# Cognitive Science and Music

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Kajetany, 16.07.2015

# Center for Modern Interdisciplinary Technologies

Why am I interested in this?

Bio + Neuro + Cog Sci + Physics =

Neurocognitive lab.

5 units with many projects testing ideas experimentally.

Main theme: maximizing human potential.
Pushing the limits of brain plasticity and understanding brain-mind relations, with a lot of help from computational intelligence!
Funding: national/EU grants.

# Our toys


NEUROSTAR
Treatment Coil
Prefrontal Cortex
Stimulated Area
Magnetic Field

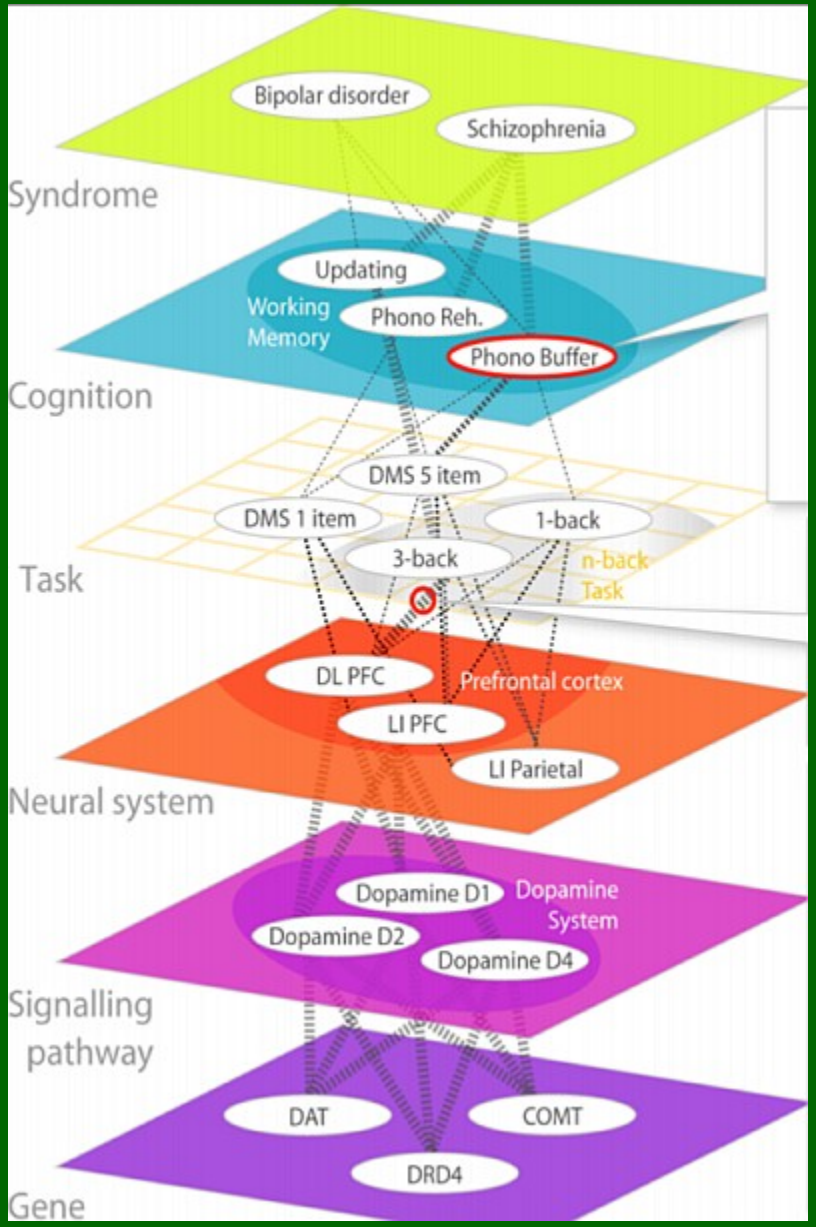
# Neurophenomics in 6 Levels

Initiated by the Consortium
for Neuropsychiatric Phenomics (CNP)
http://www.phenomics.ucla.edu

