

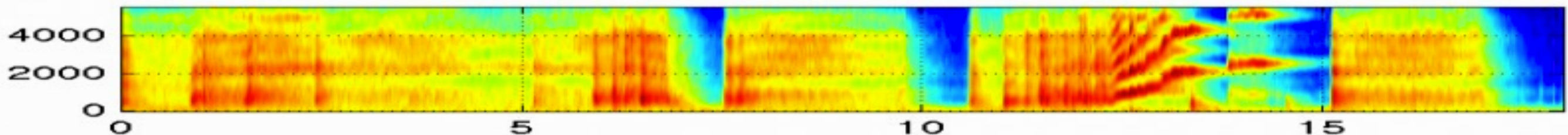
Workshop on musical timbre

Télécom ParisTech, Friday November, 14

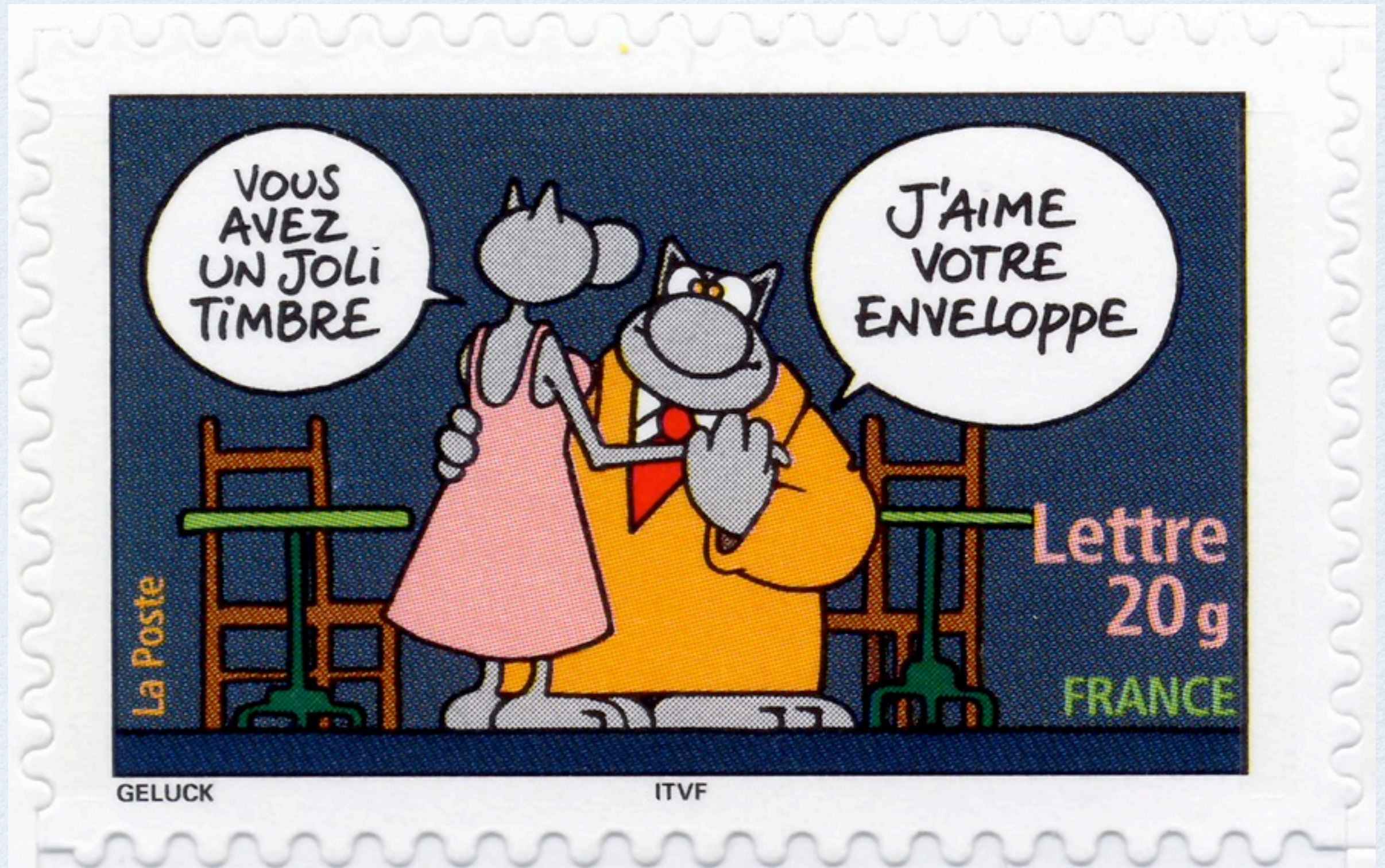
WHAT IS MUSICAL TIMBRE?

Michèle Castellengo

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CNRS - University Paris 6 - Ministry of culture



TIMBRE?



THE MEANING OF THE WORD «TIMBRE»: A QUICK SURVEY FOR MUSICIANS AND SCIENTISTS

THE FRENCH WORD «TIMBRE»

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- 1863 - Helmholtz publishes : «On the sensation of tone as a physiological basis for the theory of music». It is the first experimental analysis of what he labels «klangfarbe».

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Helmholtz' musikalische Klangfarbe is strictly restricted to the stable part of sustained sounds.

die musikalische
Klangfarbe

the musical
quality

le timbre musical

Helmholtz Wir wollen in dem vorliegenden Abschnitte zunächst von allen unregelmässigen Theilen der Luftbewegung, vom Ansetzen und Abklingen des Schalles absehen und nur auf den eigentlich musikalischen Theil des Klanges, welcher einer gleichmässig anhaltenden, regelmässig periodischen Luftbewegung entspricht, Rücksicht nehmen, und die Beziehungen zu ermitteln suchen zwischen dessen Zusammensetzung aus einzelnen Tönen und der Klangfarbe. Was von den Eigenthümlichkeiten der Klangfarbe hierher gehört, wollen wir kurz die **musikalische Klangfarbe** nennen.

English

translation In the present chapter we shall at first disregard all irregular portions of the motion of the air, and the mode in which sounds commence or terminate, directing our attention solely to the musical part of the tone, properly so called, which corresponds to a uniformly sustained and regularly periodic motion of the air, ¶ and we shall endeavour to discover the relations between the quality of the sound and its composition out of individual simple tones. The peculiarities of quality of sound belonging to this division, we shall briefly call its *musical quality*.

French

translation

Nous ferons abstraction, dans ce chapitre, de toutes les irrégularités du mouvement de l'air, ainsi que des circonstances relatives au commencement et à la fin du son, et nous n'aurons égard qu'à la partie du son véritablement musicale, celle qui correspond à un mouvement d'une durée constante et de période régulière. Nous rechercherons les rapports qui existent entre la constitution du mouvement vibratoire et le timbre du son qui en résulte, et le terme de **timbre musical** ne devra rappeler que les particularités dont nous allons nous occuper.

With a great sharpness he analyses by ears the harmonic content of sounds, in order to explain the adjectives used by musicians as «soft, piercing, braying, poor, rich etc., but he does not have the possibility to make tests with listeners.

XX^o CENTURY: PROGRESS IN SOUND TECHNIQS AND MUSICAL EVOLUTIONS

- (1877 : first sound recording - Edison)
- Early twenties : first sound synthesis: electronic musical instruments (Theremin, Ondes Martenot)
- 1950, sound recording on magnetic tape; development of sound analysers (filters, sound spectrograph) and of musical acoustics laboratories
- 1960, Computer revolution : analysis and synthesis of musical sounds : Max Mathews, J.C. Risset.
- «Orchestral writing» of music (Webern, Debussy); use of «clusters» (Stravinsky, Varèse); Schoenberg treatise (1911).
- 1913, Russolo (bruiteurs futuristes)
- 1950, Experimental music in Broadcast studios (Stockhausen, Ligeti, Berio) and musique concrète (Schaeffer)
- Computer revolution : new music composed with computers: the parameters of the sound are strictly controlled.

Some well-known acoustical researches on timbre

- Electronic sounds (variation of harmonic content) : Lichte, 1941, Bismarck 1974, Plomp 1973.
- Digitized musical instrument sounds (simplified) : Grey 1977 (16 sounds, note Eb4); MDS analysis of the results.
- A lot of other experiments (Mc Adams, Beauchamp, Krumhansl, Donnadieu, Faure) on the same pitch

Listeners of tests are only required to express a dissimilarity between two sounds (without any other indication). What are they listening to?



Examples of grey pairs

1

2

3

4

302 HAJDA, KENDALL, CARTERETTE, HARSHBERGER

The Definition of Timbre Revisited

At this point, some words must be said about developing a constitutive definition of timbre. Based on research findings and definitions which have been posited to this point, it is clear that timbre has two principle constituents: (1) It “conveys the identity of the instrument that produced it” (Butler, 1992, p. 238), and (2) It is representable by a palette or family of palettes (see Martens, 1985) in which tones from different sources can be related along perceptual dimensions.

Hajda, J. M., Kendall, R. A., Carterette, E. C., & Harschberger, M. L. (1994). Methodological issues in Timbre research. In Deliège, I. & Sloboda, J. (éds.), *Perception and Cognition of Music* (pp. 253-306): Psychology Press.

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How are they connected?

- Listen and try to qualify the sound of the instrument

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Naive listeners first try to guess the musical instrument (it is like... it seems that....and then, comment the sensations it arouses for them; it may take a long time.

Expert listeners who detect the sound manipulation write quickly «*Reverse*», that's all. They are quite unable to go further.

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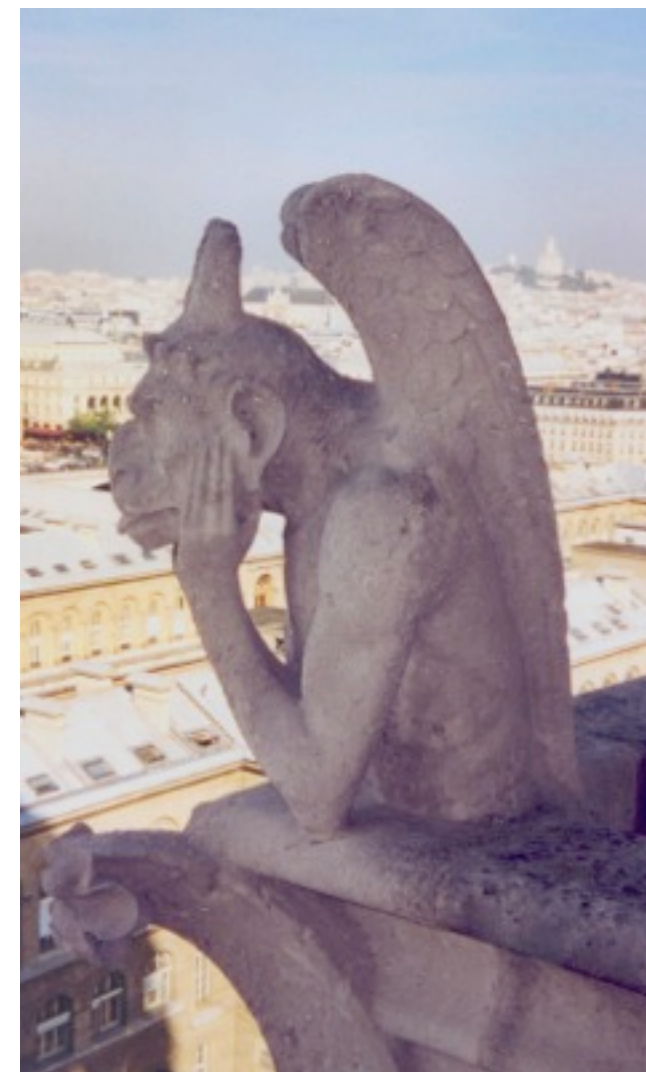
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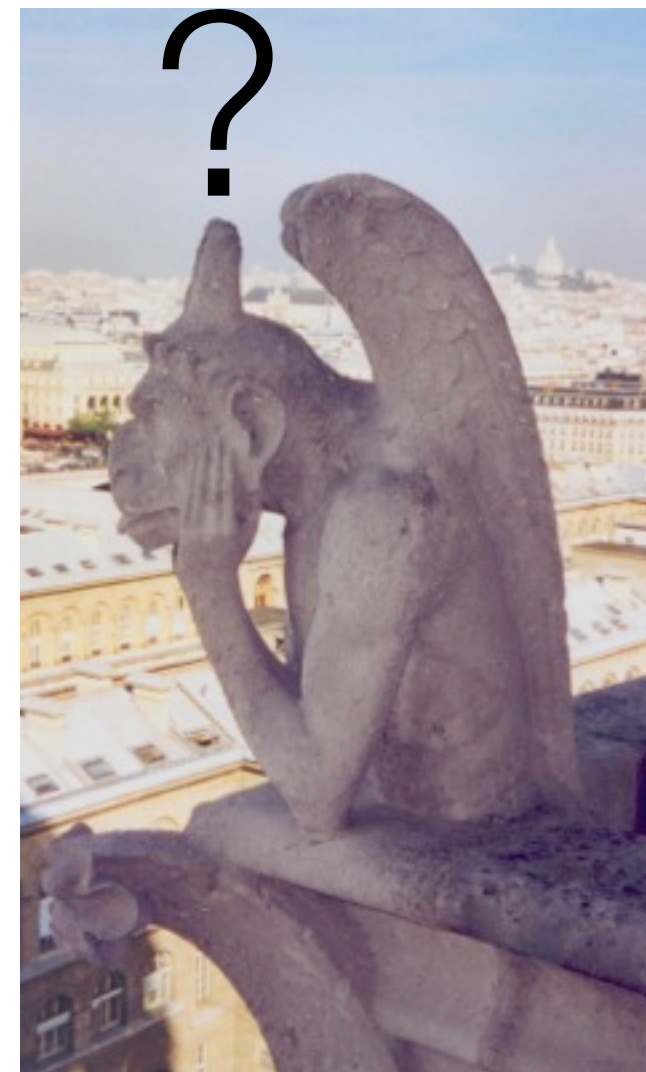
-----> It takes less than half a second to recognize the instrument.

I state that sound recognition is the first and the most important cognition process which precedes discrimination and qualification.

What is this sound ? Listen (3 times)

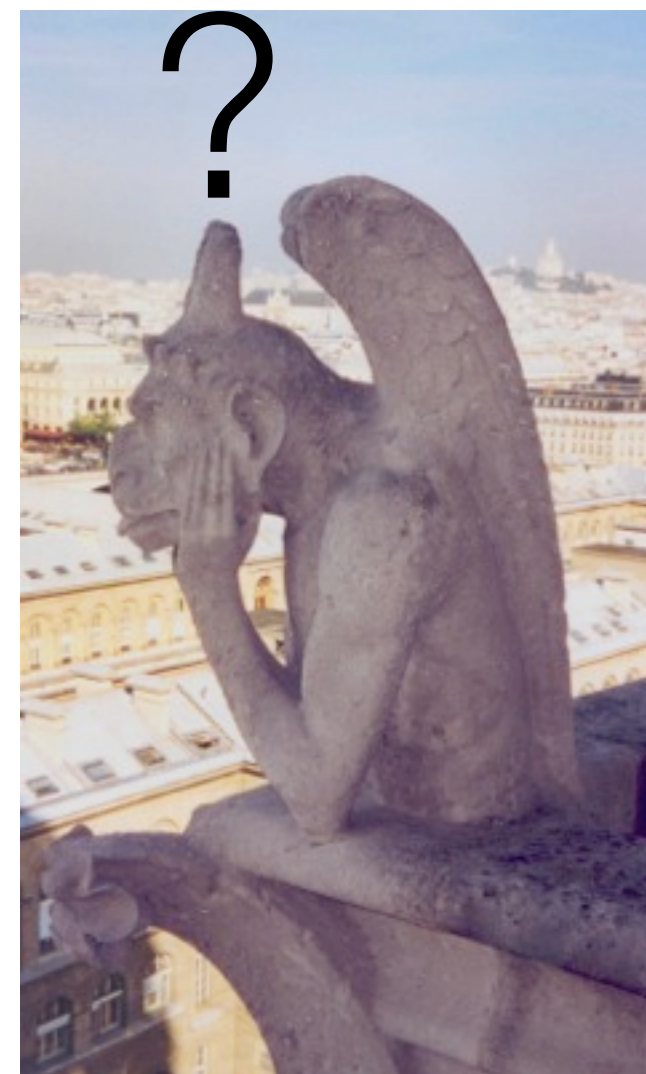


What is this sound ? Listen (3 times)



What is this sound ? Listen (3 times)

