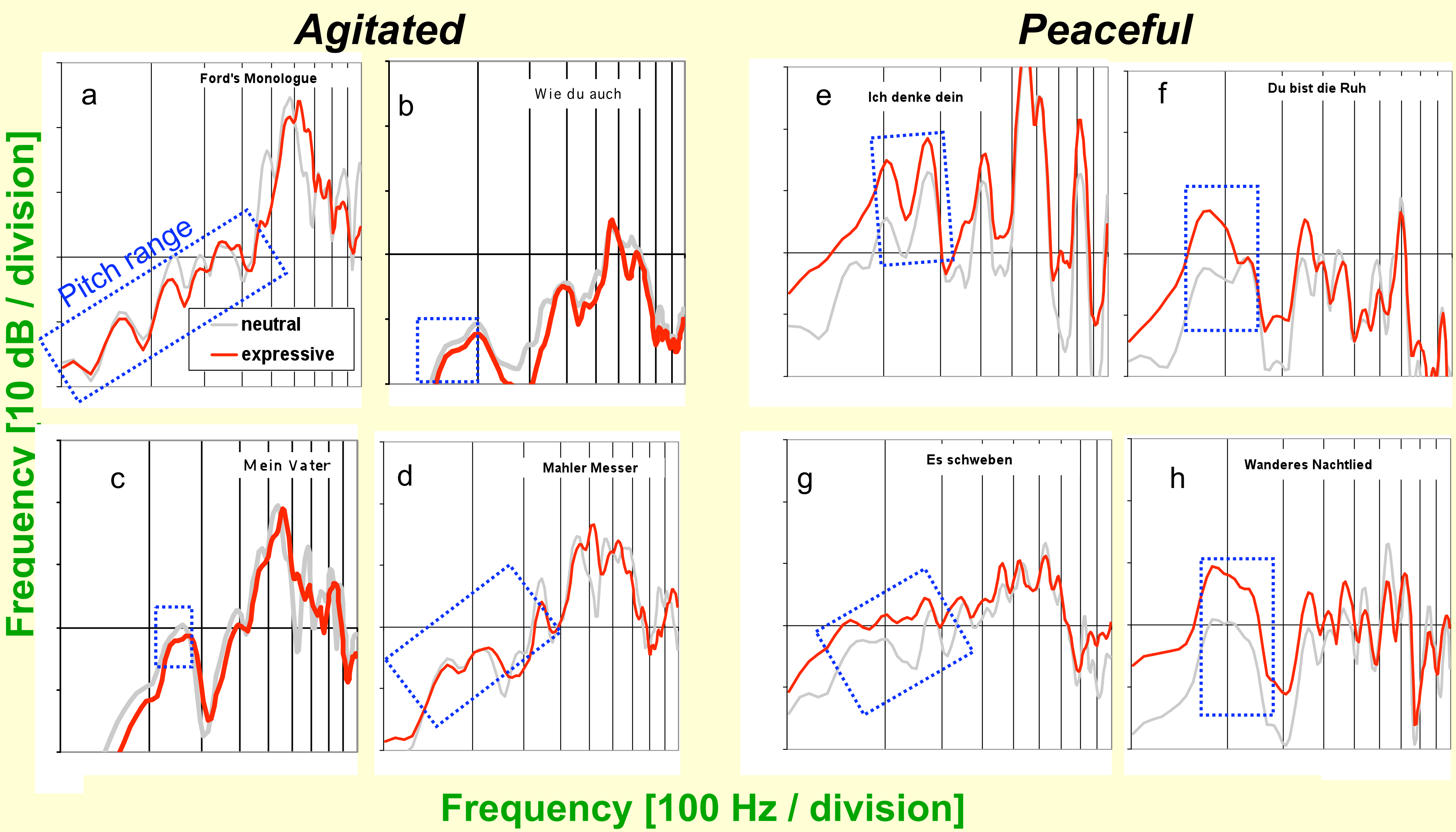


Amplitude of voice source fundamental



Long-Term-Average Spectra of expressive and neural versions of examples

Red: Expressive, Gray: Neutral



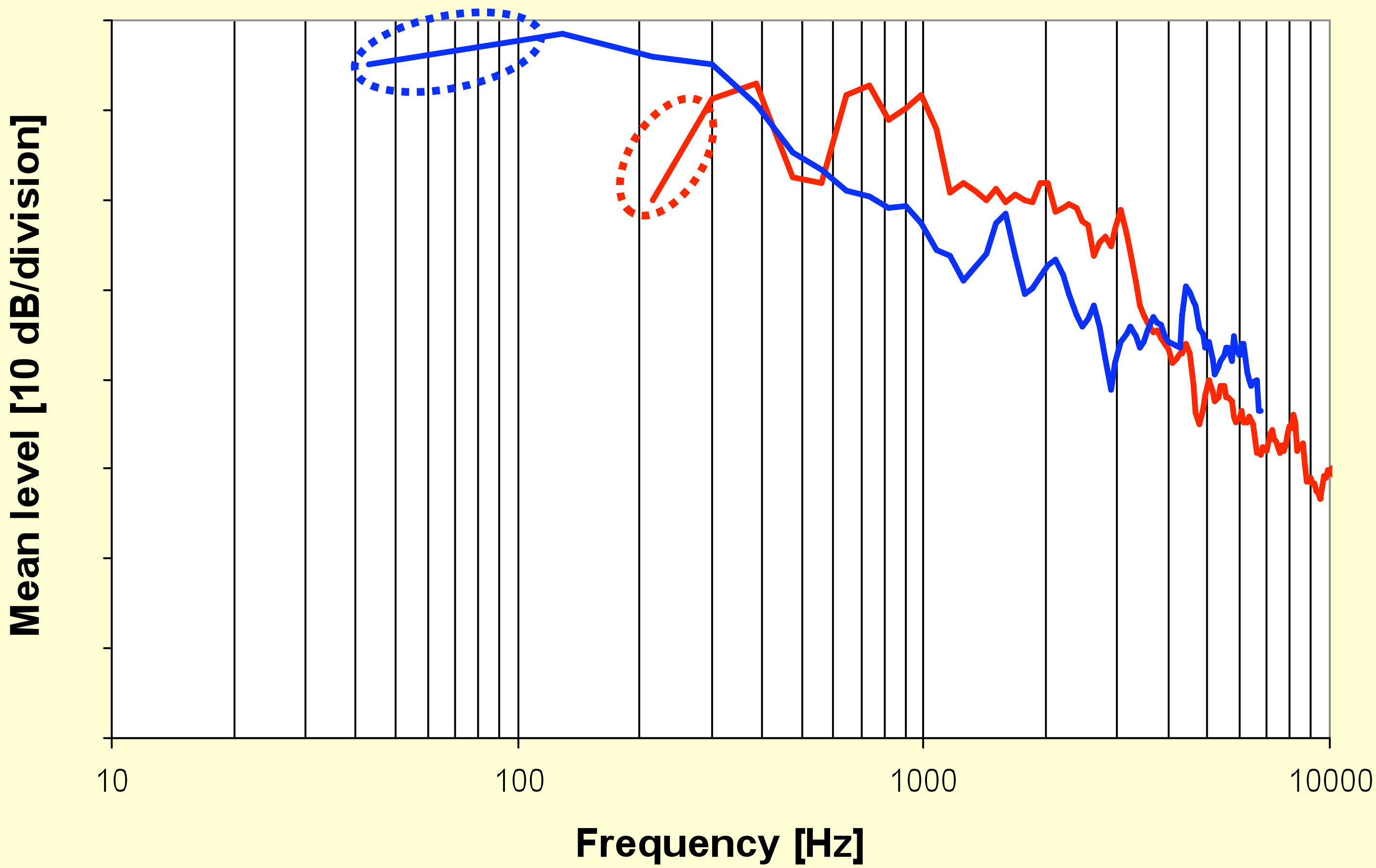
Expressor in speech:

Amplitude of fundamental

Expressor in speech:

Amplitude of fundamental

Courtesy of Klaus Scherer, Geneva



Summarising

Instrument:

Pulsating transglottal airflow, controlled by subglottal pressure, glottal adduction and vocal fold length and tension

formant, controlled by articulation

Getting heard:

Use formants to reach audibility when accompaniment is loud

Expression:

Principle 1. Mark the structure

Principle 2. Enhance contrasts

Principle 3. Emphasise important events