ΙΑΤΡΙΚΗ ΣΤΙΣ ΠΑΡΑΣΤΑΤΙΚΕΣ ΤΕΧΝΕΣ

ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης

Βασικές αρχές Ψυχοφυσικής

και Μουσική

ή

περί ήχου, μουσικής (και άλλων δαιμονίων)

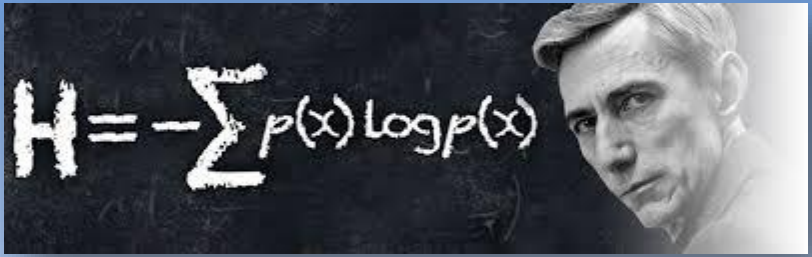
ΚΩΝ/ΝΟΣ ΠΑΣΤΙΑΔΗΣ

Δρ. ΗΜΜΥ

Αν. Καθ., Τμήμα Μουσικών Σπουδών Α.Π.Θ.

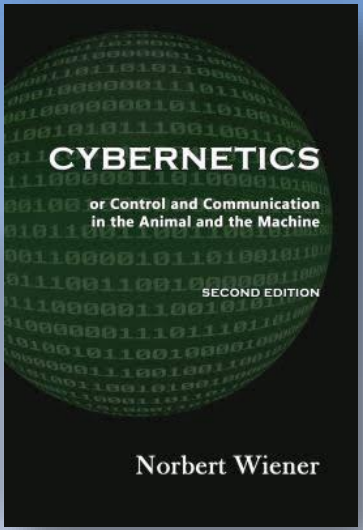
Επισκέπτης Καθ., Ιατρική Σχολή ΕΚΠΑ

A multidisciplinary issue

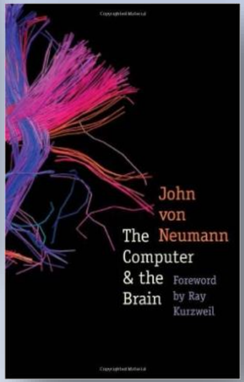


Claude Shannon
(1948)

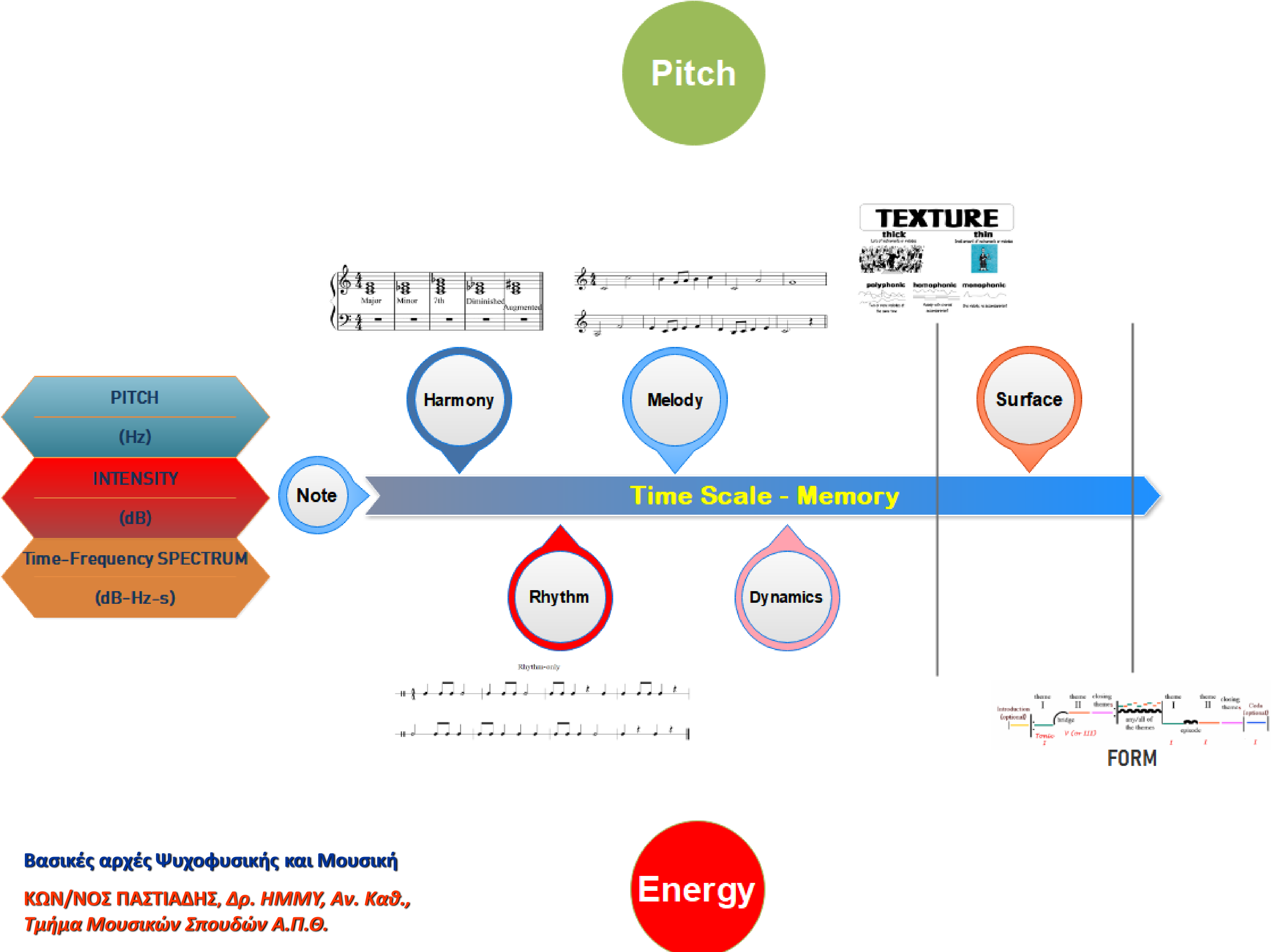
Norbert Wiener
(1948)



Jon von Neumann
(1955)



Alan Turing (1940s)
The ENIGMA
deciphering
(or Turing's Machine)



Βασικές αρχές Ψυχοφυσικής και Μουσική

ΚΩΝ/ΝΟΣ ΠΑΣΤΙΑΔΗΣ, Δρ. ΗΜΜΥ, Αν. Καθ.,
Τμήμα Μουσικών Σπουδών Α.Π.Θ.

Performance OR Perception ?