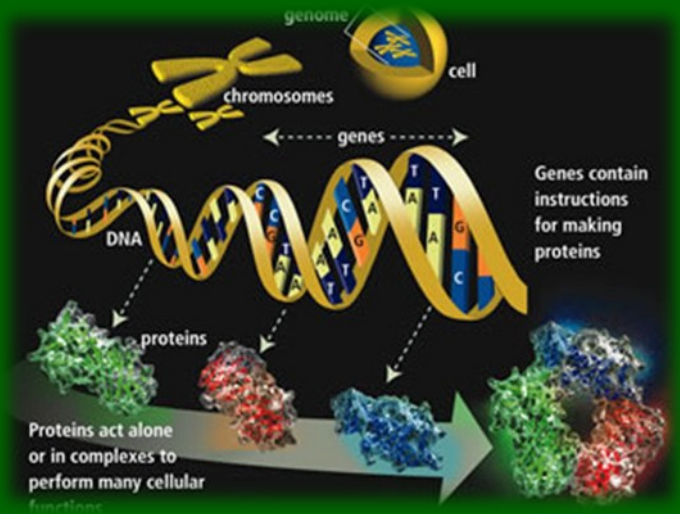
Understanding behavior at all levels.

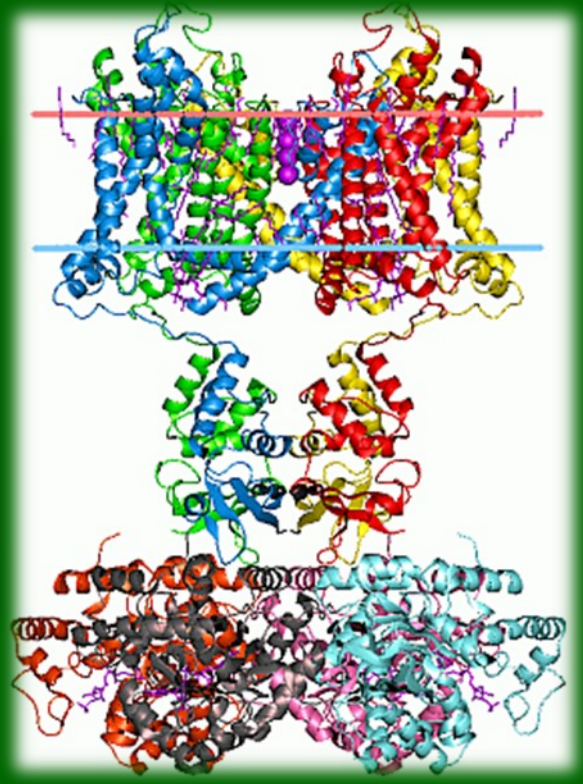
Genes, environment
=> proteins and molecules
=> tissues, neurons and glia
=> networks of neurons
=> large neuronal systems
=> tasks, cognitive subsystems
=> personality, behavioral syndromes.

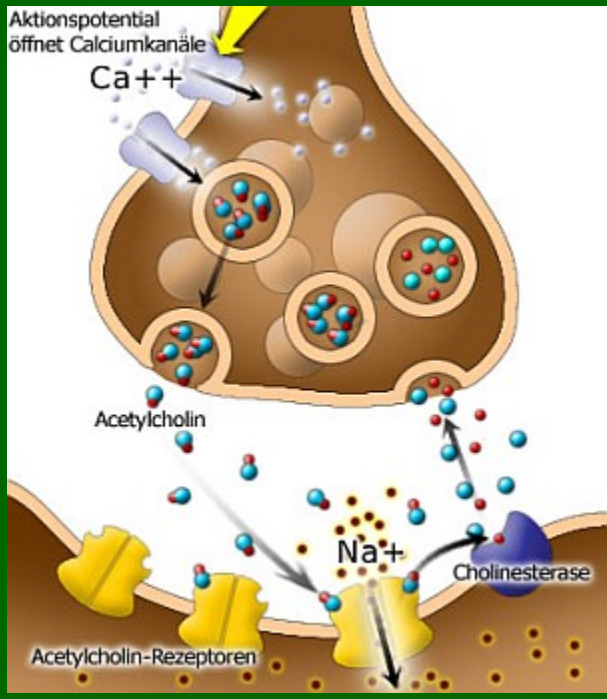
Neurons and networks are right in the middle of this hierarchy.