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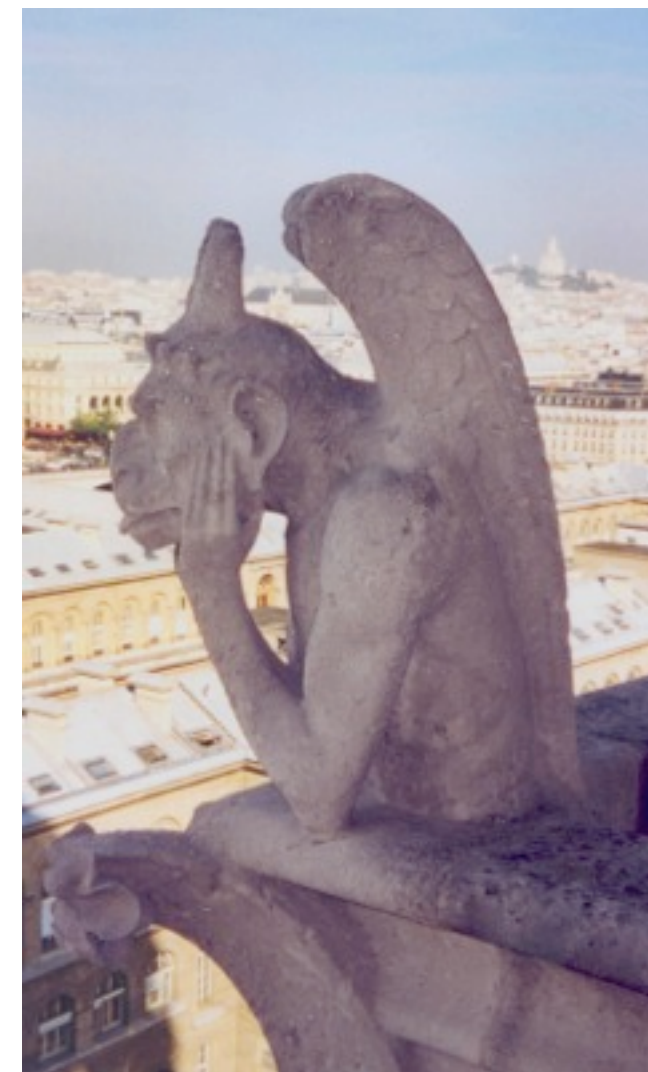
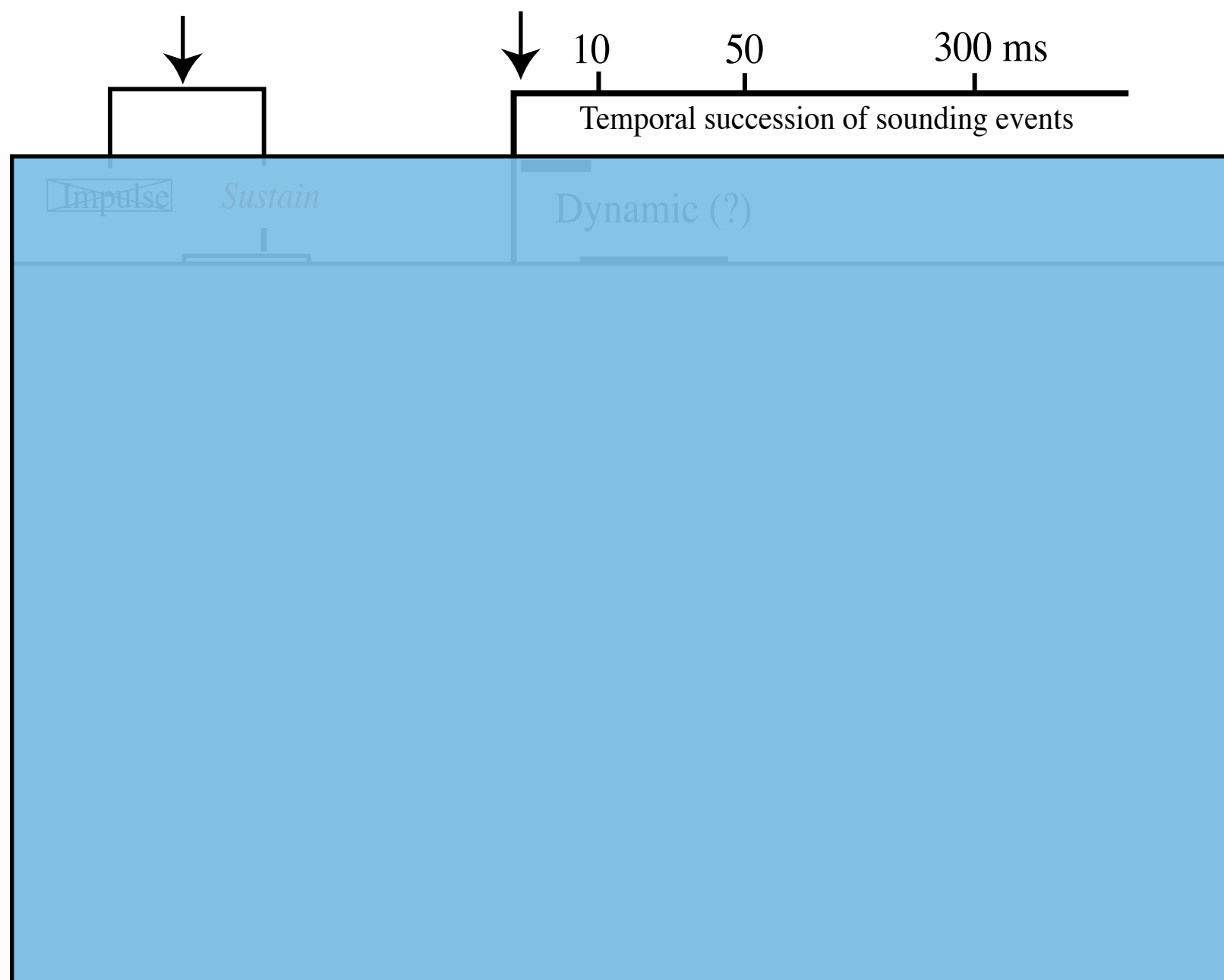
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A possible sequence of mental operations that allows us to identify the sound