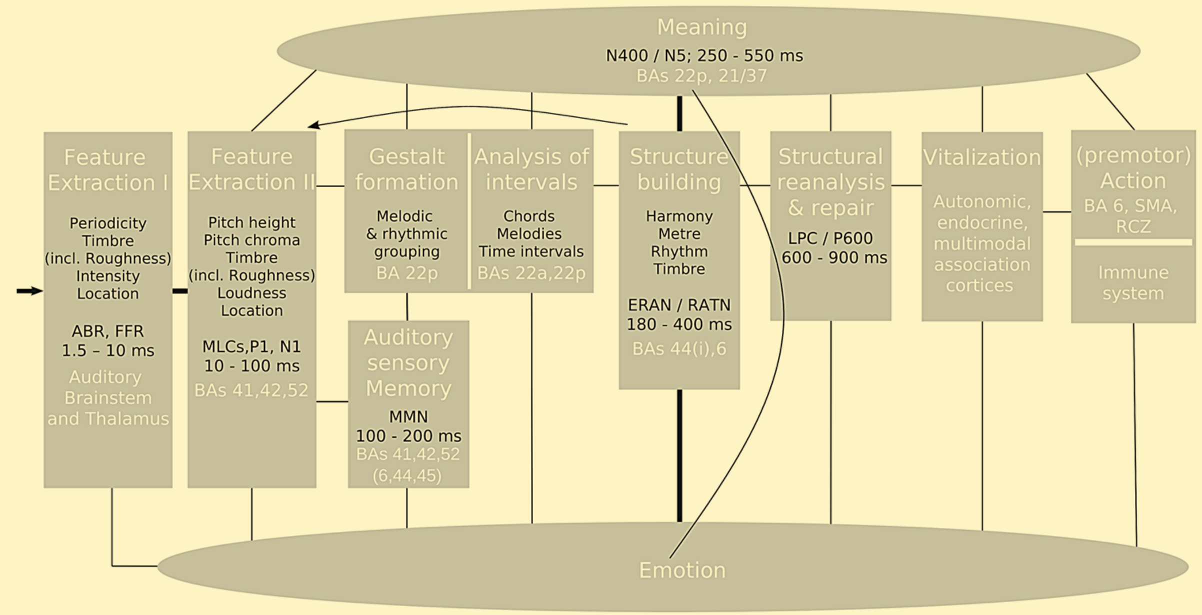
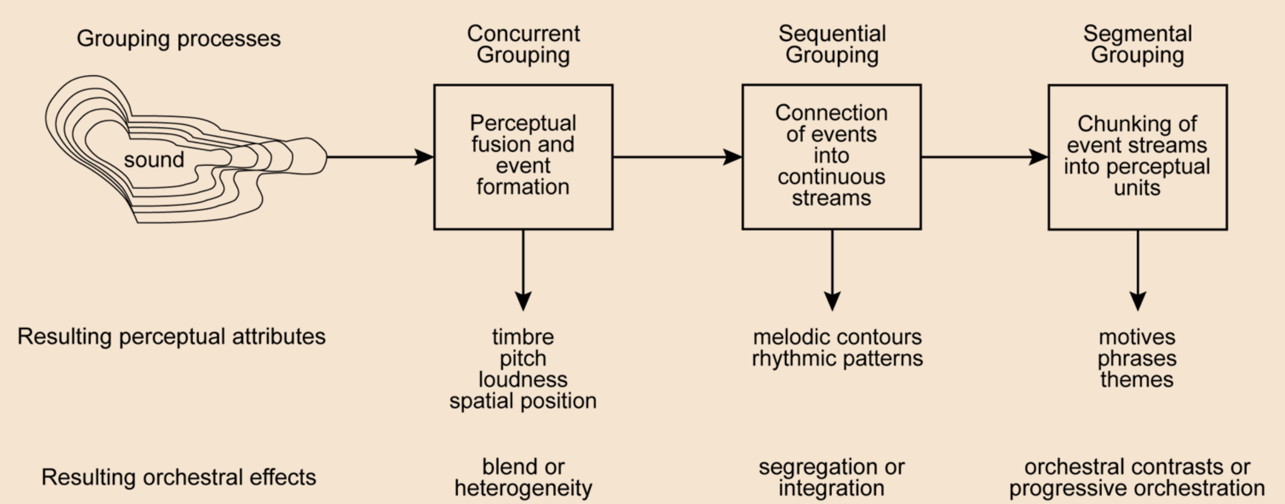


FIGURE 1 | Neurocognitive model of music perception. ABR, auditory brainstem response; BA, Brodmann area; ERAN, early right anterior negativity; FFR, frequency-following response; LPC, late positive component; MLC, mid-latency component; MMN, mismatch negativity; RATN, right anterior-temporal negativity; RCZ, rostral cingulate zone; SMA, supplementary motor area. Italic font indicates peak latencies of scalp-recorded evoked potentials.

Koelsch, Stefan. (2011). *Toward a Neural Basis of Music Perception – A Review and Updated Model.* Frontiers in psychology. 2. 110. 10.3389/fpsyg.2011.00110.

Perceptual Processes in Orchestration, Meghan Goodchild and Stephen McAdams, The Oxford Handbook of Timbre, Edited by Emily Dolan and Alexander Rehding



Βασικές αρχές Ψυχοφυσικής και Μουσική

ΚΩΝ/ΝΟΣ ΠΑΣΤΙΑΔΗΣ, *Δρ. ΗΜΜΥ, Αν. Καθ., Τμήμα Μουσικών Σπουδών Α.Π.Θ.*

Physics - Psychology

The debate in 1930s

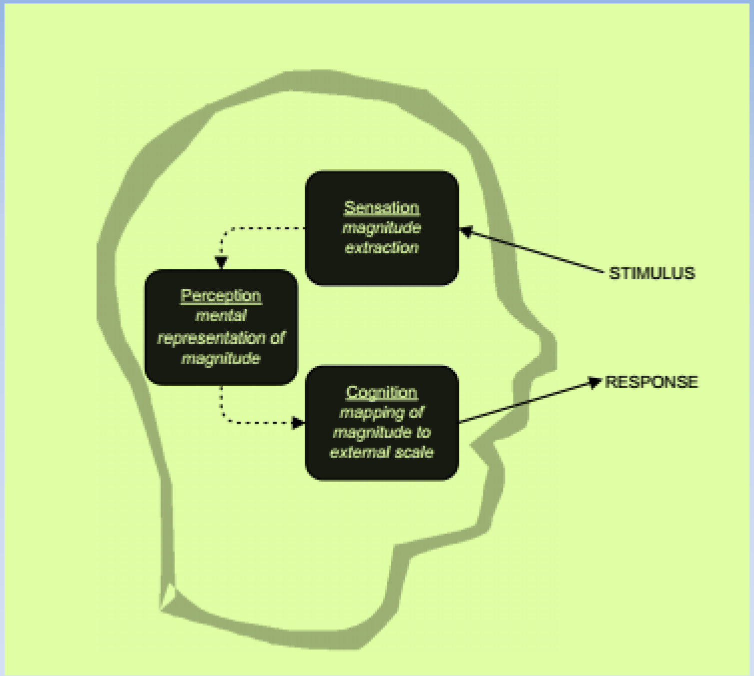
Is the quantitative estimation of sensory events possible?

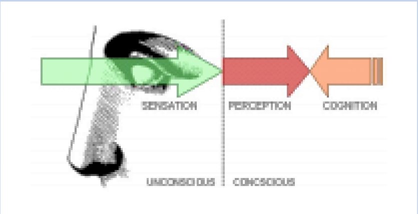
Committee of the British Association for the Advancement of Science 1930

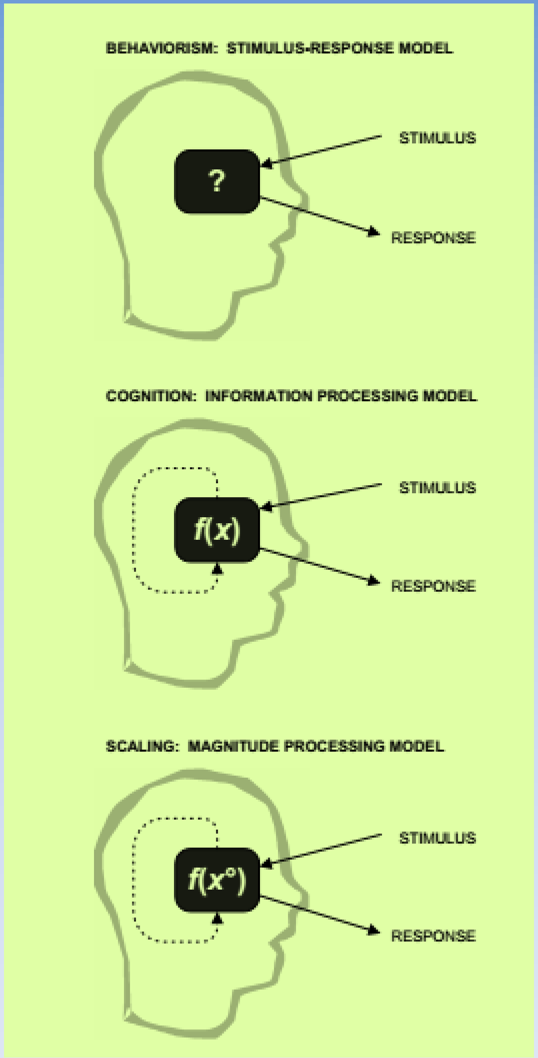
Scaling – Thresholds
Psychophysics - Psychometrics