# From Genes to Neurons

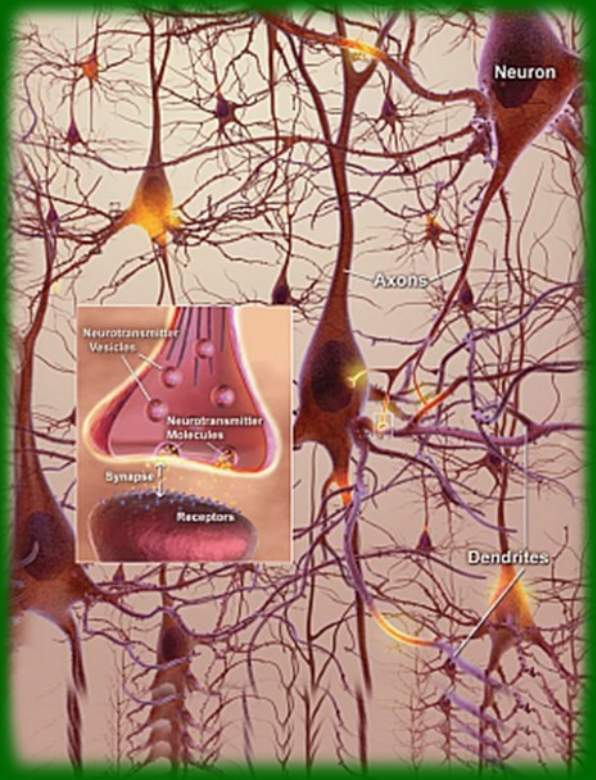


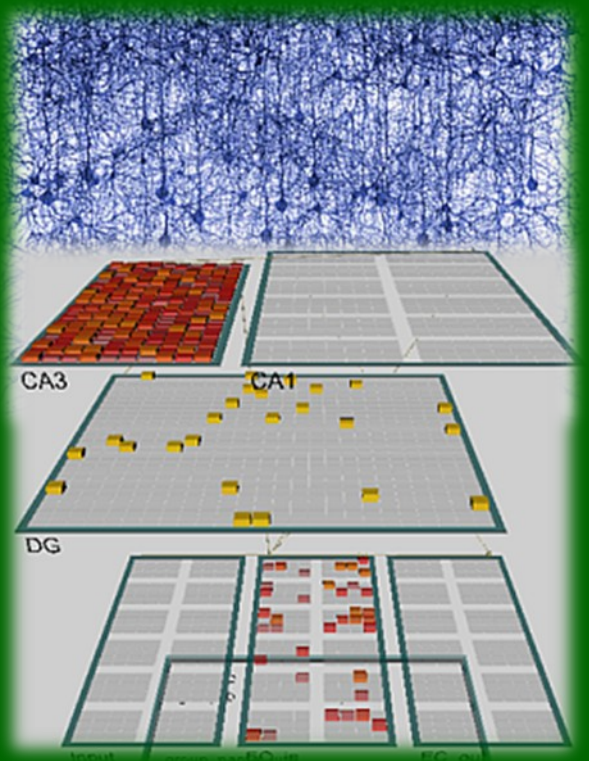






Genes => Proteins => receptors, ion channels, synapses
=> neuron properties, networks, neurodynamics
=> cognitive phenotypes, abnormal behavior, syndromes.