Categorization

Sound characteristics of categorization



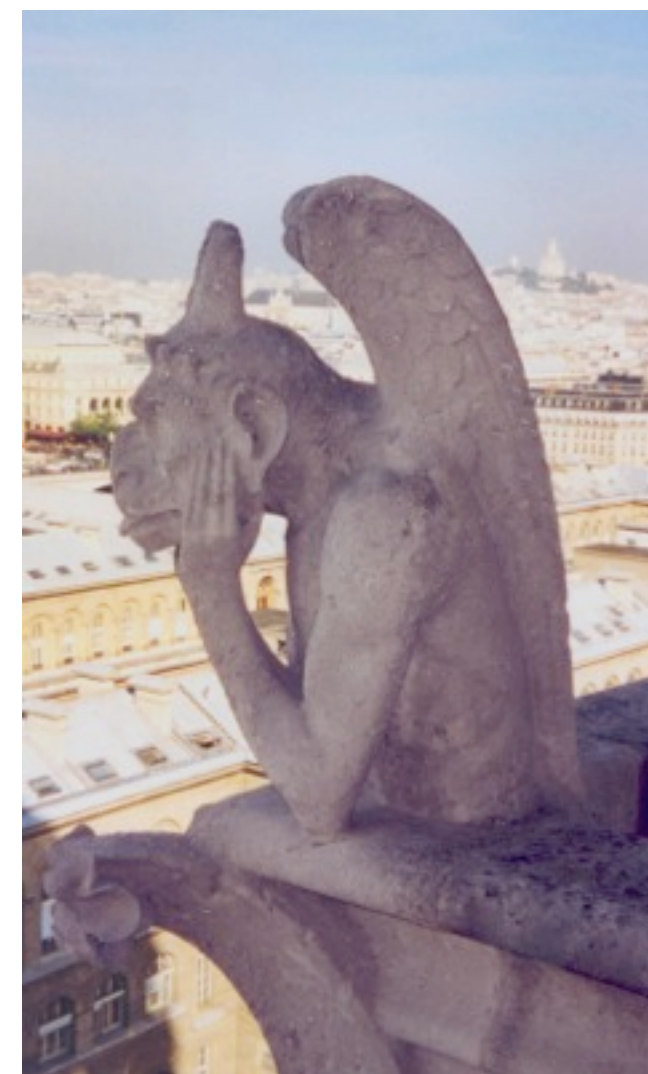
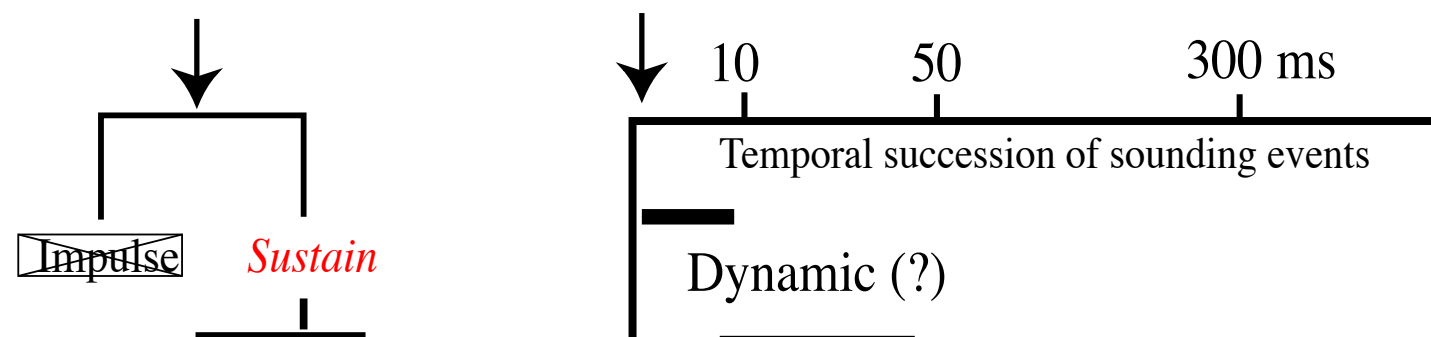
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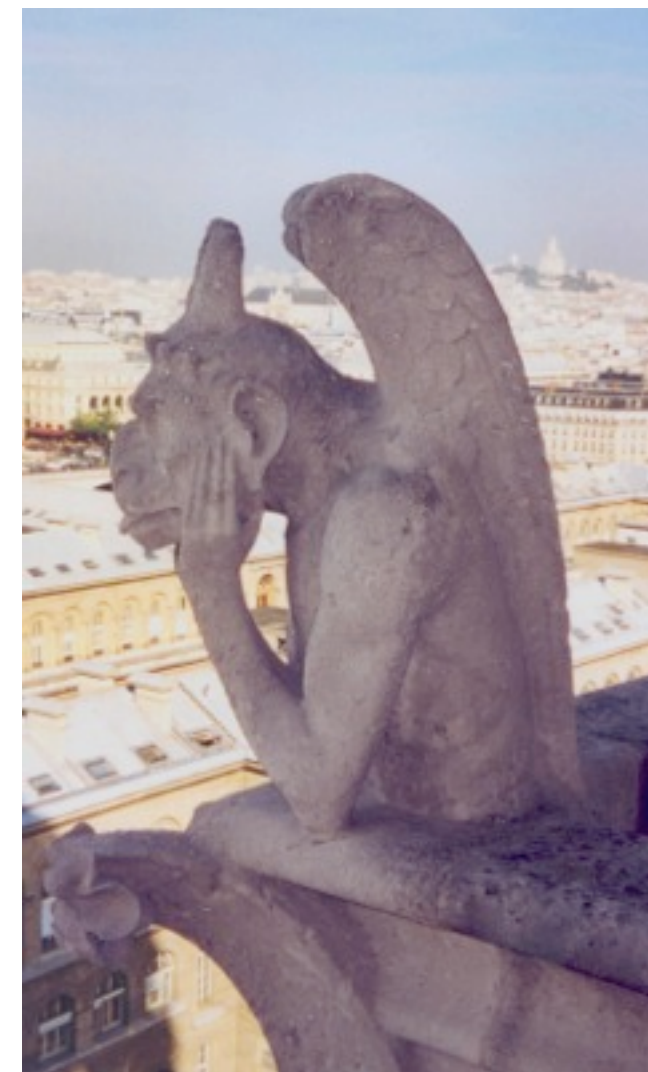
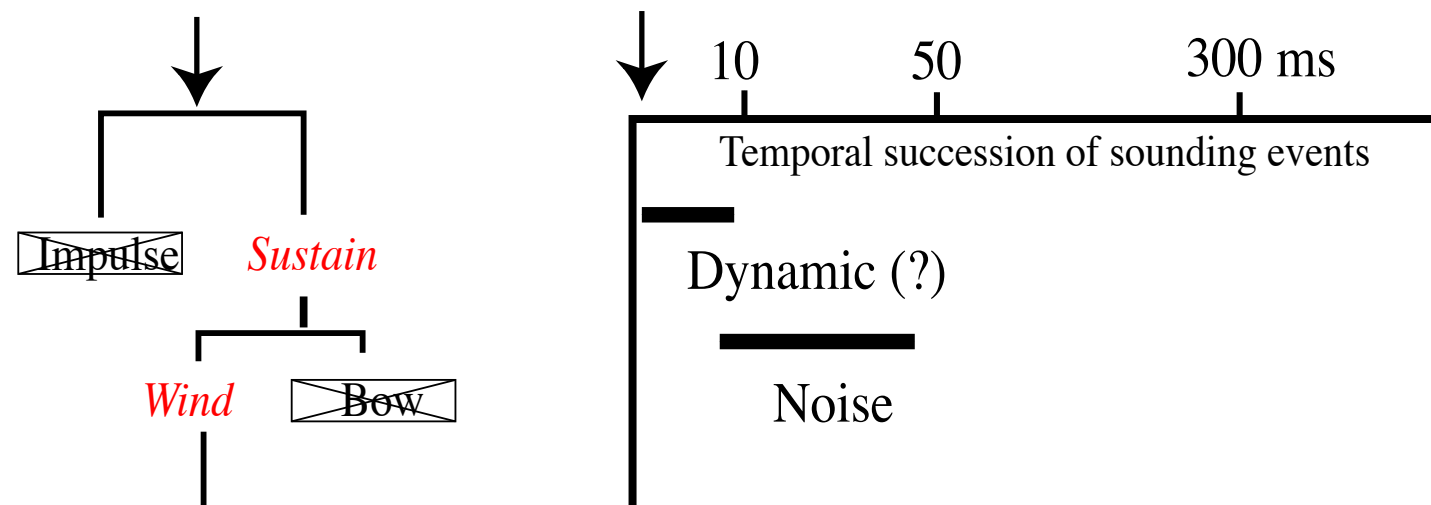
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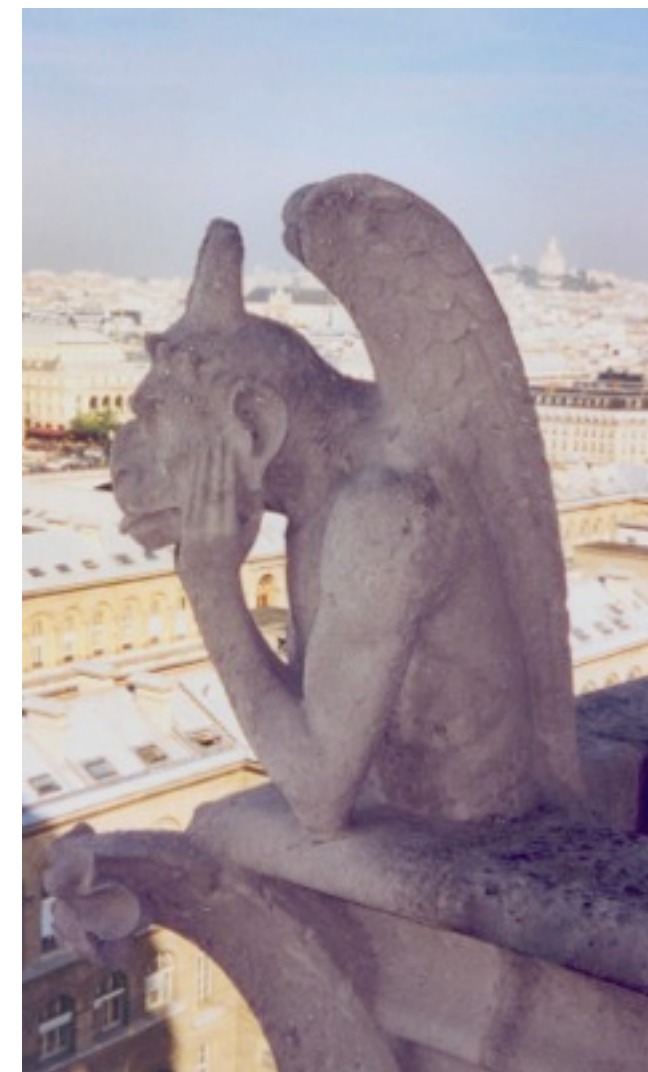
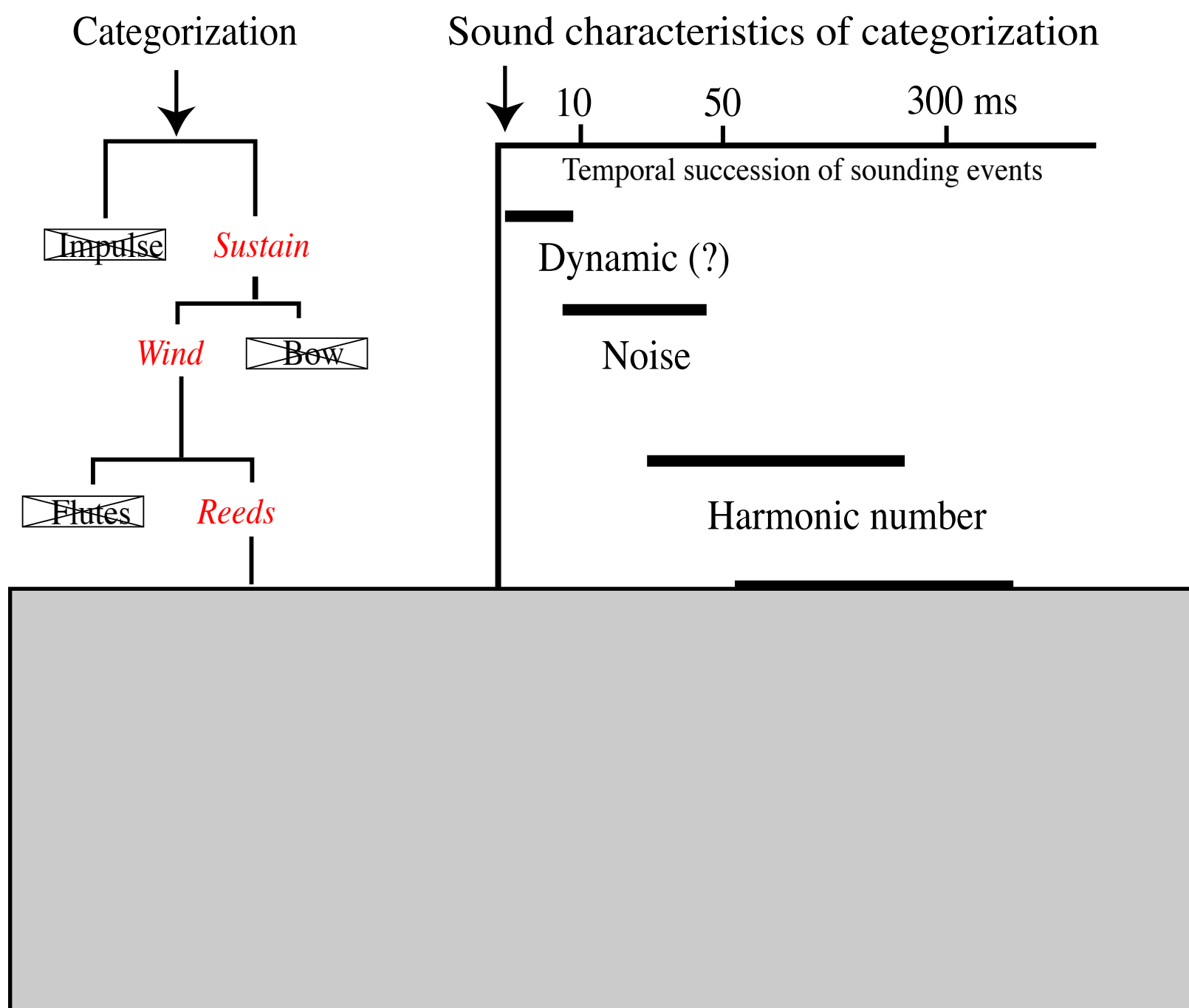
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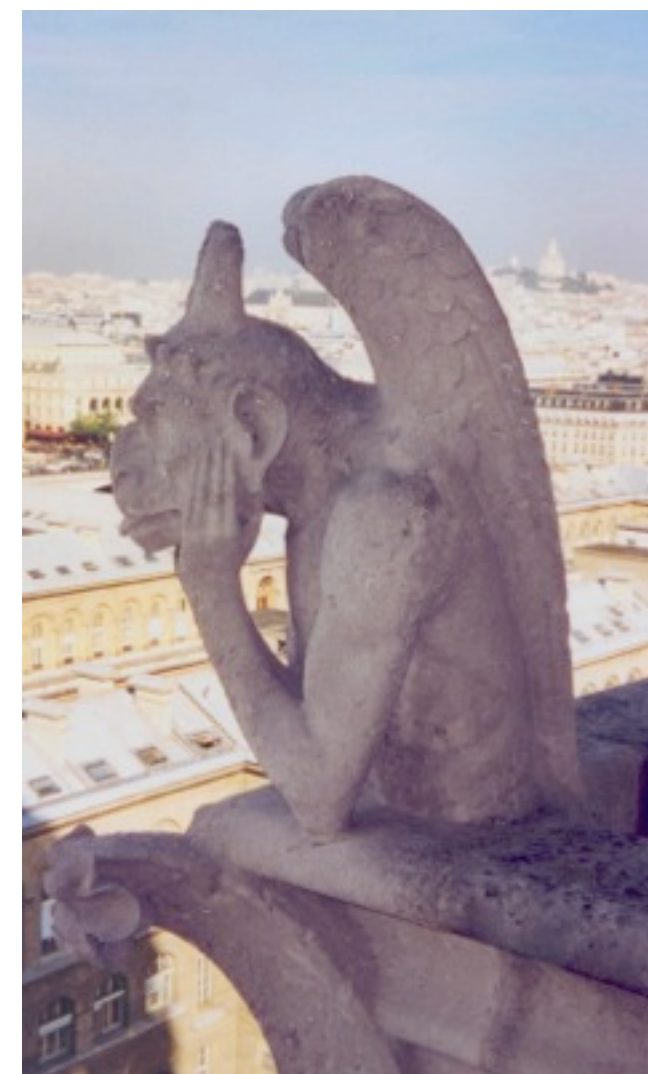
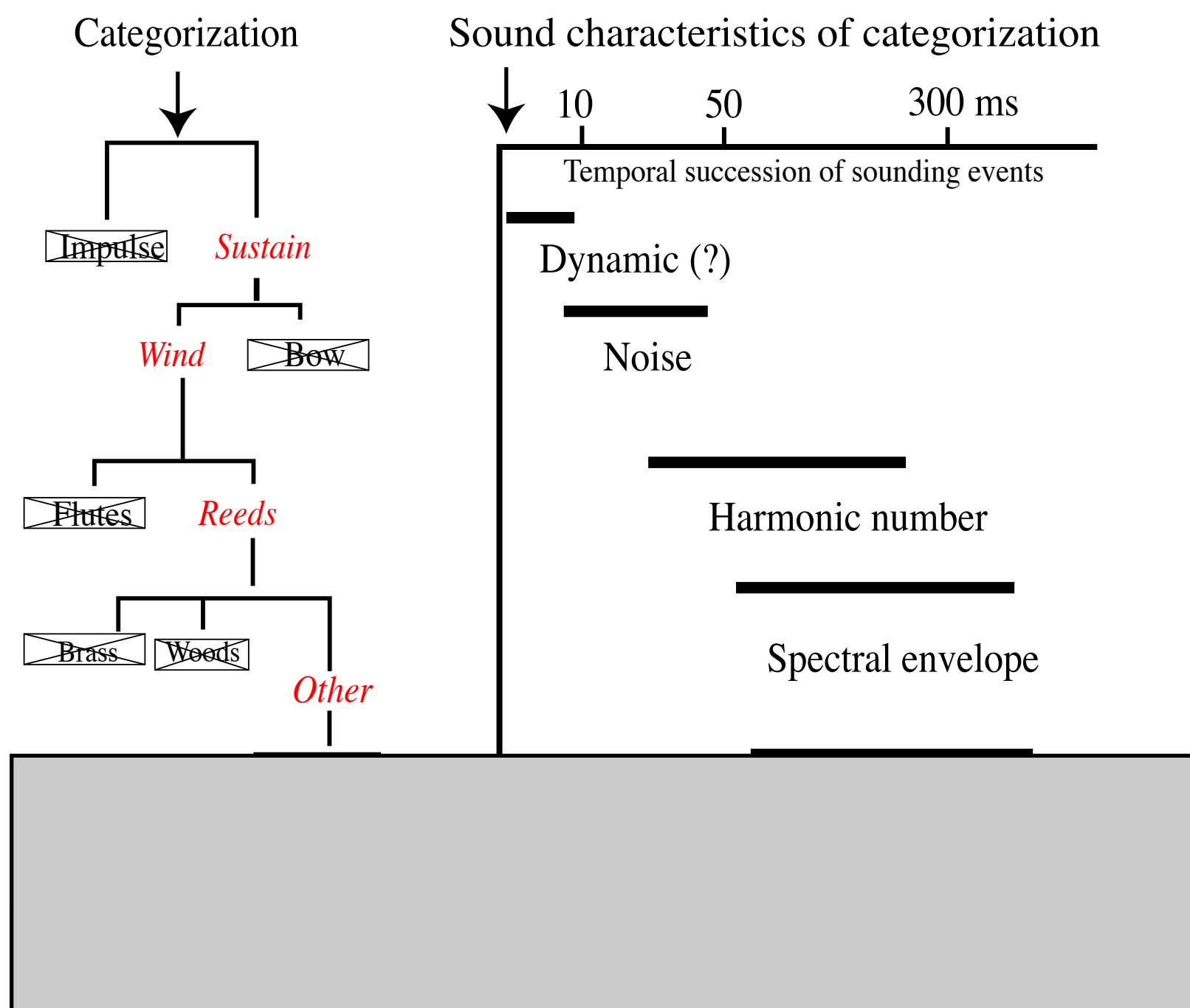
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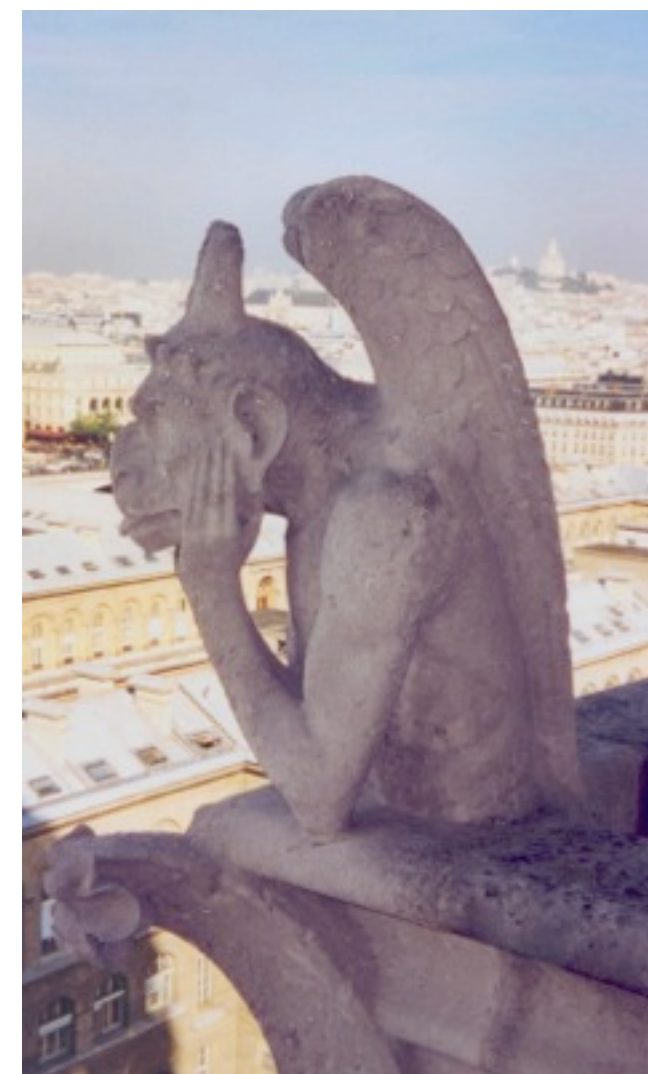
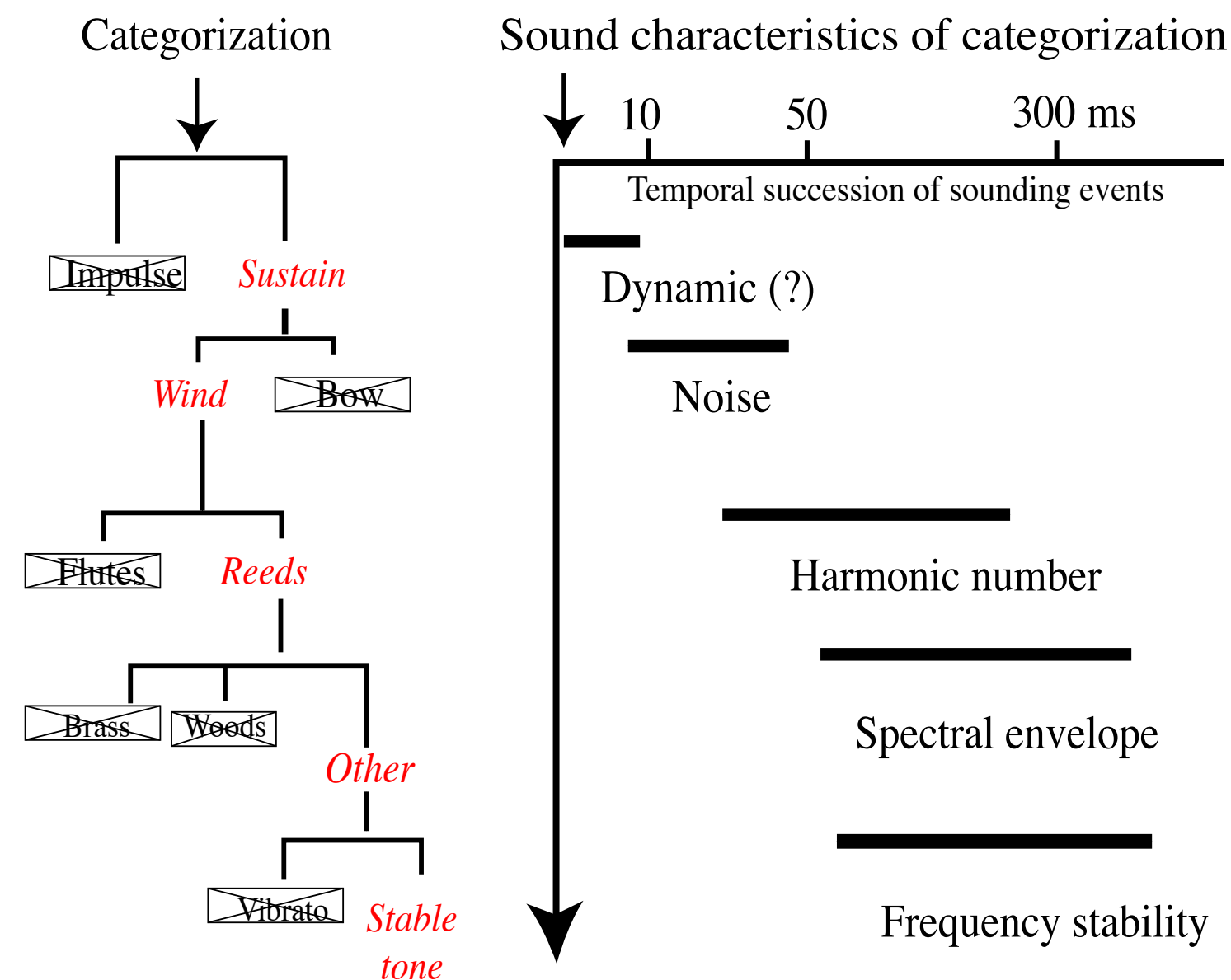
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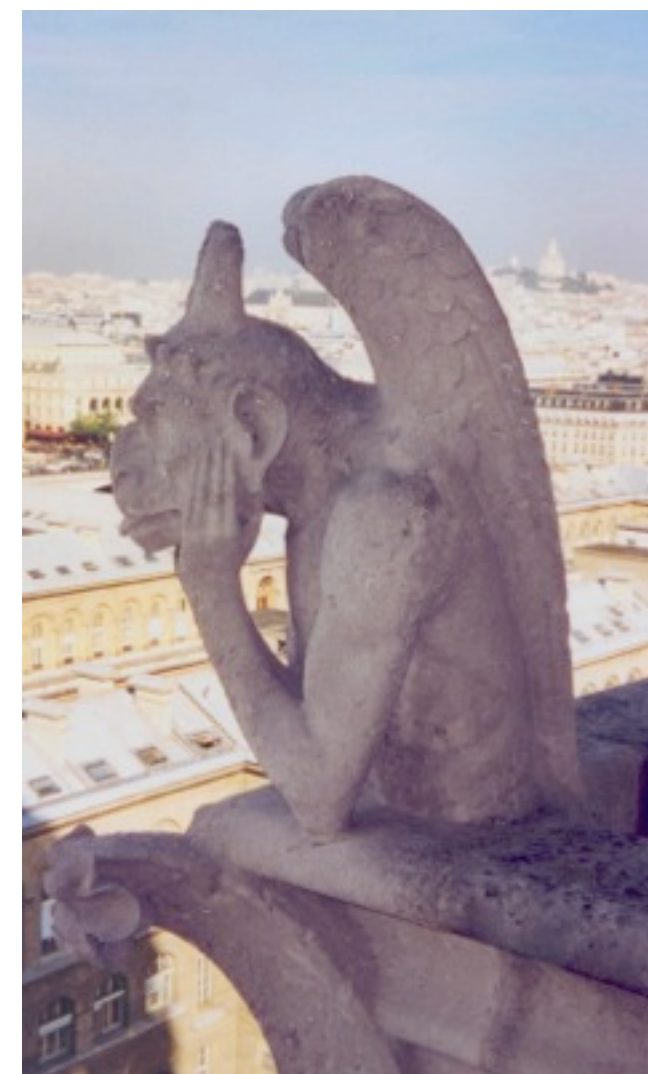
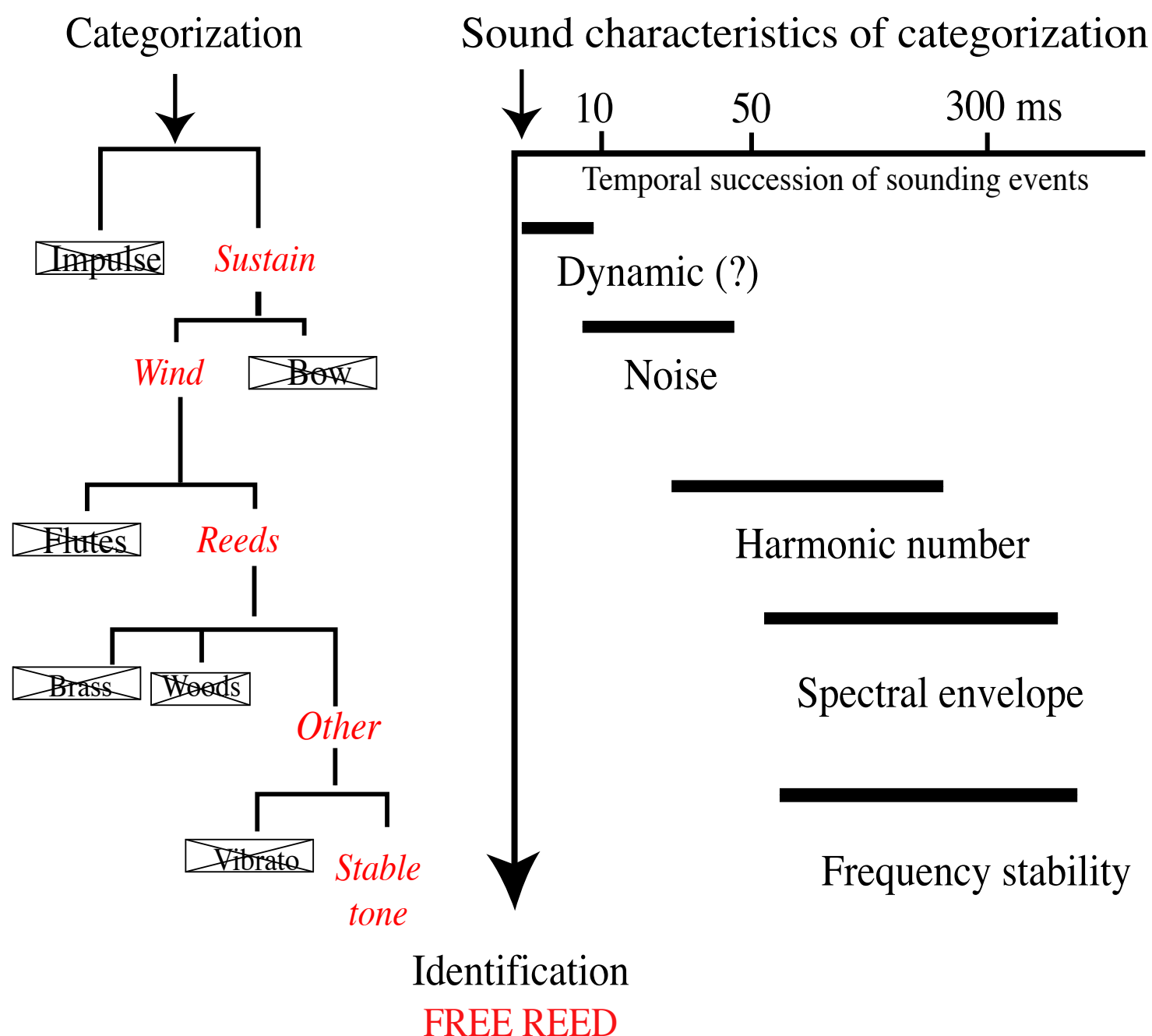
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A possible sequence of mental operations that allows us to identify the sound



Identity timbre

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Gestalt

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Gestalt

On this basis, I propose to give an analysis of some musical instrumental sounds



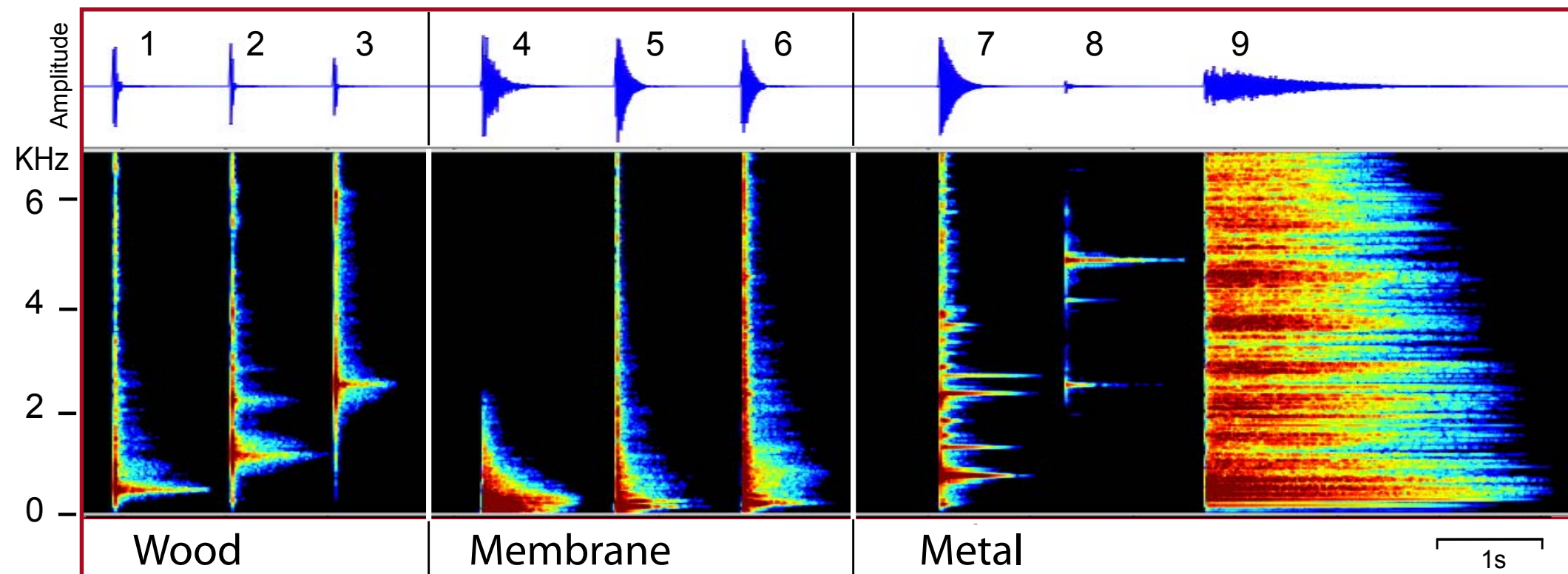
AN ACOUSTICAL EXPLORATION OF INSTRUMENTAL SOUND SOURCES

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PERCUSSIONS FIRST

Unpitched percussion instruments : the timbre is the sound of the stricken object as a whole.