Christophe Lalanne, Introduction to quantitative measurement: Psychophysics vs. Psychometrics

Human as measuring instrument



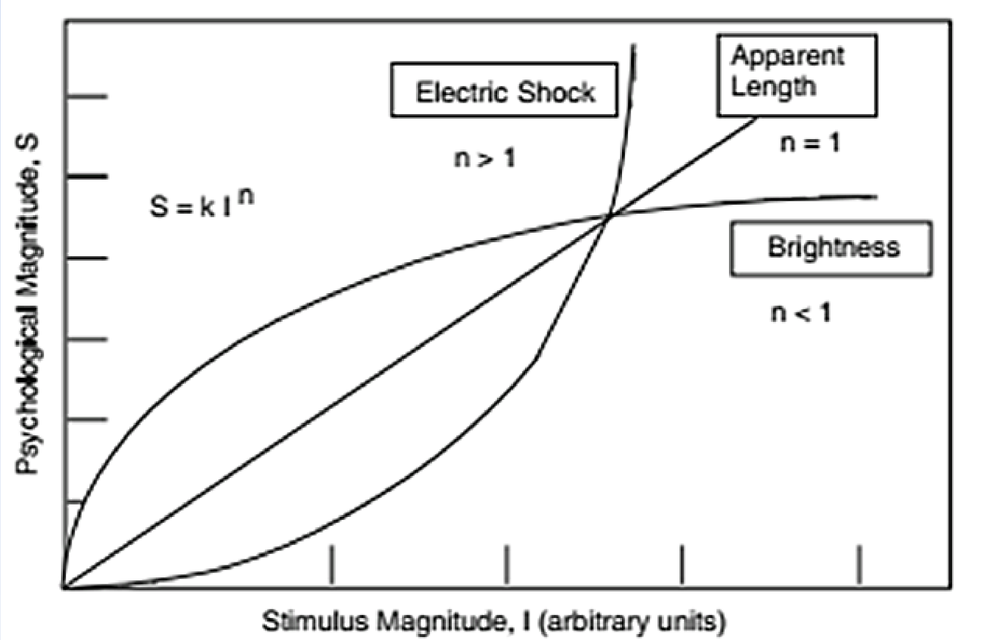




Ronald Laurids Boring, Cognition and Psychological Scaling: Model, Method, and Application of Constrained Scaling, 2004

Thresholds and scales

Absolute vs Difference thresholds



$$S = k \log I$$

$$S = kI^n$$

S is the magnitude of the auditory attribute
I is the physical parameter, and
k and n are constants specific to each auditory attribute.

For the loudness of a 1-kHz tone, the exponent is 0.6: a 10-dB increase leads to a 2-sone increase. For a 3-kHz tone, the exponent is 0.67.

Psychoacoustics

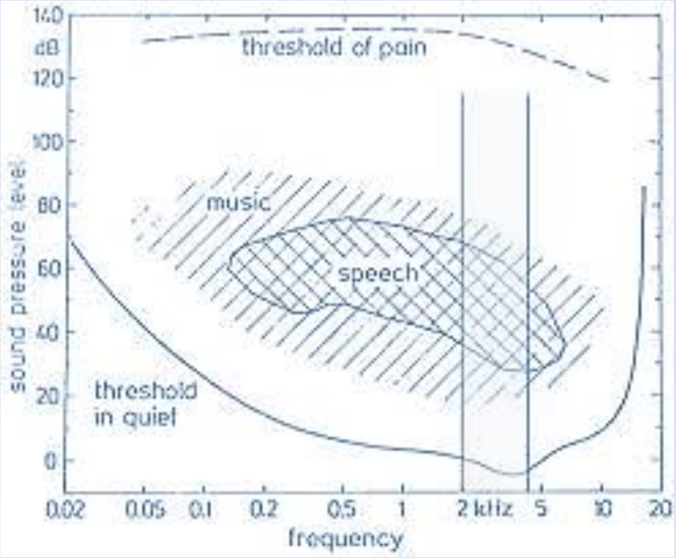
Ψυχοακουστική - Μεγέθη

Υποκειμενικά Μεγέθη

Ακουστότητα (Loudness)

Τονικό Ύψος (Pitch)

Χροιά (Timbre)



Psychoacoustics

ΑΚΟΥΣΤΟΤΗΤΑ

- Υποκειμενική Αίσθηση της Έντασης
- Σχέση με την συχνότητα   50Hz @ 70dB   3kHz @ 70dB
- Ισοδύναμη στάθμη ακουστότητας (phon):

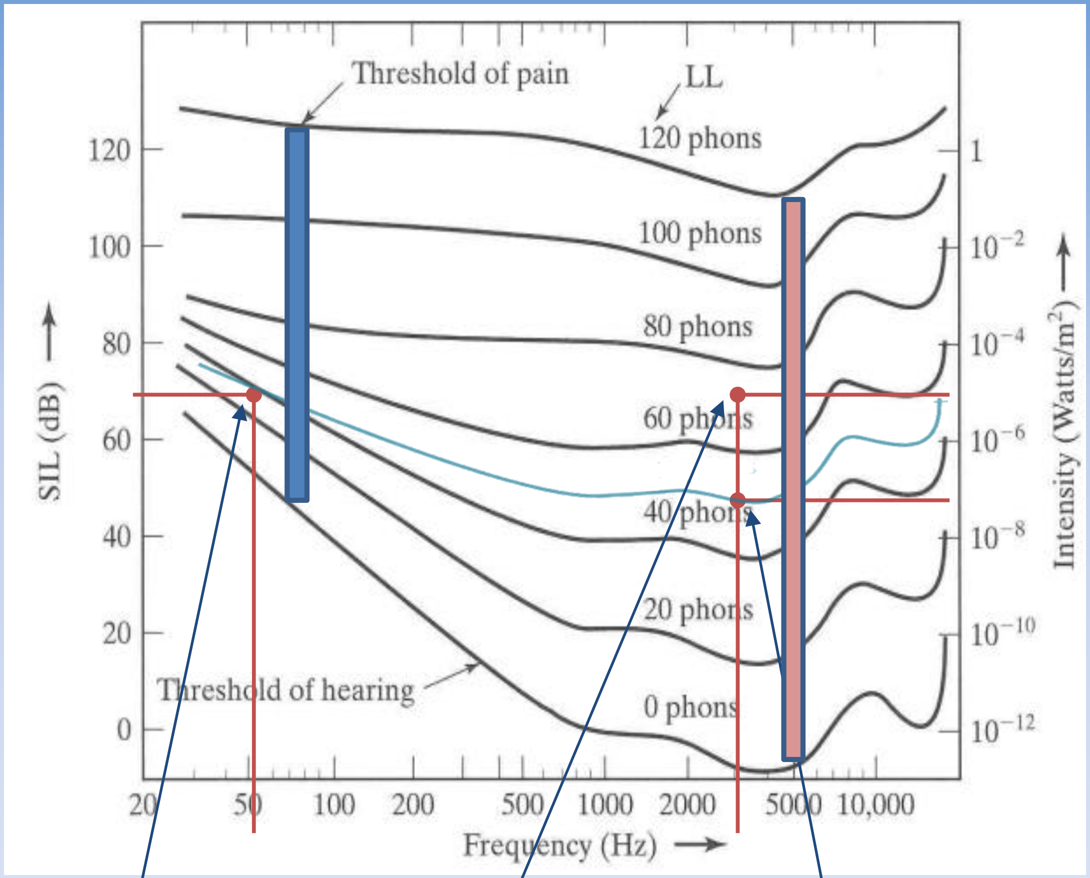
<u>Ποιά η σχέση εντάσεων δύο ήχων με διαφορετική συχνότητα ώστε να ακούγονται παρόμοια έντονοι ;</u>