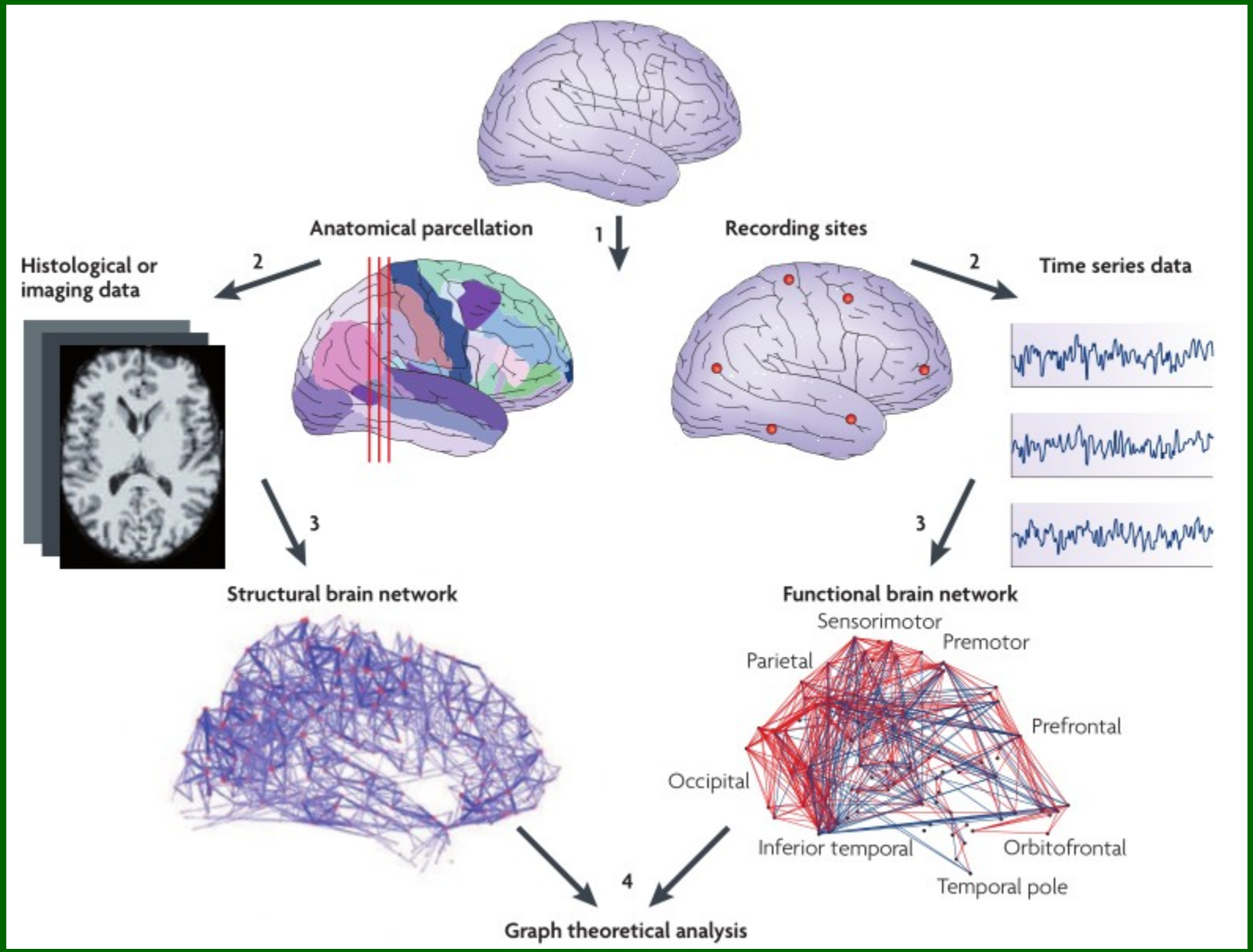
# From Neurons to Behavior




Genes => Proteins => receptors, ion channels, synapses
=> neuron properties, networks
=> **neurodynamics** => cognitive phenotypes, abnormal behavior!

# Structure and function



# Neurophenomenology

Relations between conscious subjective knowledge and brain objective knowledge, understanding “first person perspective”.