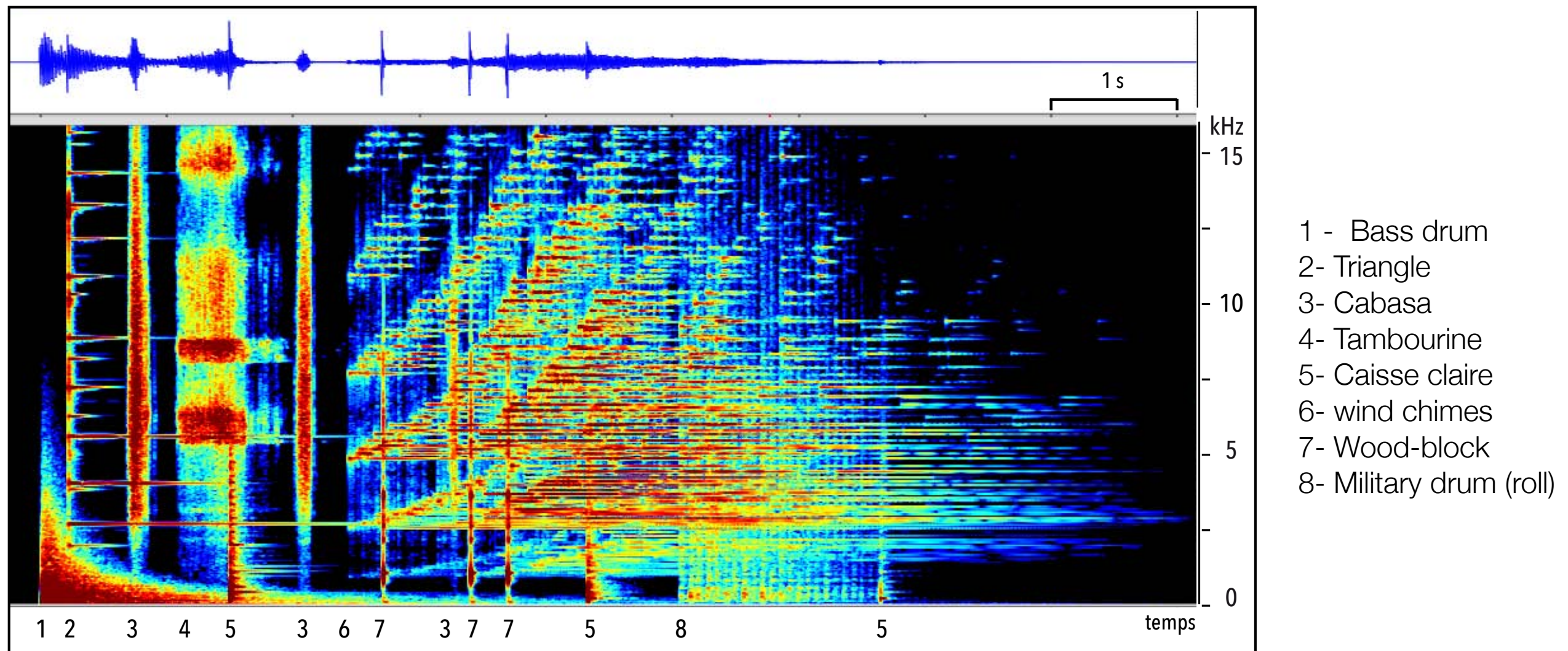
- The material the instrument is made of determines both sound duration and spectral bandwidth
- Three categories : wood, membrane and metal, of roughly three different sizes to produce low, medium and high sounds (spectral pitch : tonotopic coding)



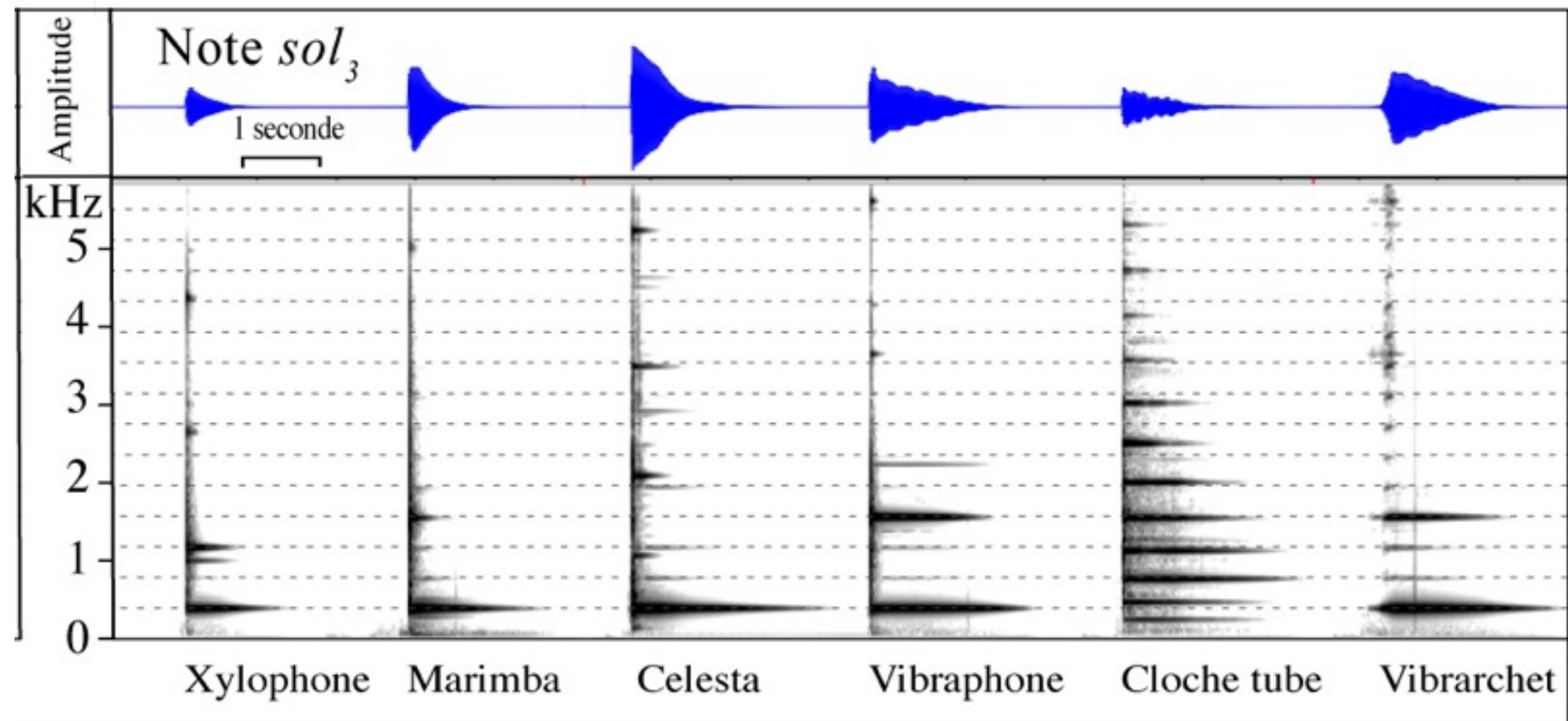
Each sound is a pattern, a Gestalt : «it has a very strong centrifugal force» said Boulez (1984)

You can't blend different percussion instruments.

Unpitched percussion instruments are easy to identify on a spectro-temporal analysis.



Pitched percussion instruments; what do we hear: the pitch (note) or timbre?

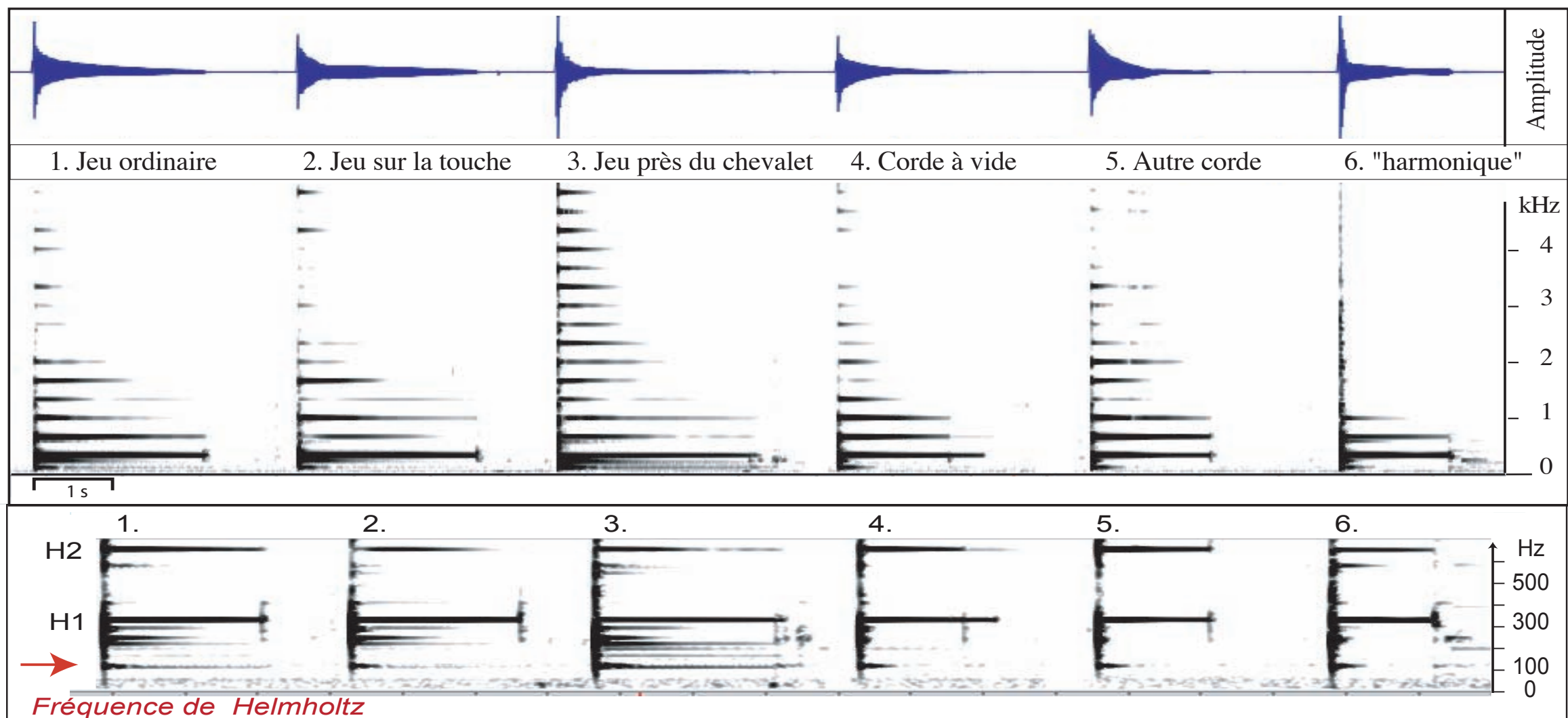


- Marimba (wood), tympani (membrane), vibraphone (metal) give tuned pitch.
- The striking point is imposed by the desired pitch.
- Pitch and sound quality are not fully independent of each other

Percussion instruments: the plucked strings

Relations between timbre and pitch become complex

Guitar : there are different «timbres» for one pitch



Sustained instruments: winds, strings, (voice)

We enter a new sound world

- Sustained instruments open a large field for timbre where coexists:
 - the instrumental timbre (identity timbre)
 - and the pitch timbre (quality timbre) which may vary during the time course
- According to my propositions, the study of sustained instruments timbre implies that we select sounds which are immediately recognizable.

An informal test of sound instrument recognition

- select typical sounds representing the main sustained sound instruments categories.
- 120 isolated sounds extracted from 4 sound-data bases (Mc Gill; RWC; Iowa; Orchidee).
 - Two pitches (60 C4 sounds, 60 A4 sounds), various intensities, with or without vibrato, different durations.



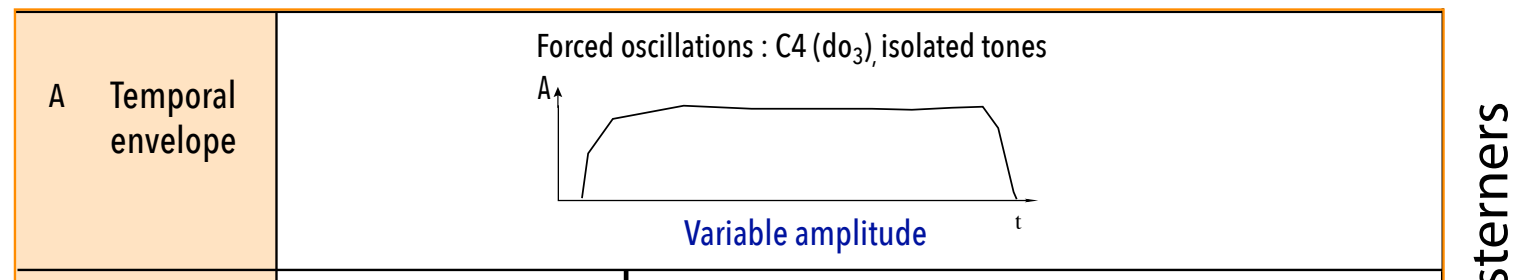
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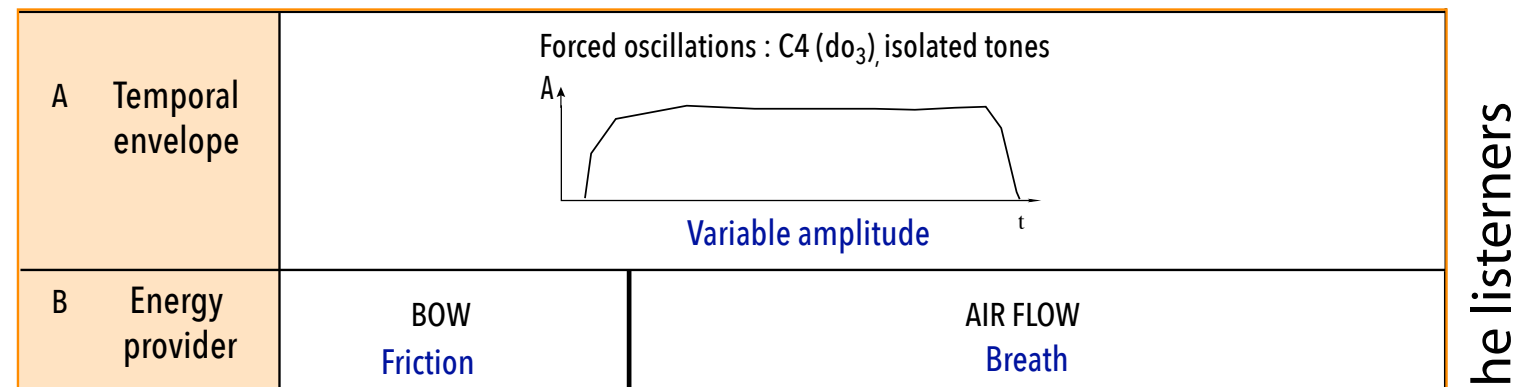
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 - 13 listeners (6 good musicians, 7 persons without musical knowledge); different listening conditions (headphone, H.P.)
- Instruction : listen to the sound one time and write down quickly the name of the musical instrument; then, listen to the following one, and so on. If the instrument is not recognized, skip it.