50Hz @ 70dB   3kHz @ 50dB

Psychoacoustics

Ισοφωνικές Καμπύλες

- Σταθερή αντίληψη της στάθμης κατά μήκος μιας καμπύλης
- Μικρότερη διακριτική ικανότητα της στάθμης σε χαμηλές και υψηλές συχνότητες (συμπίεση;), μεγαλύτερη στις μεσαίες
- Loudness Correction
- Music DR = max. 80dB
- DR Response (Auditory Cortex)



50Hz @ 70dB

3kHz @ 70dB

3kHz @ 50dB

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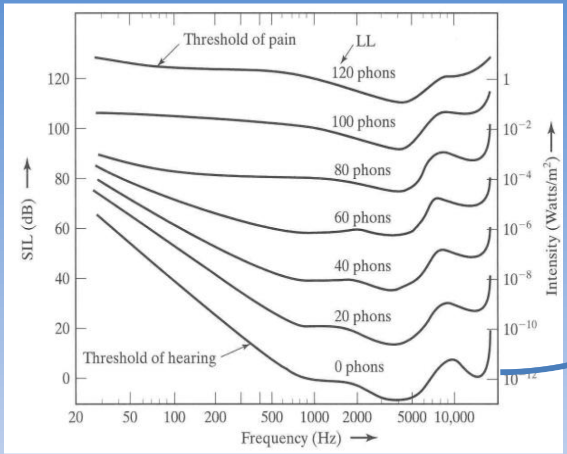
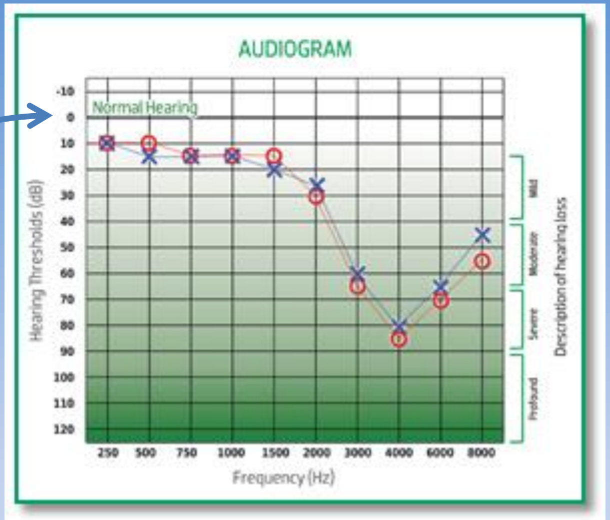
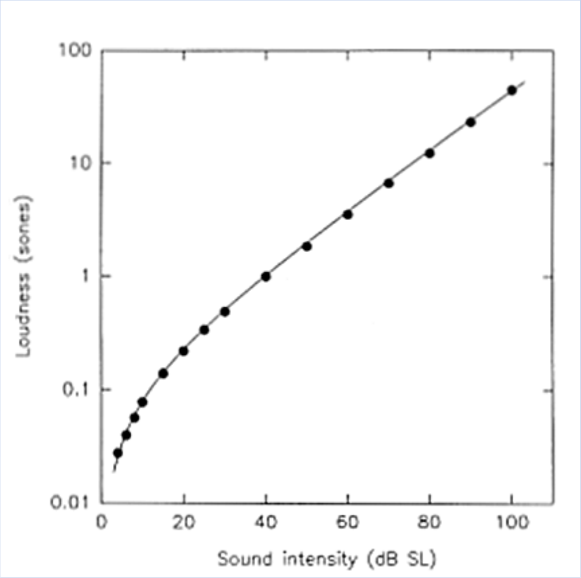
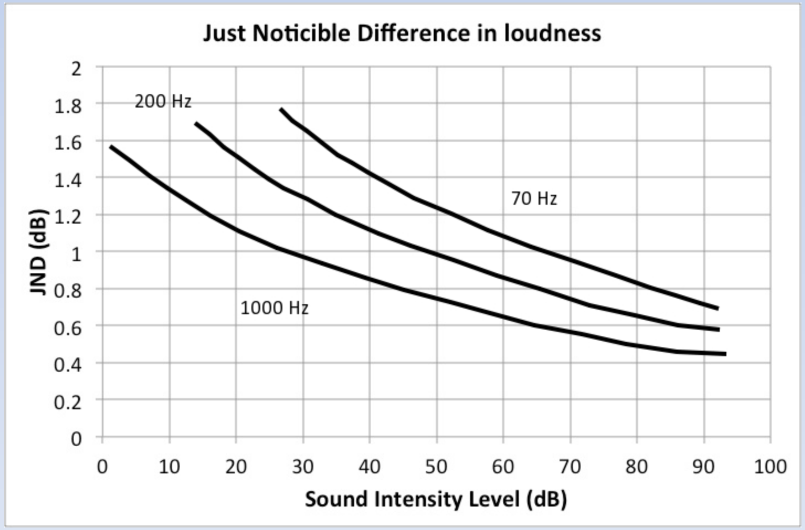








Kraemer J., SOUND POWER OF MODERN AND HISTORICALORCHESTRAL INSTRUMENTS, 2011

	Scales [dB]		Single Notes [dB]		
	L_{wff}	L_{wpp}	L_{wff}	L_{wpp}	L_{wf}
Historic Violin	90	75	95	56	85
Modern Violin	88	75	95	52	84
Historic Viola	88	70	94	57	85
Modern Viola	91	77	97	58	87
Historic Violoncello	93	73	102	57	91
Modern Violoncello	98	90	97	63	89
Historic Doublebass	90	80	100	66	91
Modern Doublebass	89	65	100	65	92

FIG. 15. Dynamic range of all examined modern and historical bowed string instruments. Both the measured maximum and minimum sound power level for the time-averaged steady-state amount of single notes and a fast played scale as well as a calculated mean forte sound power level L_{wf} is shown.