The content of our beliefs and thoughts involves concepts, but content of perceptual experiences has non-conceptual qualities that cannot be reduced to symbolic concepts. Even simple questions related to the non-conceptual content are hard to answer. Eg:

Eric Schwitzgebel, Do People Still Report Dreaming in Black and White? An Attempt to Replicate a Questionnaire from 1942. Perceptual & Motor Skills 2003
Why in 1942 people thought that dreams are in black and white?

Without better neurophenomenological characterization of subjective experience, understanding of varieties of ways in which different brains create conscious experiences, including music, it will be hard to draw any reliable conclusions, compare our experiences.

Introspectionism and associationism failed in XIX century for similar reasons ...

# What do I know about myself?


Usually much less than I would like to:

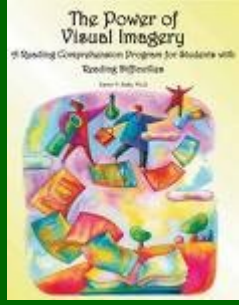
Russell T. Hurlburt and Eric Schwitzgebel,
Describing Inner Experience? Proponent Meets Skeptic, MIT Press 2007.

Conclusion: “I don’t know if this book is in any way an advance.”
Does not even attempt to identify relevant dimensions for mental events.

Eric Schwitzgebel, The Unreliability of Naive Introspection.
Philosophical Review, 117 (2008), 245-273.

We **are prone to gross error** about our own ongoing conscious experience.
Self-knowledge is faulty and untrustworthy.
We are not simply fallible at the margins but broadly inept. Infallible judgments about ongoing mental states are simply banal cases of self-fulfillment.

Examples include: emotional experience [...], peripheral vision [...], and the phenomenology of thought [...].




# Visual imagery

Large field, with several journals, ex:

- Journal of Mental Imagery (1977), official journal of the International Imagery Association (not much neuroscience).
- Imagination, Cognition and Personality (1980), mostly psychological.
- Journal of Imagery Research in Sport and Physical Activity (2007).
- Neuroimaging of Mental Imagery: A Special Issue of the European Journal of Cognitive Psychology (2004)

S. V. Thompson, Visual Imagery: a discussion. Educ. Psych. 10, 1990 , 141-167

Individual differences in visual imagery, together with a lack of understanding that others may think in a radically different way in this respect, may have had a profound effect on theories of thought and knowledge, yet attempts to validate measures of this variable in terms of educationally significant correlates have been relatively unsuccessful.

- Verbalizers and Imagers, division important in education.
  Better tests? More subtle divisions? Statistics?