Results : a hierarchical categorisation based on acoustical features



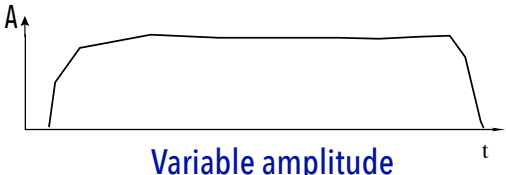
- 5 general categories of musical instruments sounds that all listeners are able to distinguish. **Note that flute family is clearly distinct from the other woods.**
- Only expert musicians are able to recognize the 7 sub-categories, with some errors (horn and trombone ; saxophone and clarinette)

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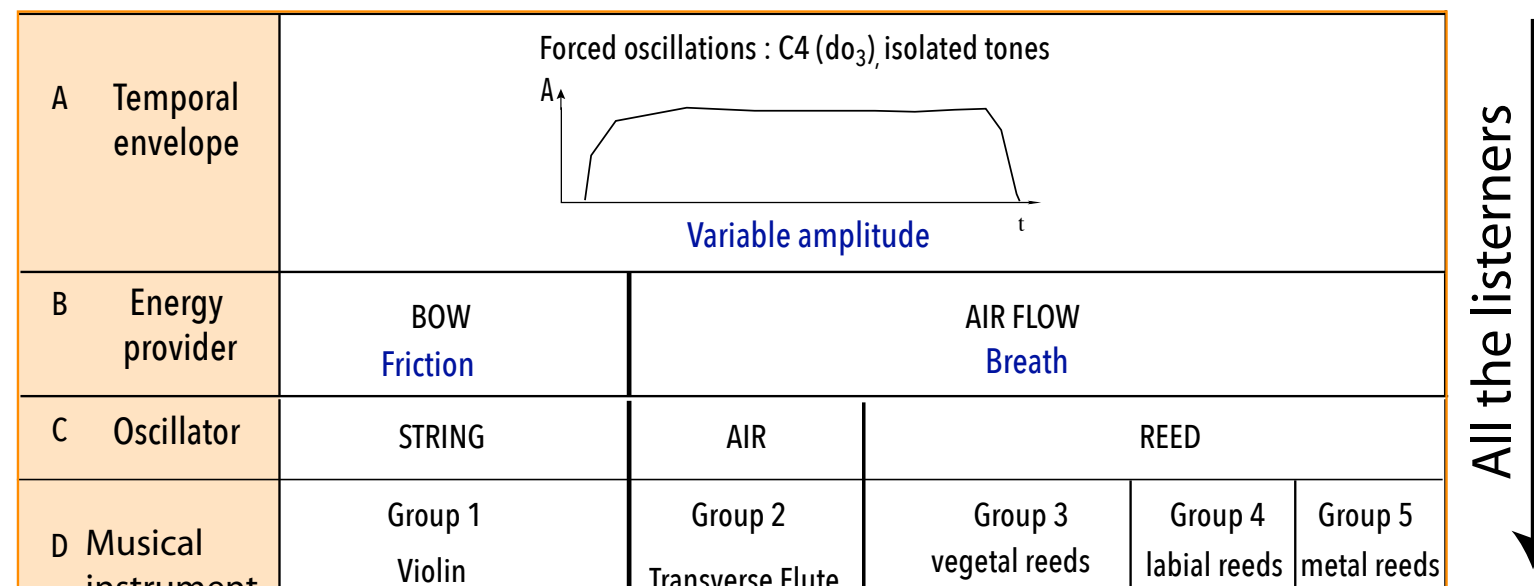
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A Temporal envelope	<p>Forced oscillations : C4 (do₃), isolated tones</p> 		
B Energy provider	BOW Friction	AIR FLOW Breath	
C Oscillator	STRING	AIR	REED

All the listeners

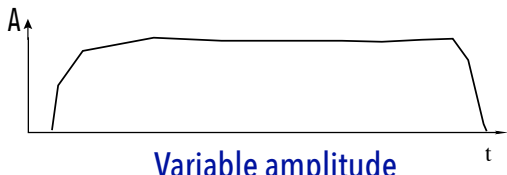
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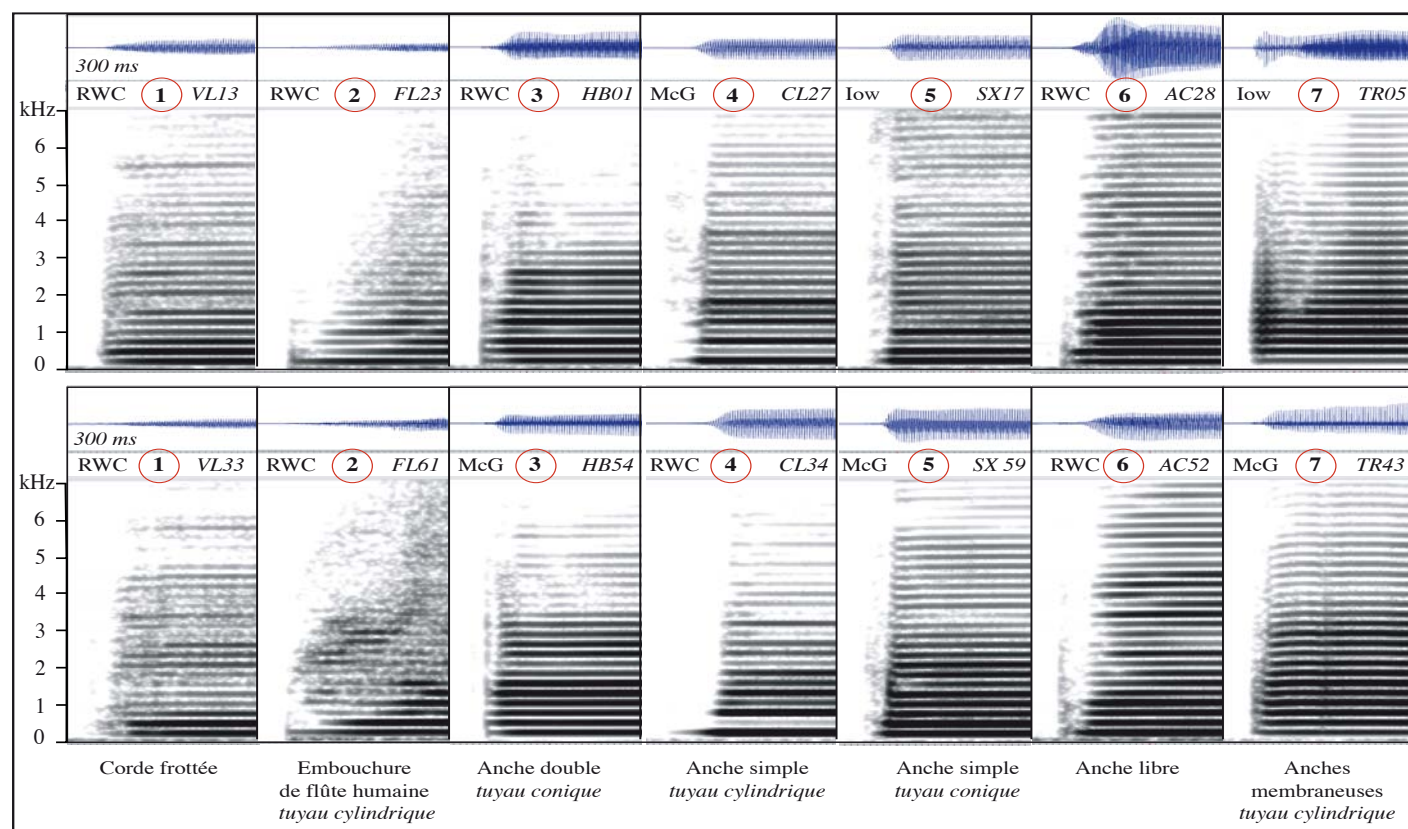
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B	Energy provider	BOW Friction		AIR FLOW Breath						
C	Oscillator	STRING		AIR	REED					
D	Musical instrument	Group 1 Violin (or family)		Group 2 Transverse Flute (or family)	Group 3 vegetal reeds		Group 4 labial reeds			Group 5 metal reeds
					Ob Fag Cl Sax		Trpt Hrn		Acc	Experts only

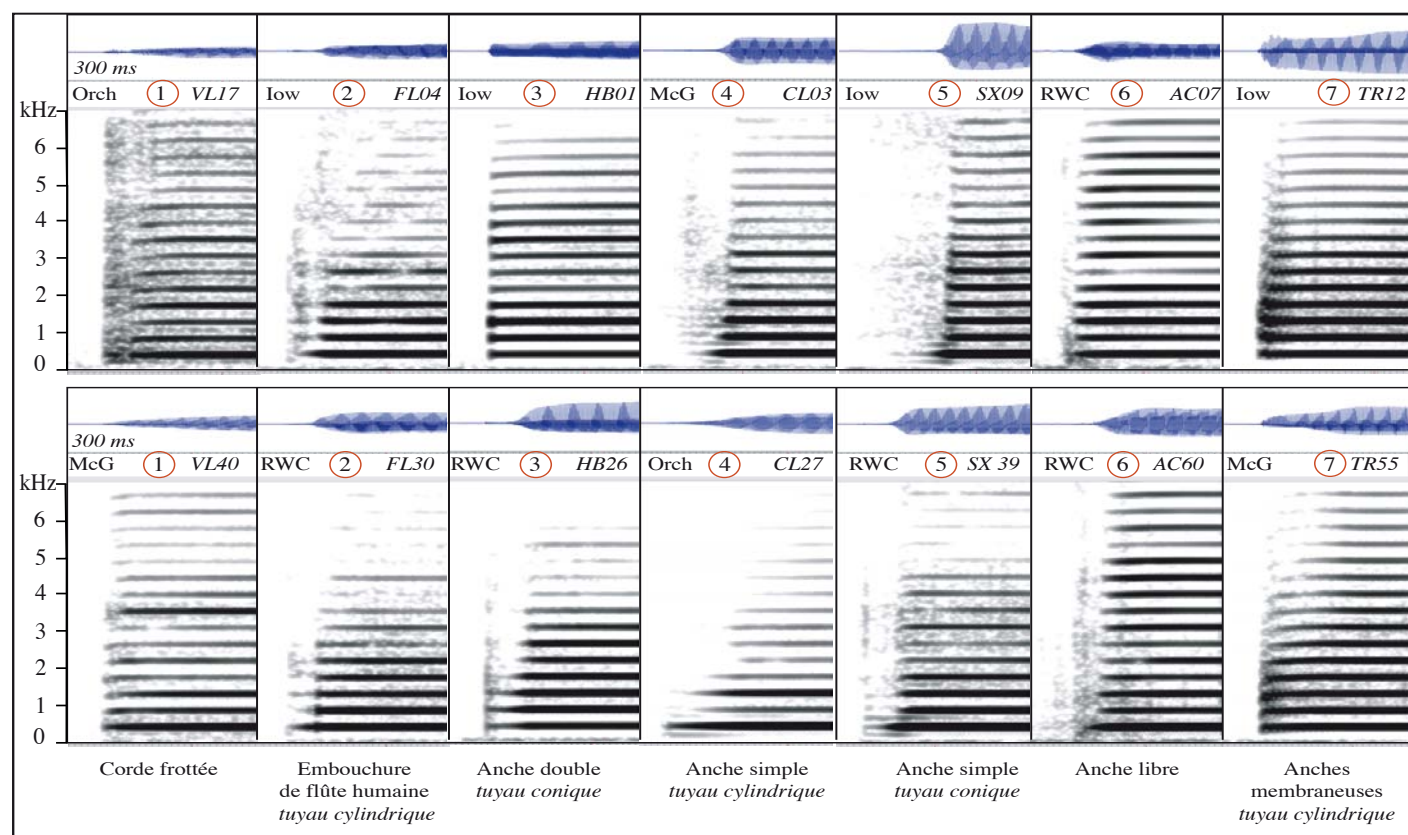
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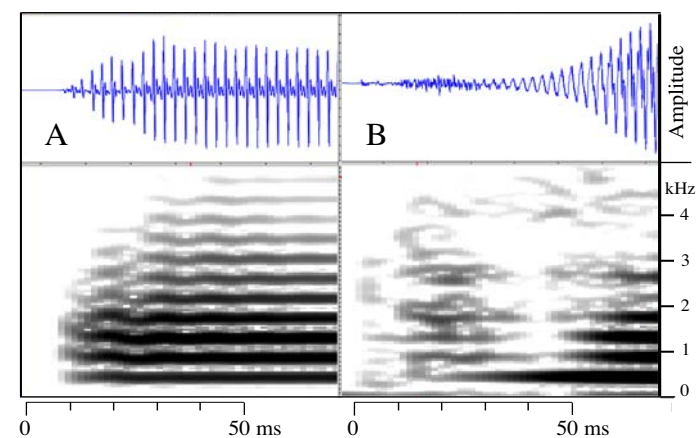
C4



A4



- The two tones, best recognized in each family are chosen for analysis.
- The analyses are focused on the very beginning of the sound (300 ms) to observe delay between noises and first harmonics; frequencies oscillations and other wellknown transients characteristics.
- Ex: temporal zoom on brass and flute typical transients.



A4 (la3) - Iowa TR12 and Iowa fl04

VARIABILITY

Sound variability with time: the acoustician nightmare

«C'est la variété qui rend le son agréable et s'il n'est varié, il mérite plutôt d'être appelé bruit que son harmonique»

Variability is what makes sound pleasant; and if it does not vary it deserves to be called noise rather than music (translation S.G.)

Marin Mersenne, 1636, Harmonie universelle.

*The most musically significant thing about sounds, timbral objects, is not that they are recognizable, identifiable, nor that they are multidimensional wholes, individual and various: it is that they exist in time, have a shape in time, exhibit changes during their time course, and still retain their identity.**

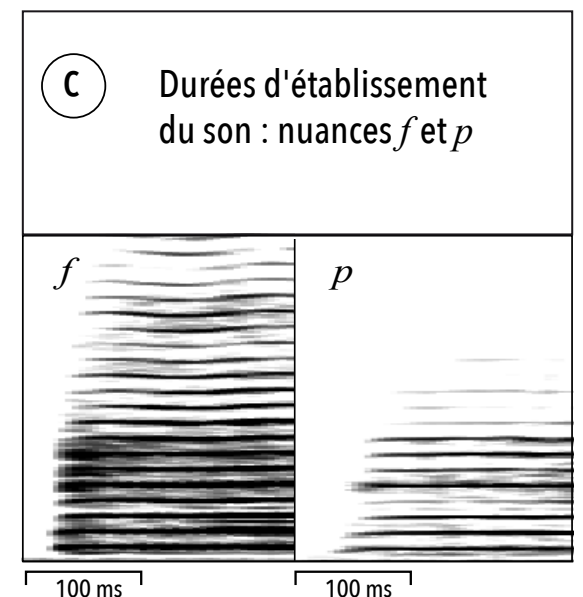
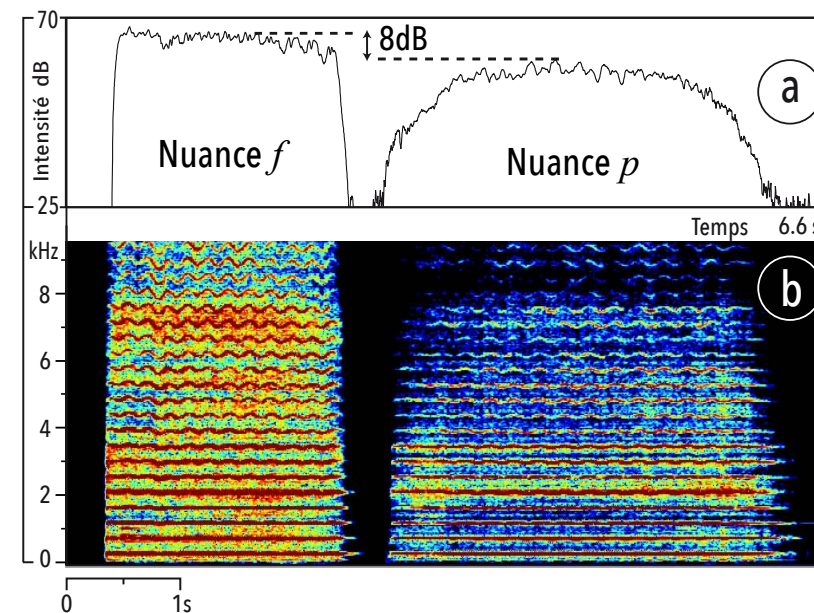
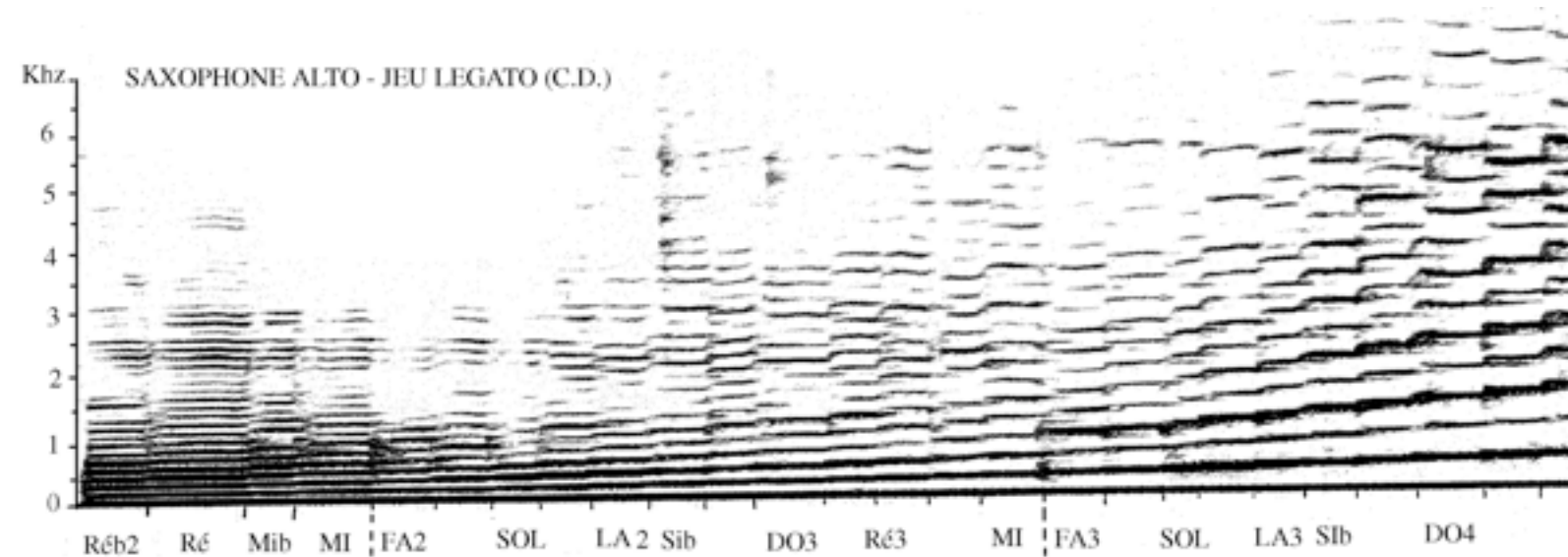
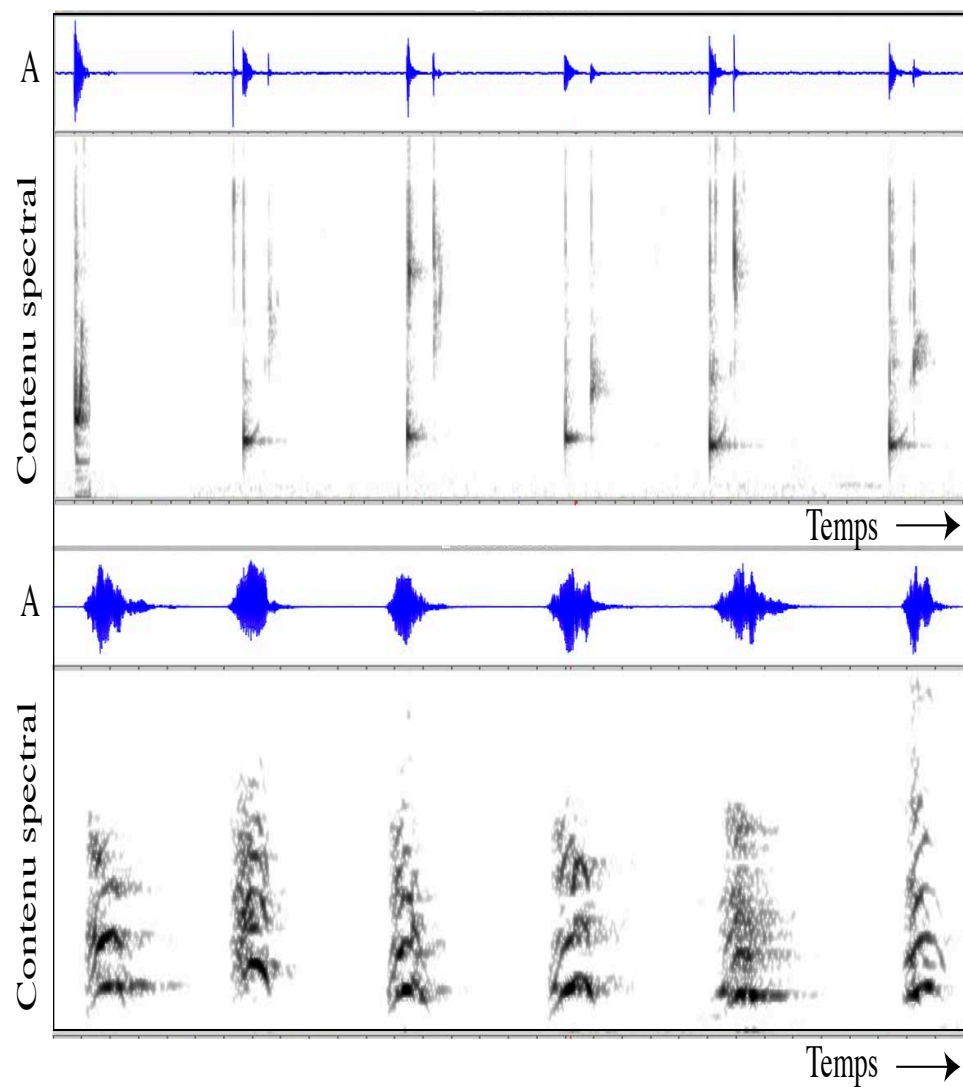
Robert Erickson, 1975, Sound structure in music ; University of california press, p. 58.