TABLE 1: SOUND POWER AND DYNAMIC RANGE OF INSTRUMENTS

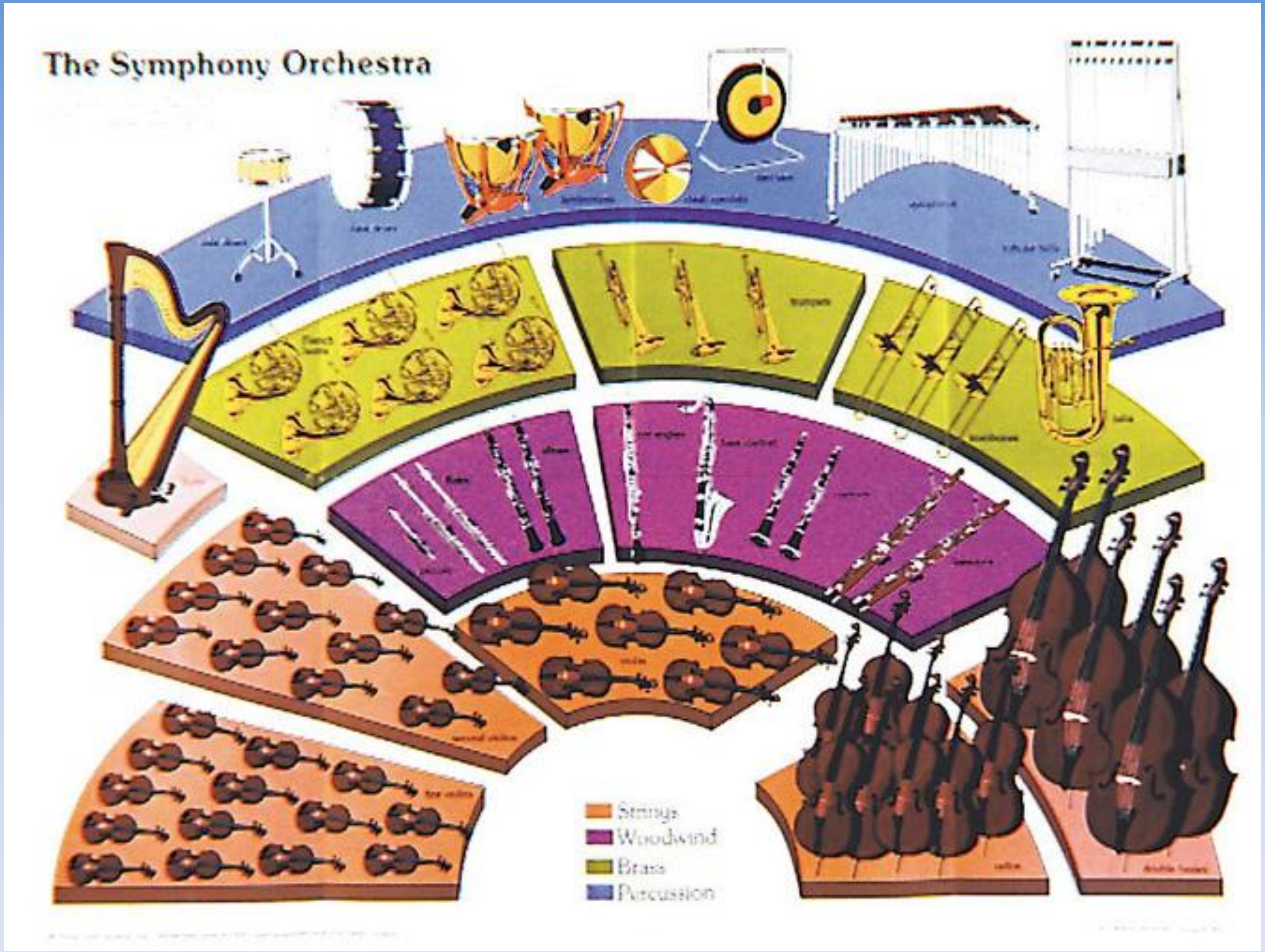
Instrument	Average sound power playing forte (milliwatts)	Practical dynamic range (decibels)
Violin	0.8	35
Viola	0.5	30
Cello	1	30
Double bass	1.6	30
Flute	1.3	20
Oboe	2	30
Clarinet	2	40
Bassoon	2	30
Horn	16	40
Trumpet	13	30
Trombone	13	35
Tuba	20	30
Full orchestra (without percussion)	250	65

Instrument	Average sound power playing forte (mW)	Intensity at 10 m in open ($W\,m^{-2}$)	SPL (dB)
Violin	0.8	6.37×10^{-7}	58
Viola	0.5	3.98×10^{-7}	56
Cello	1	7.96×10^{-7}	59
Double bass	1.6	1.27×10^{-6}	61
Flute	1.3	1.03×10^{-6}	60
Oboe	2	1.59×10^{-6}	62
Clarinet	2	1.59×10^{-6}	62
Bassoon	2	1.59×10^{-6}	62
Horn	16	1.27×10^{-5}	71
Trumpet	13	1.03×10^{-5}	70
Trombone	13	1.03×10^{-5}	70
Tuba	20	1.59×10^{-5}	72

$$p^2 = W\rho c\left(\frac{Q}{4\pi r^2} + \frac{4}{R}\right)$$

$$L_p = L_w + 10\log_{10}\left(\frac{Q}{4\pi r^2} + \frac{4}{R}\right)$$

the bodybuilder and the egg



the bodybuilder and the egg

A medium size symphony orchestra has 10 first violins, 10 second violins, 10 violas, 10 cellos, 6 double basses, 2 flutes, 2 clarinets, 2 oboes, 2 bassoons, 4 horns, 2 trumpets, 3 trombones and 1 tuba.

Using the values from the table in Question 1, calculate the total sound power in (a) the string section; (b) the woodwind section; (c) the brass section; (d) the whole orchestra, when all the instruments are playing forte.

Strings:

Violins: $20 \times 0.8 = 16\,\mathrm{mW}$. Violas:$10 \times 0.5 = 5\,\mathrm{mW}$. Cellos: $10 \times 1 = 10\,\mathrm{mW}$. Double basses: $6 \times 1.6 = 9.6\,\mathrm{mW}$.

Total string section: $40.6\,\mathrm{mW}$.

Woodwind:

Flutes: $2 \times 1.3 = 2.6\,\mathrm{mW}$. Oboes: $2 \times 2 = 4\,\mathrm{mW}$. Clarinets: $2 \times 2 = 4\,\mathrm{mW}$. Bassoons: $2 \times 2 = 4\,\mathrm{mW}$.

Total woodwind section: $14.6\,\mathrm{mW}$.

Brass:

Horns: $4 \times 16 = 64\,\mathrm{mW}$. Trumpets: $2 \times 13 = 26\,\mathrm{mW}$. Trombones: $3 \times 13 = 39\,\mathrm{mW}$. Tuba: $1 \times 20 = 20\,\mathrm{mW}$.

Total brass section: $149\,\mathrm{mW}$.

Total orchestra: 204.2 mW.

Comments: Woodwind section is relatively weak, and is oftened strengthened by having 3 or 4 of each instrument. Brass section is inherently the most powerful and if not restrained can drown the rest of the orchestra!

timbral and room effects on the perception of DR

Table 3
Relationship Between Dynamic Symbols Written by Performer and Listeners' Perceptions

Listeners' Judgment	Performer's Intention *p*	*mp*	*mf*	*f*
a. Violin				
pp	7 (4.6%)			1 (1.3%)
p	80 (52.6%)			9 (11.8%)
mp	55 (36.2%)			21 (27.6%)
mf	9 (5.9%)			13 (17.1%)
f	0 (0.0%)			29 (38.2%)
ff	0 (0.0%)			3 (3.9%)
No Answer	1 (0.7%)			0 (0.0%)
Total	152 (100%)			76 (100%)
b. Recorder				
pp	21 (13.8%)		10 (13.2%)	1 (0.4%)
p	69 (45.4%)		26 (34.2%)	13 (4.9%)
mp	52 (34.2%)		36 (47.4%)	88 (33.1%)
mf	7 (4.6%)		2 (2.6%)	120 (45.1%)
f	0 (0.0%)		0 (0.0%)	42 (15.8%)
ff	0 (0.0%)		0 (0.0%)	1 (0.4%)
No Answer	3 (2.0%)		2 (2.6%)	1 (0.4%)
Total	152 (100%)		76 (100%)	266 (100%)
c. Oboe				
pp	18 (7.9%)	6 (3.9%)	0 (0.0%)	
p	73 (32.0%)	64 (42.1%)	10 (6.6%)	
mp	97 (42.5%)	68 (44.7%)	50 (32.9%)	
mf	37 (16.2%)	9 (5.9%)	65 (42.8%)	
f	2 (0.9%)	0 (0.0%)	25 (16.4%)	
ff	0 (0.0%)	0 (0.0%)	1 (0.7%)	
No Answer	1 (0.4%)	5 (3.3%)	1 (0.7%)	
Total	228 (100%)	152 (100%)	152 (100%)	

Note—The data indicate the number and percentages of subject judgments that agreed with the performer's intentions as indicated by his use of dynamic symbols. *pp* = pianissimo (very soft), *p* = piano (soft), *mp* = mezzopiano (moderately soft), *mf* = mezzoforte (moderately loud), *f* = forte (loud), and *ff* = fortissimo (very loud).