(*A common behaviour of natural sounds)

The problem of variability

- The study of the identity timbre of an instrument requires the exploration of all the sound variations in order to express them in terms of «laws» of variation which are specific of a sound source category.
- The human listener learns to forget these variations in order to elaborate a prototype of the identity timbre of an instrument: a spectro-temporal pattern (Gestalt) which remains unaffected by transformations and anamorphosis

Gestalts of droplets, dogs and musical sounds



Sound variability with tessitura, and with the player

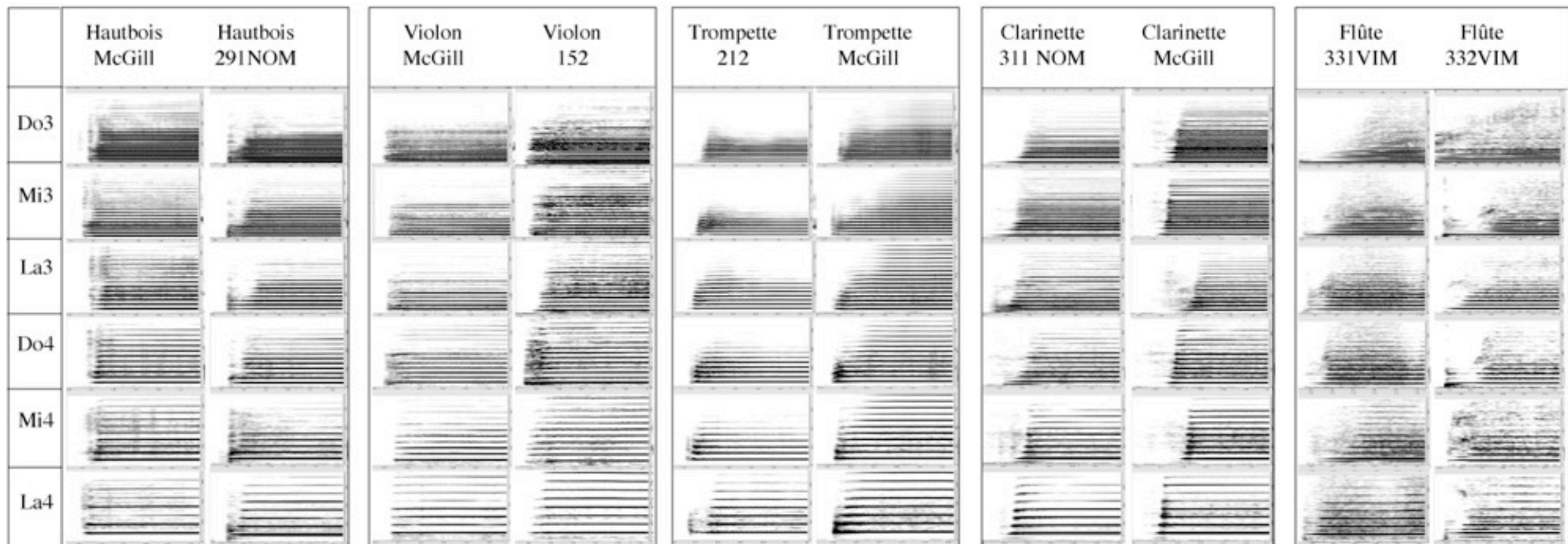
Oboe

Violin

Trumpet

Clarinet

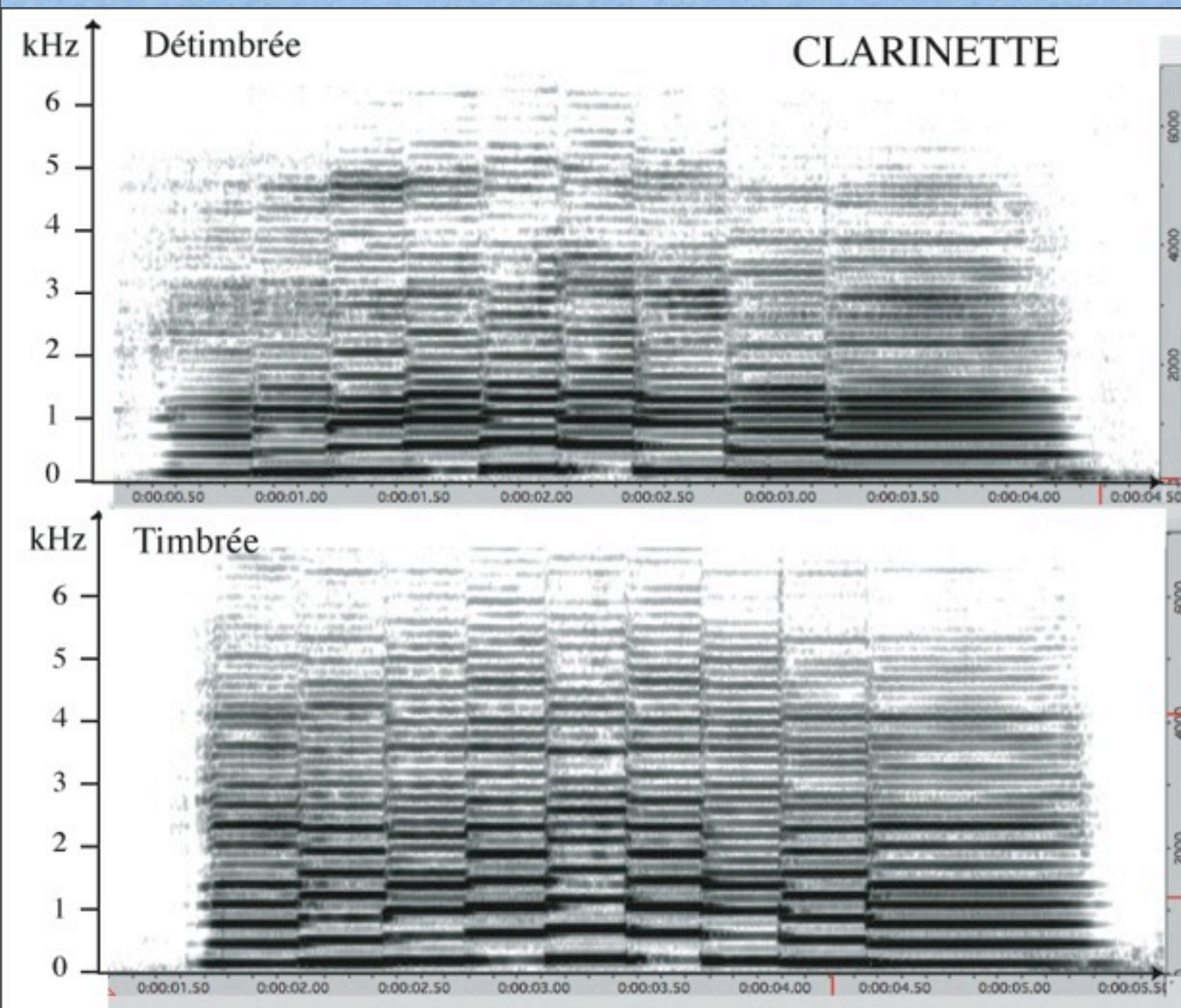
flute



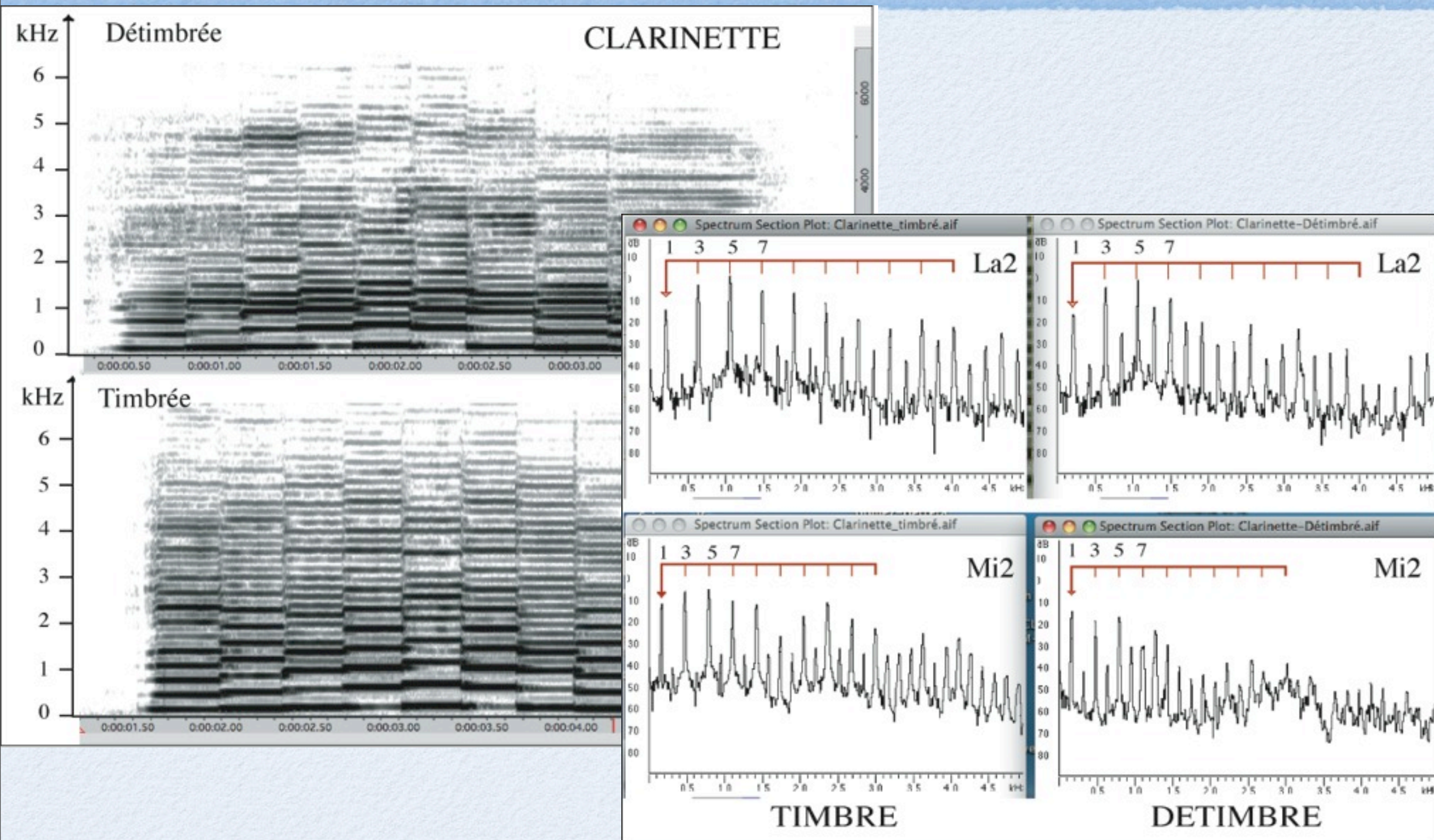
THE WORDS TO SPEAK ABOUT
SOUND
THE FRENCH EXPRESSION
«TIMBRÉ»