Nakamura T., The communication of dynamics between musicians and listeners through musical performance, 1987

A Drummer’s Perspective

- Drummer’s mass moving (legs, arms) $\sim 20\ kg$
- Drummer playing @ $\sim 100\ bpm$ is moving his legs and arms at a speed $u \approx 6\ mph = 2.68\ m/s$ [http://drumworldking.freeservers.com/drum.htm]
- So, @ $\sim 100\ bpm$ he performs $\sim 100\ hits\ per\ min$, which is $\sim 200\ movements\ per\ min$ (due to hit & return motion) , which consumes $E = 2 * 100 * .5 * m * u^2 = 2 * 100 * 0.5 * 20 * 2.68^2 = 14364 \frac{Joules}{min} \triangleq 861868 \frac{Joules}{h} \triangleq 206 kcal$
- But, to obtain this he has to increase his heart rate from $\sim 80 pulses\ per\ min$ to $\sim 110\ pulses\ per\ min$. Energy expenditure due only to heart operation at this rate is $\sim 240 \frac{kcal}{h}$

  [Estimating Energy Expenditure from Heart Rate in Older Adults: A Case for Calibration, Jennifer A. Schrack, Vadim Zipunnikov, Jeff Goldsmith, Karen Bandeen-Roche, Ciprian M. Crainiceanu, Luigi Ferrucci, PLoS One. 2014; 9(4): e93520]
- To this, add also the increased energy consumption of the respiratory work, which is estimated as 0.5 of heart energy consumption, namely $\sim 120\ kcal/h$
- $\sum = 206 + 240 + 120 = 566 \frac{kcal}{h}$
- Ergometry-based estimates for drummers yield $623 \pm 168 \frac{kcal}{h}$

[De La Rue SE, Draper SB, Potter CR, Smith MS , **Energy expenditure in rock/pop drumming,** Int J Sports Med. 2013 Oct;34(10):868-72]

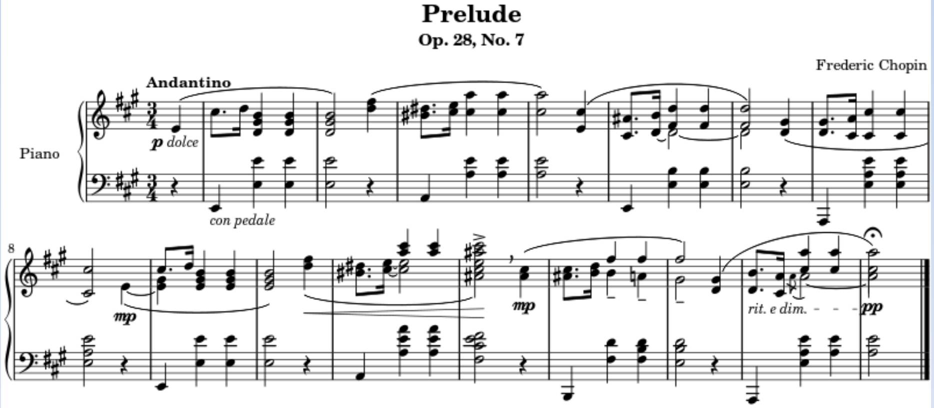
- What does this imply for a loss of loudness corresponding to 3dB only (due to loudness recruitment effect at these high SPL for a mild Hearing Loss) ?

Psychoacoustics

ΤΟΝΙΚΟ ΥΨΟΣ - PITCH

- **Υποκειμενική Αίσθηση της Συχνότητας**
- **Tonotopy : periphery - cortex**
- **Ο ρόλος στην επικοινωνία**
- **Μελωδίες / Αρμονίες**
- **Διακριτική ικανότητα και μουσικά συστήματα**

Ας κάνουμε ένα πείραμα !!!



300Hz – 319Hz

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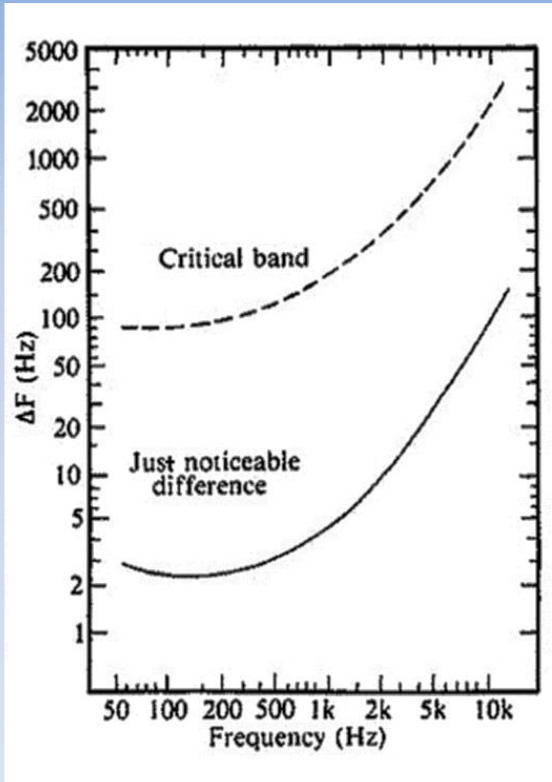
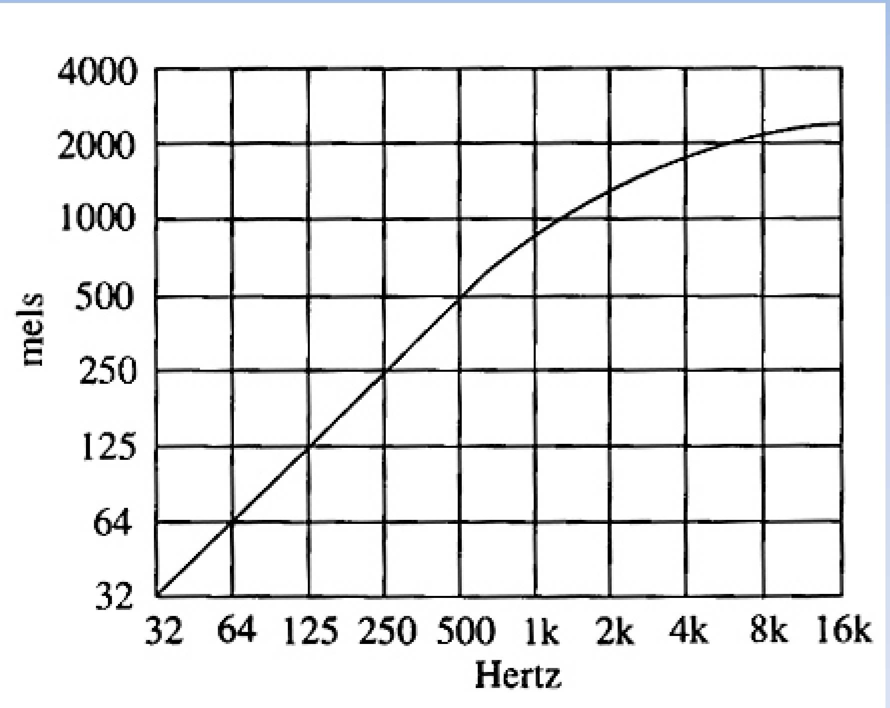
ΤΟΝΙΚΟ ΥΨΟΣ - PITCH