CLARINET TIMBRÉE-DÉTIMBRÉE

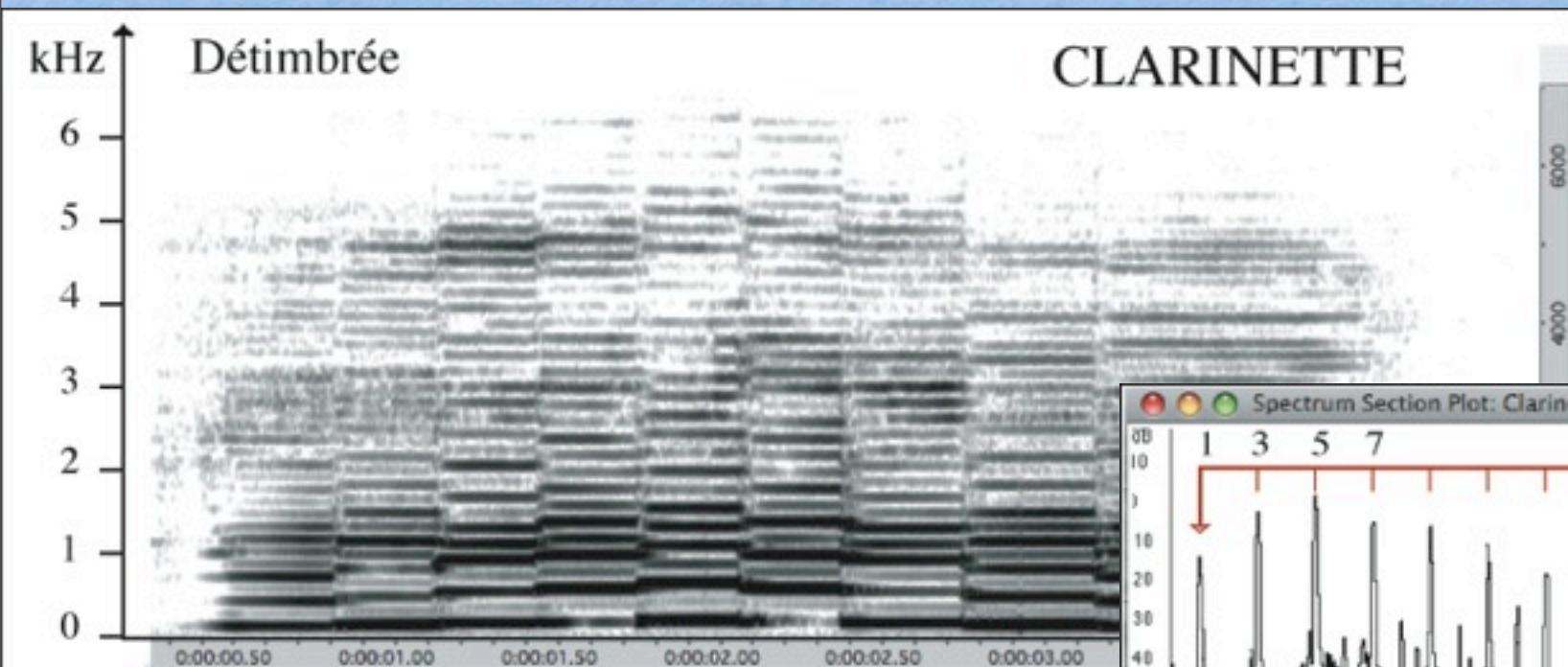
CLARINET TIMBRÉE-DÉTIMBRÉE



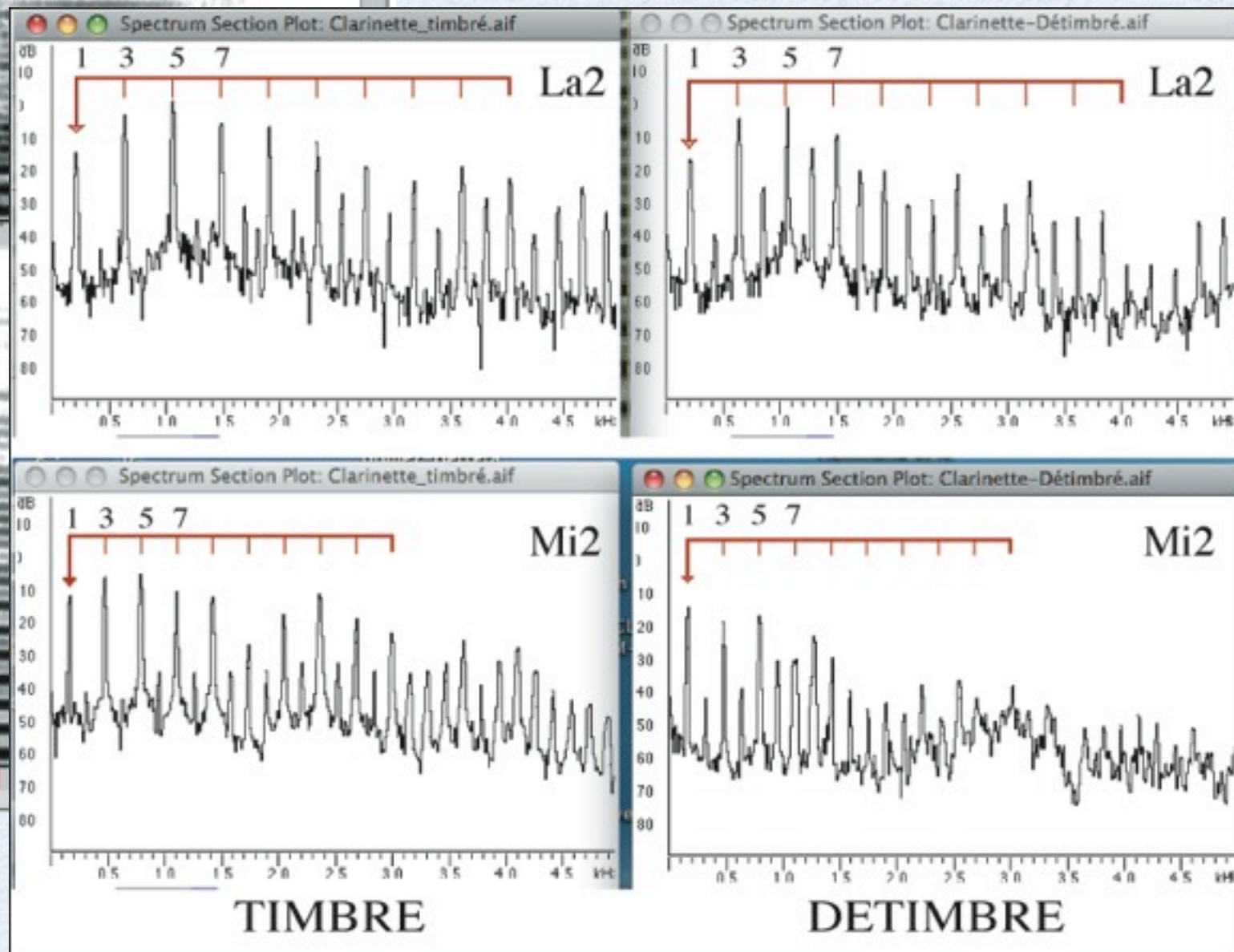
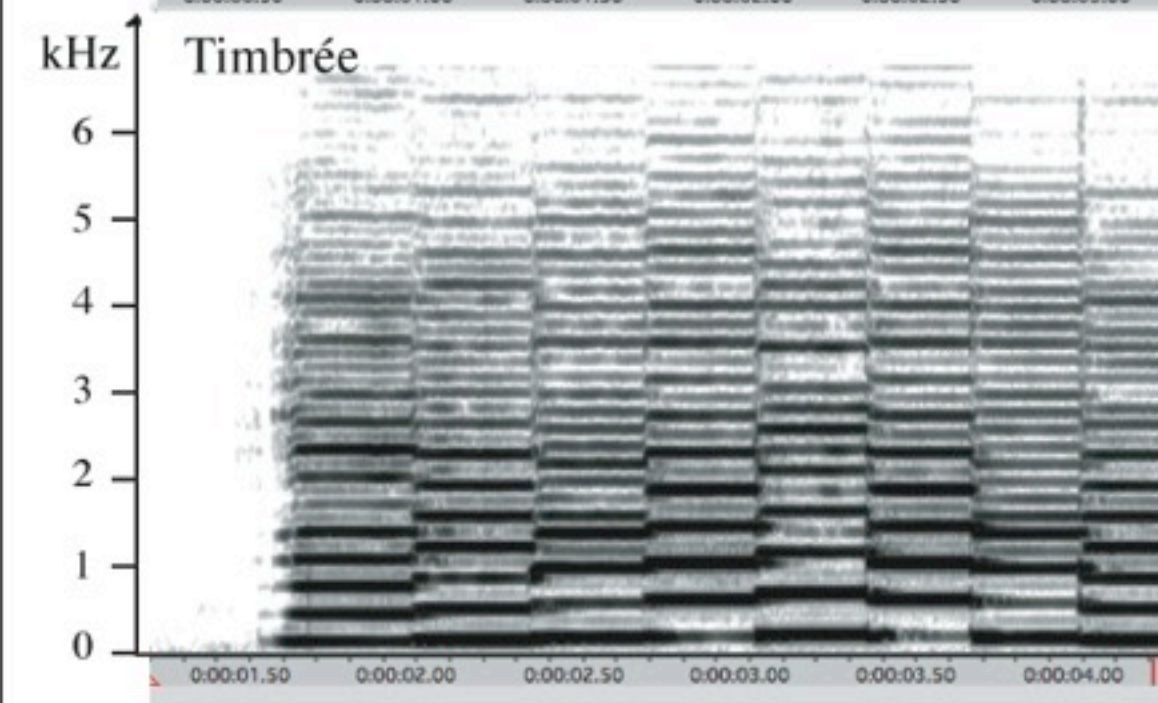
CLARINET TIMBRÉE-DÉTIMBRÉE



CLARINET TIMBRÉE-DÉTIMBRÉE

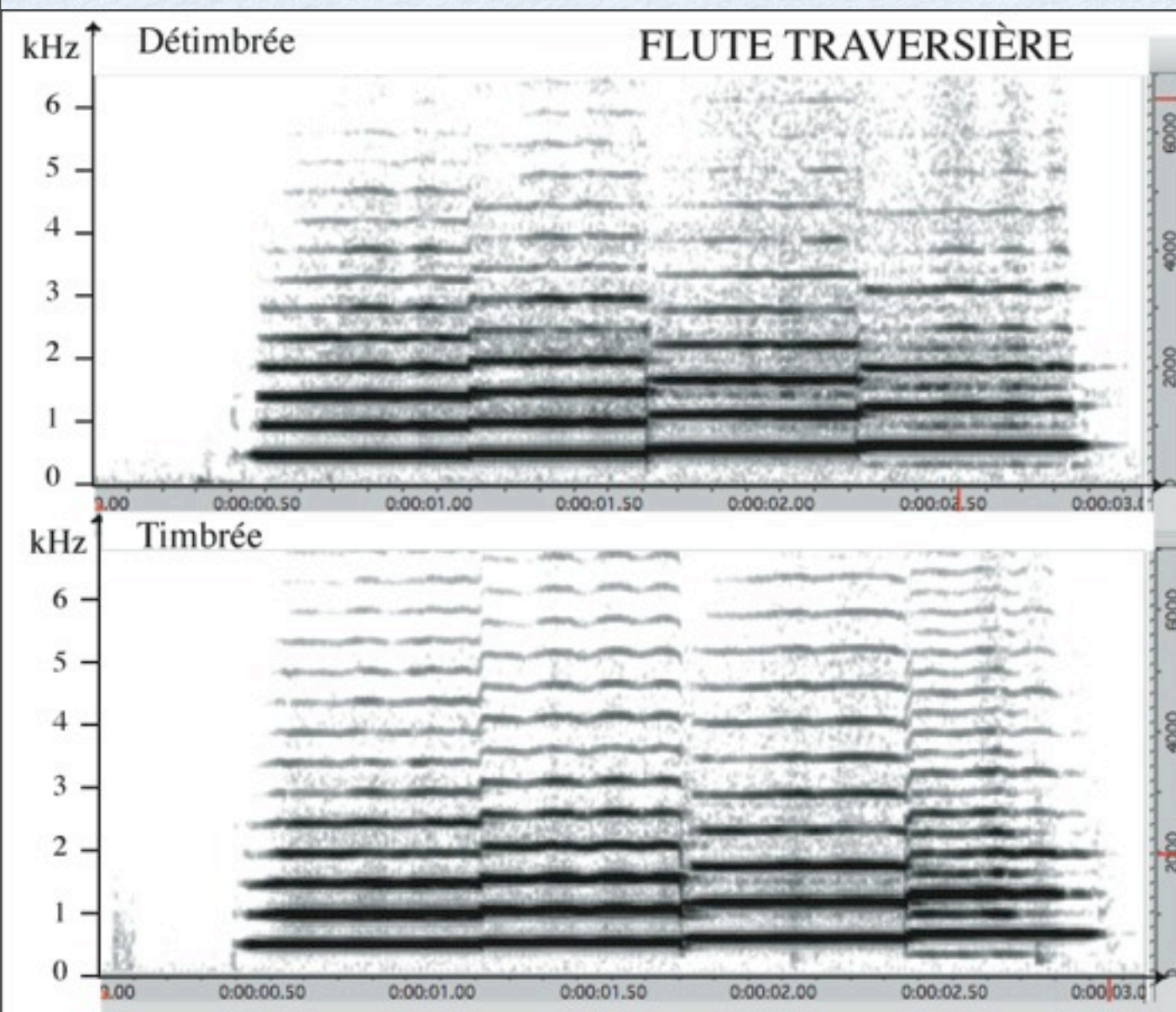


Timbré:
odd harmonics boosted
more harmonics

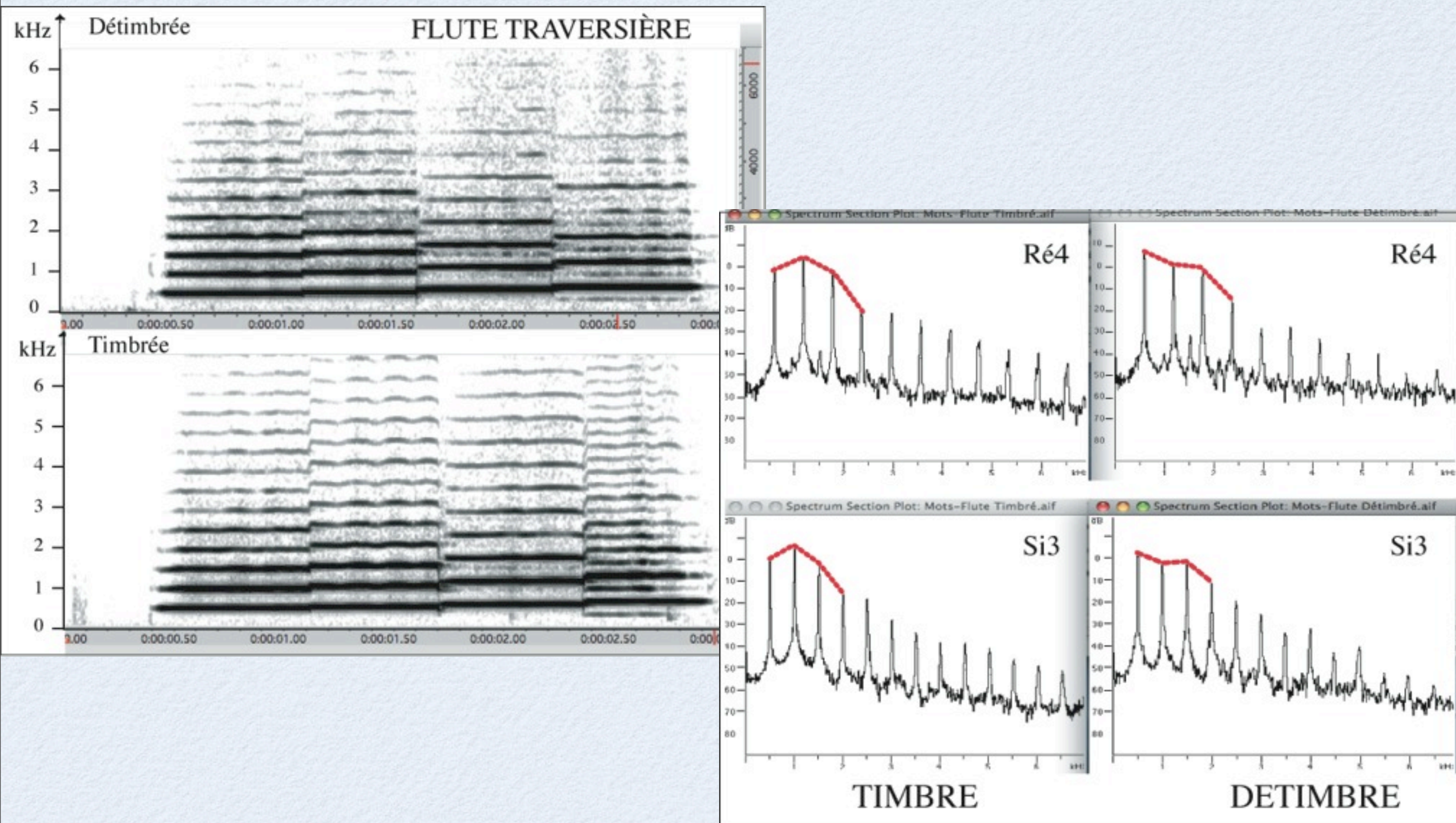


FLUTE TIMBRÉE-DÉTIMBRÉE

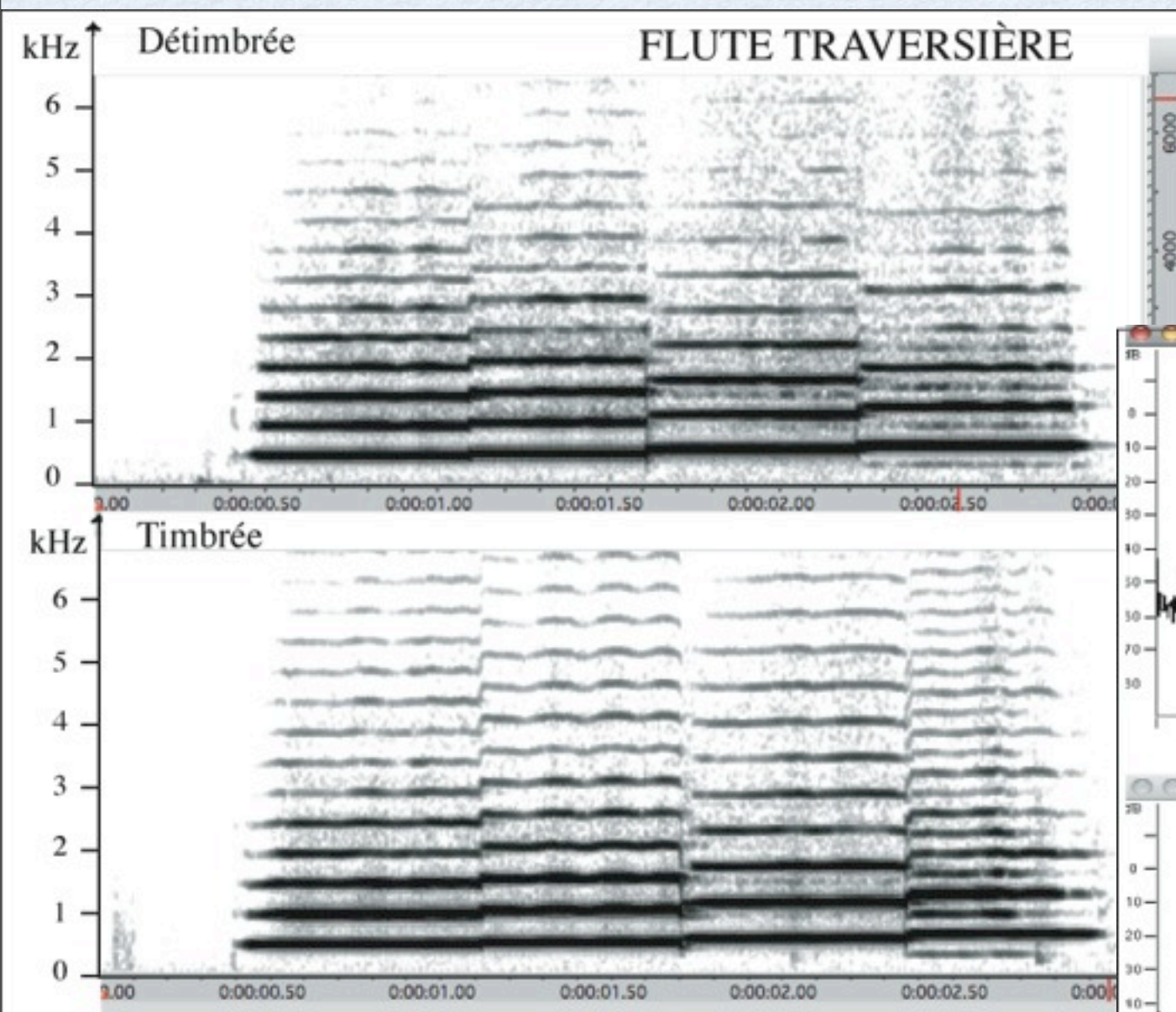
FLUTE TIMBRÉE-DÉTIMBRÉE



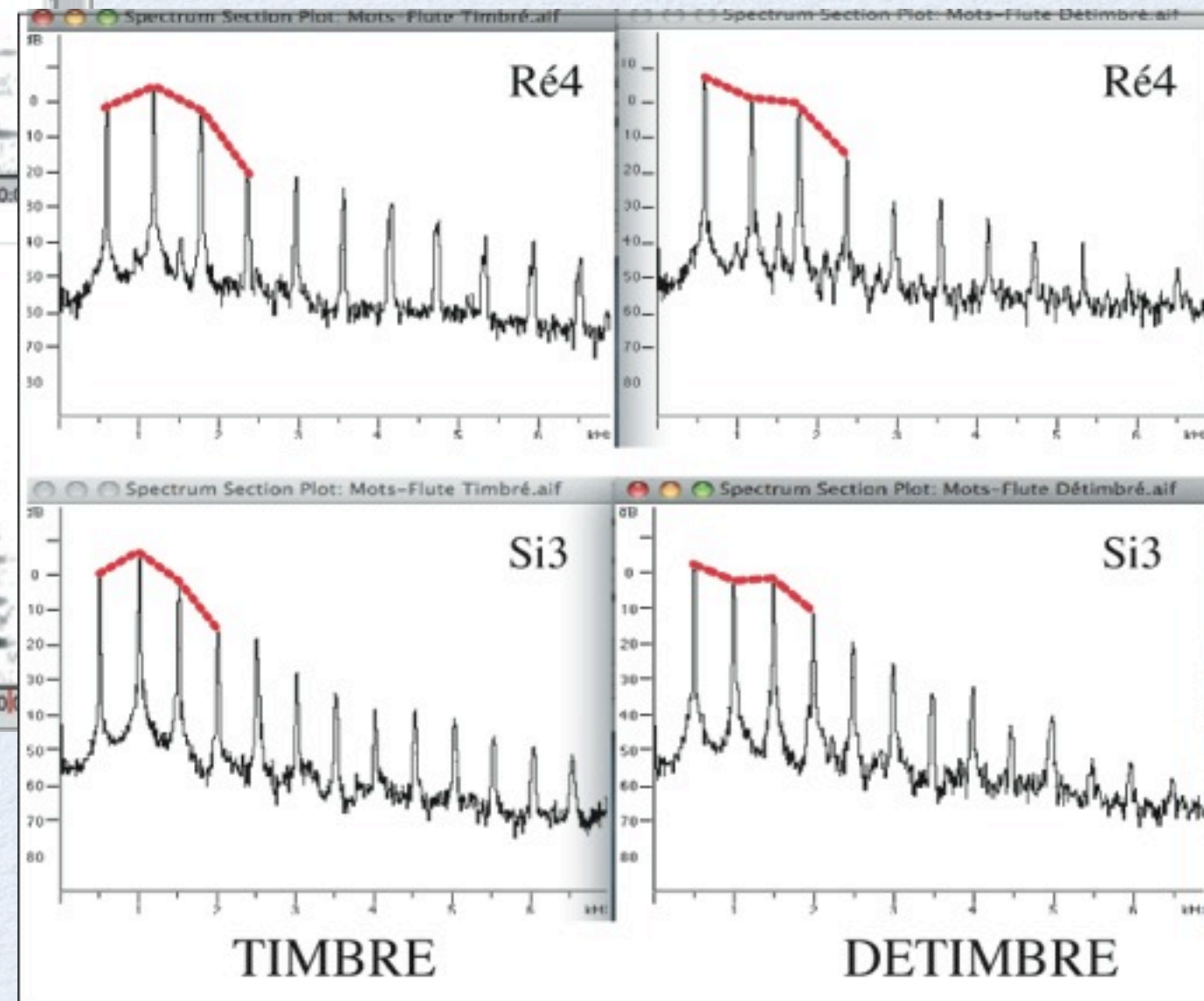
FLUTE TIMBRÉE-DÉTIMBRÉE



FLUTE TIMBRÉE-DÉTIMBRÉE

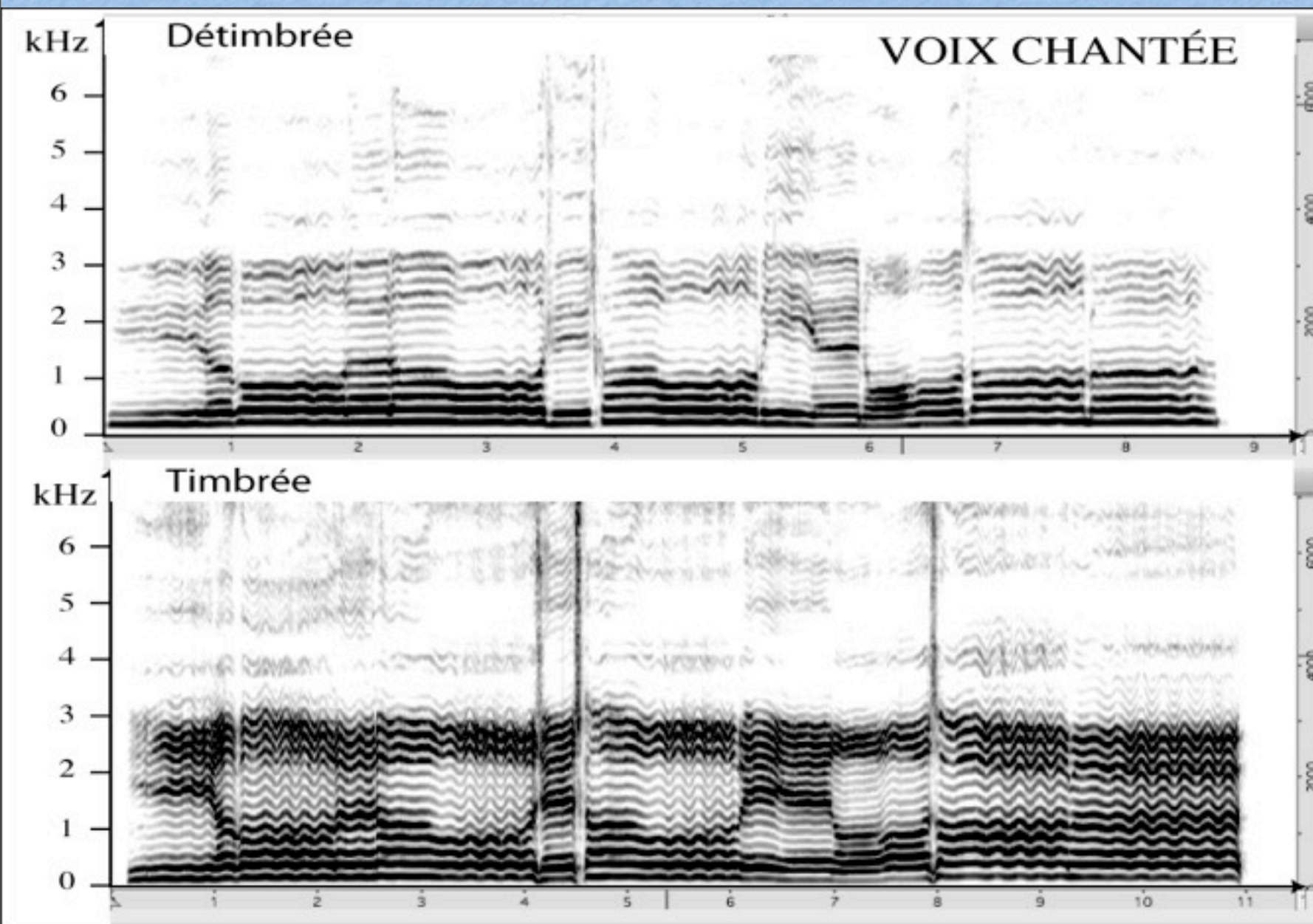


Timbré:
H2 dominant
more harmonics

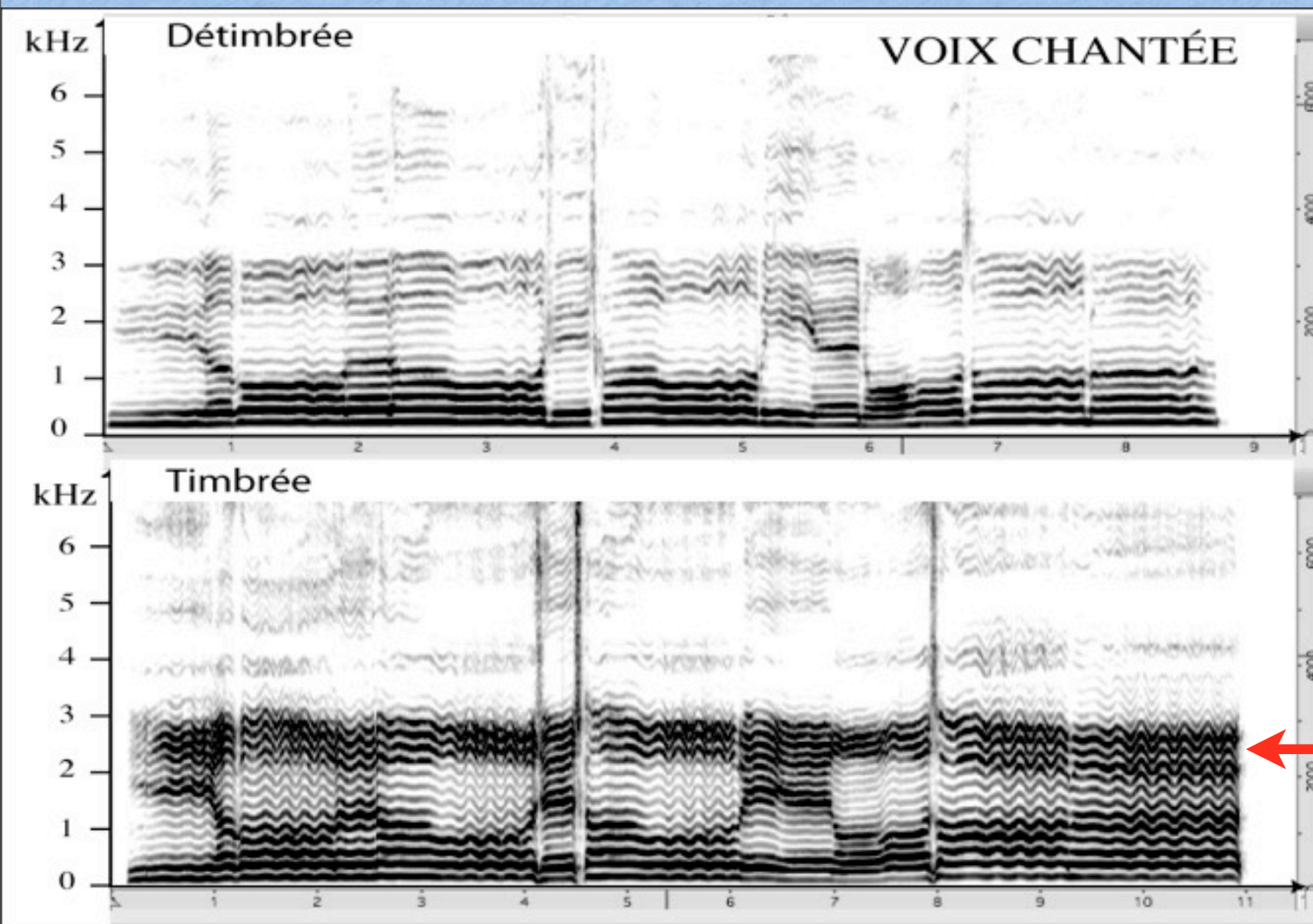


VOICE : TIMBRÉE-DÉTIMBRÉE

VOICE : TIMBRÉE-DÉTIMBRÉE



VOICE : TIMBRÉE-DÉTIMBRÉE



Timbré:
singing formant
reinforced,
more harmonics

SF

- A given quality, named «timbré», consists in different changes of the sound content.
- Excepted for brightness (related to spectral centroid) and perhaps for some primary oppositions (soft / piercing), the links between the variations of the perceived qualities and those of the spectro-temporal pattern is peculiar to each category of sound.

MUSICAL REFERENCES ON TIMBRE

- Berlioz and other orchestration treatises (Koechlin, Rimsky-Korsakov)
- A collective book: *Le timbre : métaphore pour la composition*; 30 authors; (edited by J.B. Barrière, 1991) with texts from composers, instrumentalists, philosophers, even acousticians.
- The impressive book, *Sound structure in music*, (1975) of an enlightened composer: Robert Erickson, who asks the good questions.
- The forthcoming book I have written, *Ecoute musicale et acoustique*, Eyrolles éd., 2015, to continue the discussion!

-----> The terms in use : identification timbre and qualification timbre.

THE TWO PERCEPTIVE STAGES

In ordinary life, hearing, just as the other senses, is firstly used to decipher the world around us.

1 - The first reaction on hearing a sound is WHAT ? WHERE ? (What's going on ?)

One must understand quickly to react to a possible danger. The whole process is made easier if the context makes it predictable.

This process relies on the listener's ability to detect, in the acoustic signal, the invariant cues that are specific of every sound production mode.

The identification timbre is but a specific field of the musical sounds.

This process consists probably in a low level treatment (bottom-up) of acoustical cues - a spectro-temporal pattern - completed by top-down (efferent) information on foreseeability to create meaning. It is partly unconscious, but at the end of the process, the meaning is given by the listener.

2 - The second stage of the process is that of sound qualification: HOW ? which must be applied to known sounds.

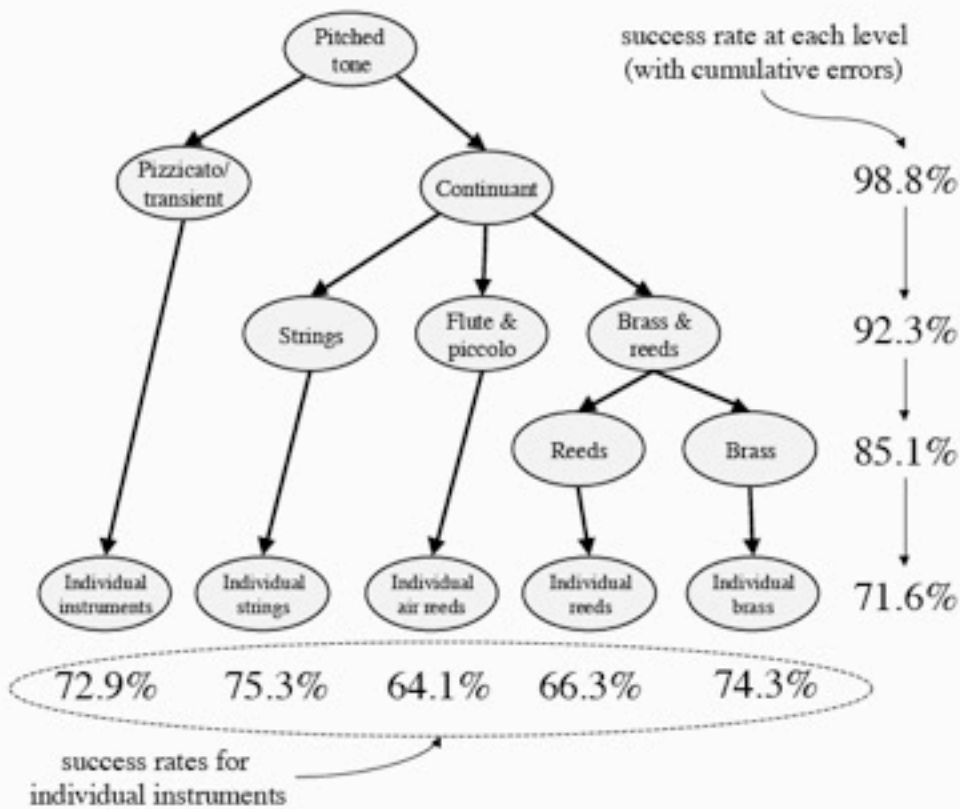
It consists in discriminations, compared analysis and needs the use of language to describe precisely the sensation as well as communicate with other listeners. The qualification is a negotiation between experts belonging to the same culture.

And just as specialists in wine, musicians developed a specific vocabulary specific to each community of instrument players: that of flutists is different from that of pianists. Even for the same instrument (i.e. the piano) the meaning of the adjectives is different whether used by an instrument maker, a pianist or a composer.

It seems improbable to imagine an automatic research on sounds based on vocabulary (but I do not know the state of art on that subject).

Martin

Classification results

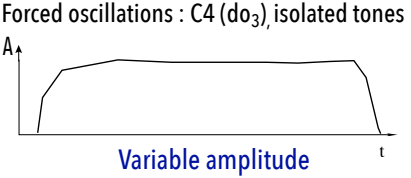


It turned out to be necessary to modify the proposed classification hierarchy somewhat. The “woodwind” family of orchestral instruments does not appear to be acoustically unified, at least for the features examined here. The best classification results were achieved when the “air” reed instruments (flute/piccolo) formed a separate class, as shown here.

These preliminary results are extremely promising. The hierarchical-classification scheme performed better than several non-hierarchical schemes, including a *k*-nearest neighbor classifier.

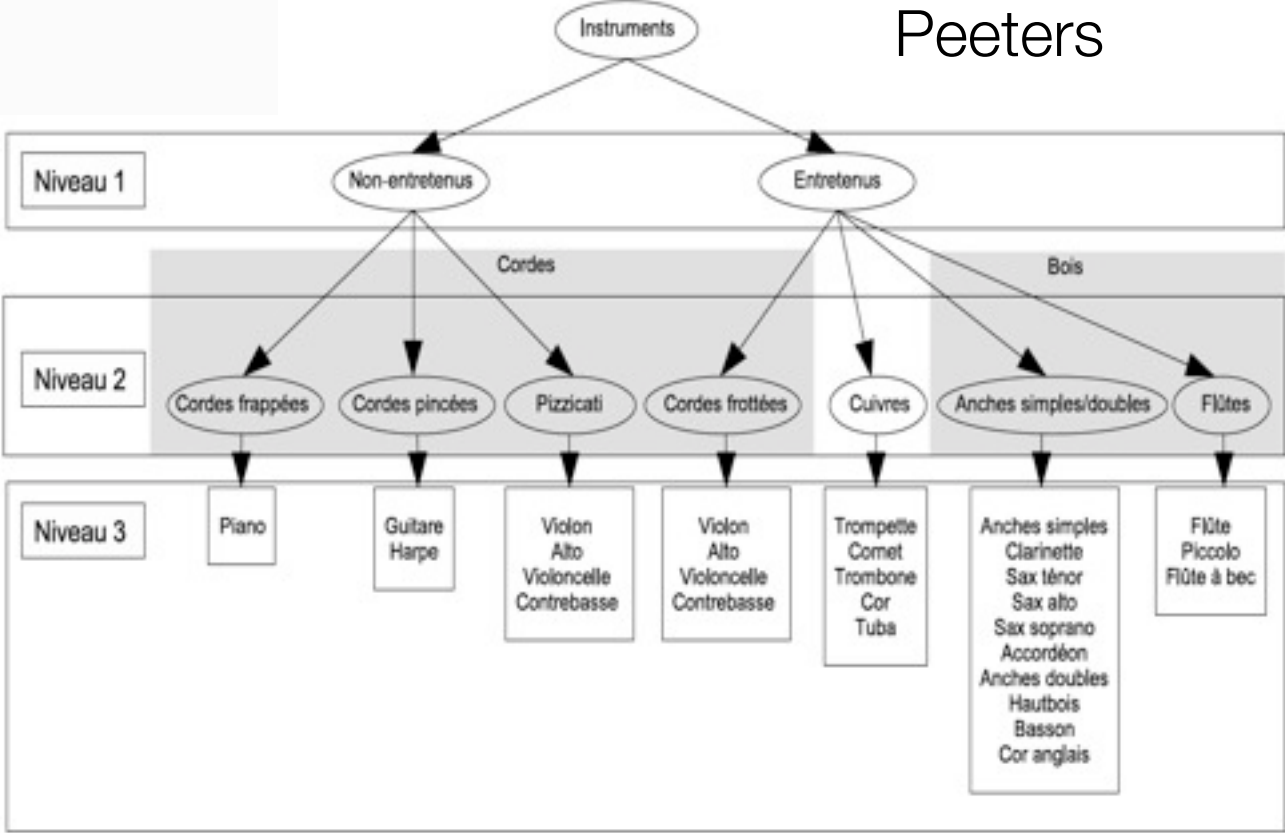
It would be interesting to weight the results of automatic recognition tests according to the level of categorization

Castellengo

A	Temporal envelope					
		Forced oscillations : C4 (do ₃), isolated tones				
B	Energy provider	BOW Friction	AIR FLOW Breath			
C	Oscillator	STRING	AIR	REED		
D	Musical instrument	Group 1 Violin (or family)	Group 2 Transverse Flute (or family)	Group 3 vegetal reeds	Group 4 labial reeds	Group 5 metal reeds
				Ob Fag Cl Sax	Trpt Hrn	Acc

All the listeners
↓
Experts only

Peeters



MAIN ISSUES (among others) and SUGGESTIONS

A - The intrinsic variability of natural sounds in general and musical sounds specifically. That which is necessary to make sounds interesting and alive; And that of the sounds of an instrument: pitch range, nuances in interpretation.

B - Perceptive paradox

---> To recognize a sound, one must ignore contingent variations and have memorized a pure prototype of each sound category.

---> To qualify correctly, one has to increase sound sensitivity to detect the tiniest variations both in time and spectral dimension. And to achieve that, one has to have stocked in memory all the sounds of a given category of instruments.

C - Suggestions for tests

Identification timbre: mix sounds of different pitches and nuances during training.

Qualitative timbre: work with a huge quantity of sounds coming from the same instrument, on the same pitch, varying the interpret, the nuances.

Repeat the exercise varying the pitch, as many times as you want !

The end . . .