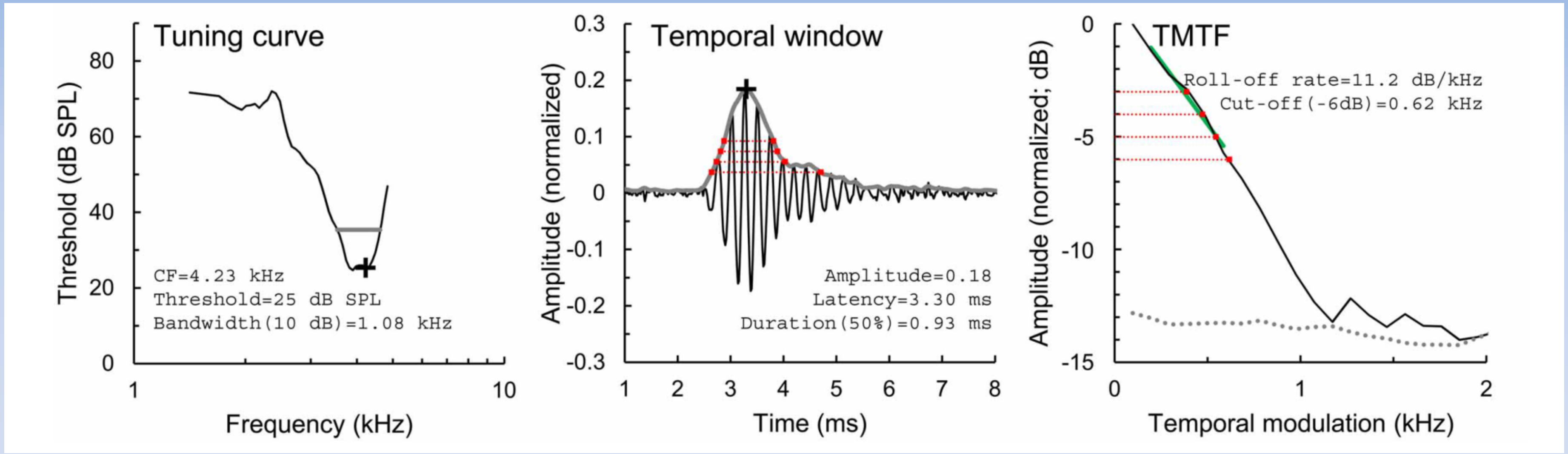




http://acousticslab.org/psychoacoustics

Psychoacoustics

Noise-induced hearing loss increases the temporal precision of complex envelope coding by auditory-nerve fibers



Kenneth S. Henry, Sushrut Kale, Michael G. Heinz, *Noise-induced hearing loss increases the temporal precision of complex envelope coding by auditory-nerve fibers*, Front. Syst. Neurosci., 17 February 2014

Effects on music/speech perception (?)

Psychoacoustics

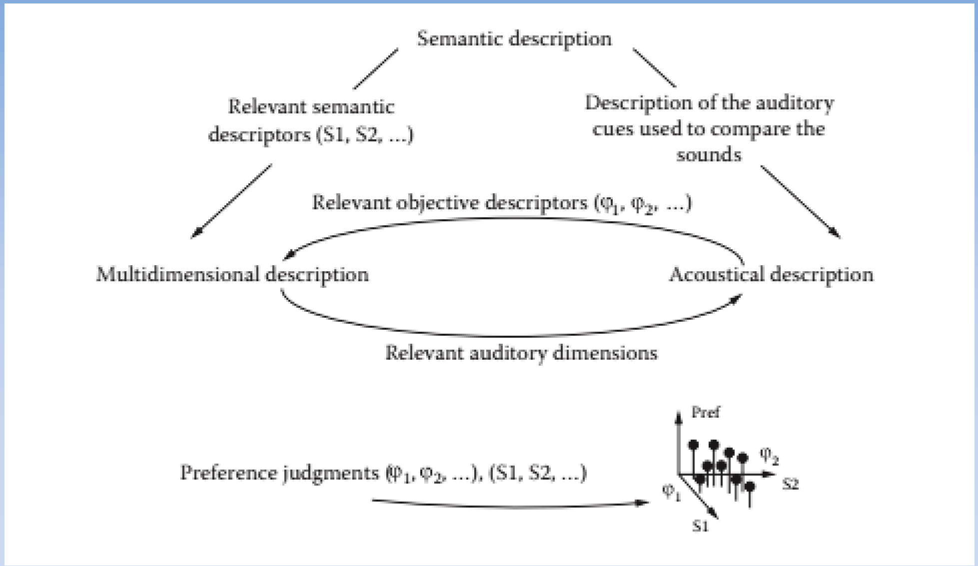
ΧΡΟΙΑ - TIMBRE

- **Υποκειμενική αίσθηση...αλλά τίνος ?**
- **Δομικό στοιχείο της Μουσικής**
- **Scaling ? Thresholds ?**
- **Σχέση με την συχνότητα / ένταση**
- **Χρονοσυχνοτικό μέγεθος**

Psychoacoustics

ΧΡΟΙΑ - TIMBRE

- **Semantics**
- **Similarities**
- **Features**



Susini, Lemaitre, McAdams, Psychological measurement for sound description and evaluation

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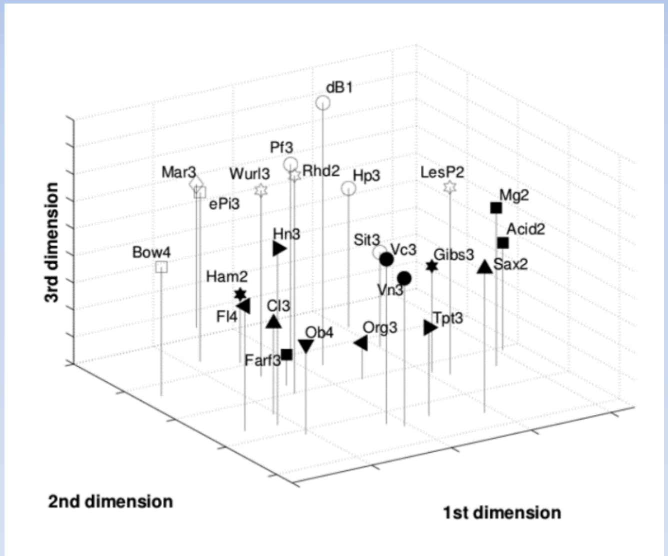
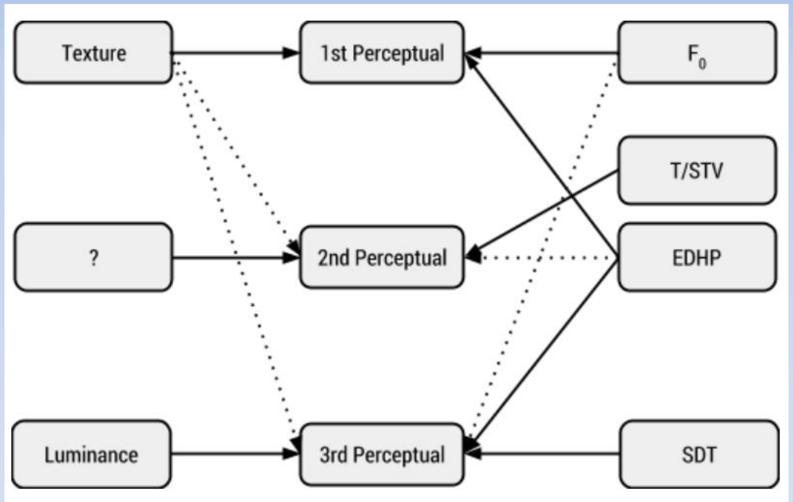
ΧΡΟΙΑ - TIMBRE





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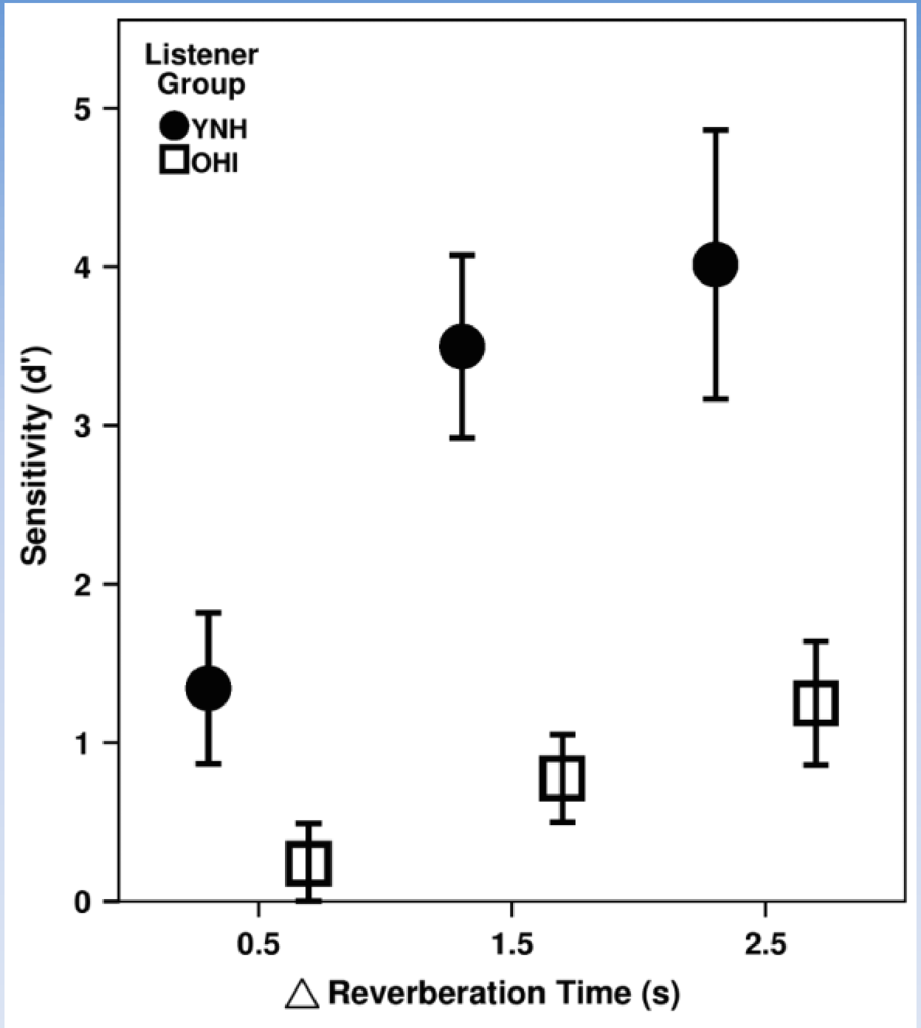
ΧΡΟΙΑ - TIMBRE



Reinhart, Paul & Souza, Pamela. (2018). *Effects of Varying Reverberation on Music Perception for Young Normal-Hearing and Old Hearing-Impaired Listeners.* Trends in Hearing. 22. 233121651775070. 10.1177/2331216517750706.

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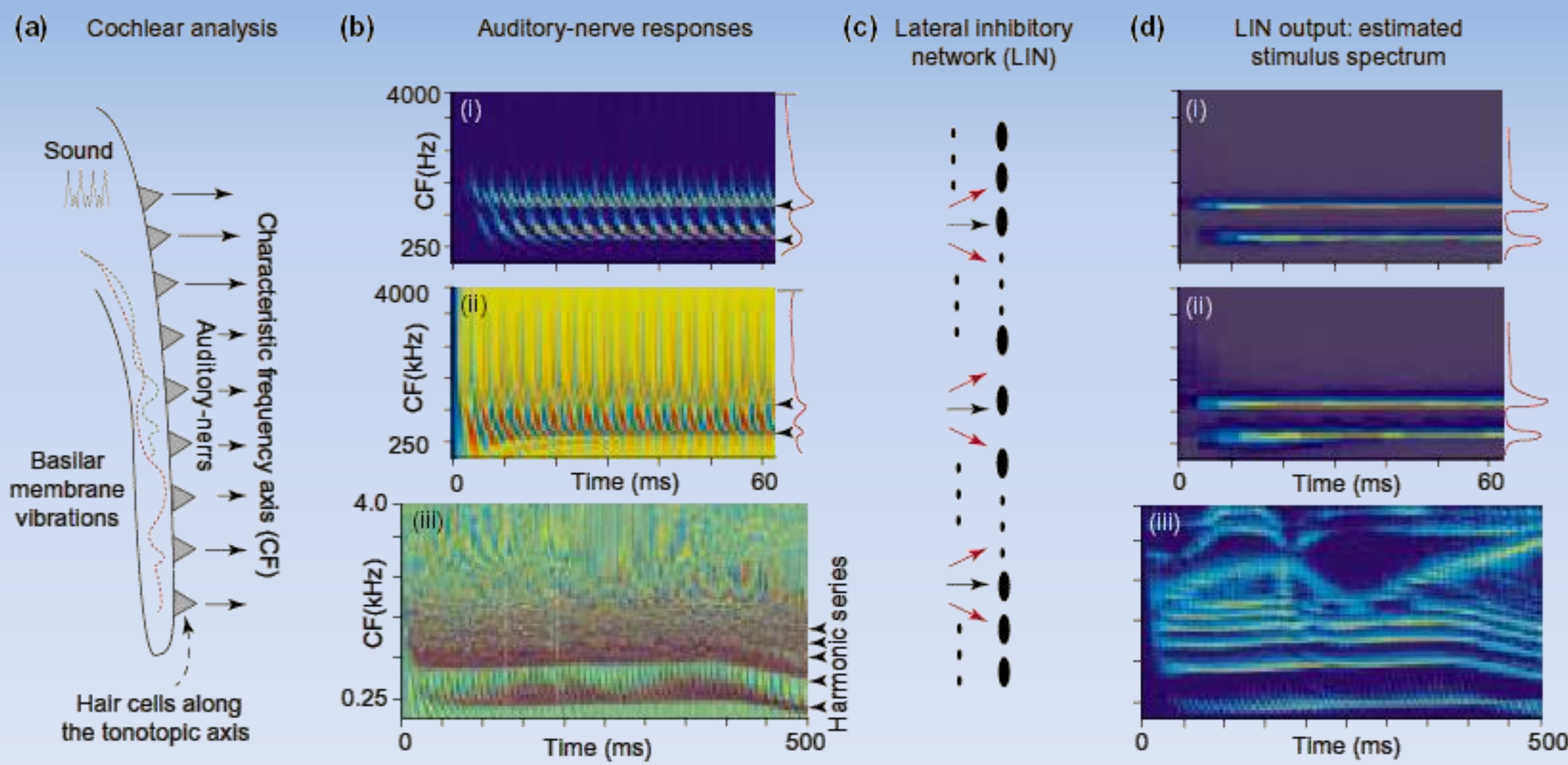
ΧΡΟΙΑ - TIMBRE

Computational Modeling in Timbre Perception



Psychoacoustics

- Μελέτη Χαρακτηριστικών Αντίληψης της Μουσικής
- Συμπεριφορικά
- Αντικειμενικά
- Συνδυασμός
- Τεχνολογίες Υποβοήθησης (π.χ. Hearing Aids-Implants)

ΨΥΧΟΑΚΟΥΣΤΙΚΗ

ΜΟΥΣΙΚΗ ΑΚΟΥΣΤΙΚΗ

ΑΚΟΥΟΛΟΓΙΑ

ΨΥΧΟΛΟΓΙΑ της ΜΟΥΣΙΚΗΣ

ΙΣΤΟΡΙΑ της ΜΟΥΣΙΚΗΣ - ΑΙΣΘΗΤΙΚΗ

ΕΘΝΙΚΟ ΚΑΙ ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ

Αριστοτέλειο Πανεπιστήμιο Θεσσαλονίκης

ΙΑΤΡΙΚΗ ΣΤΙΣ ΠΑΡΑΣΤΑΤΙΚΕΣ ΤΕΧΝΕΣ

Βασικές αρχές Ψυχοφυσικής και Μουσική

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περί ήχου, μουσικής (και άλλων δαιμονίων)

ΚΩΝ/ΝΟΣ ΠΑΣΤΙΑΔΗΣ

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Επισκέπτης Καθ., Ιατρική Σχολή ΕΚΠΑ