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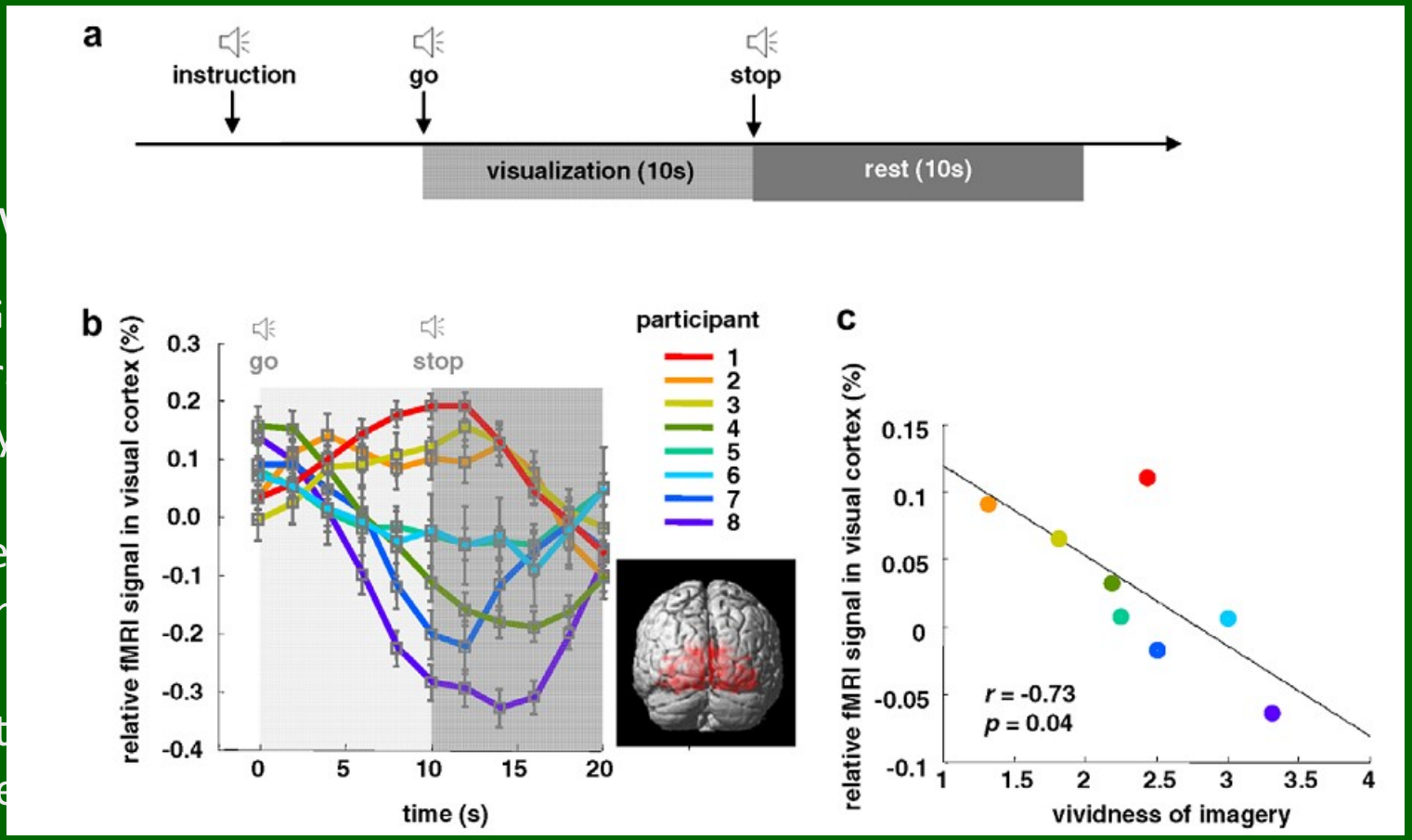
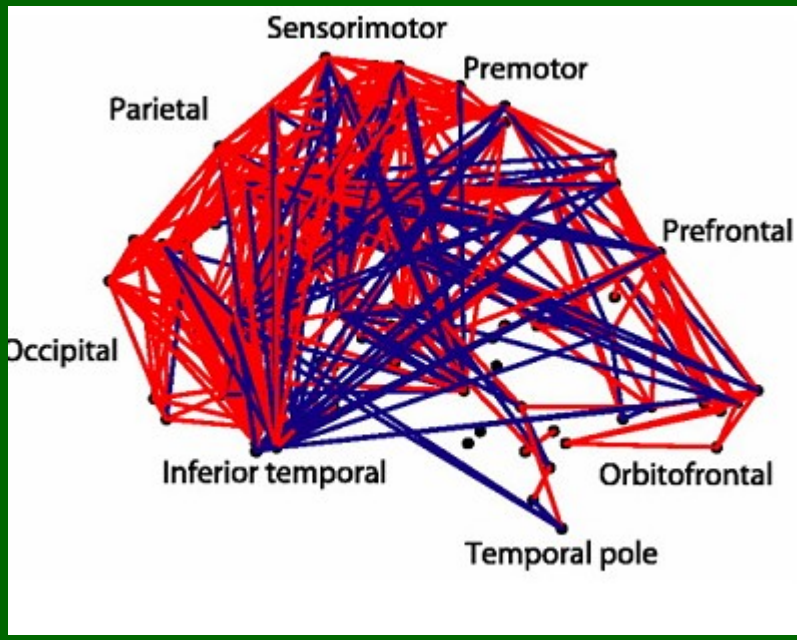



Reported Vividness of Visual Imagination (VVIQ) correlates well with the early visual cortex activity relative to the whole brain activity measured by fMRI (r=-0.73), and the performance on a novel psychophysical task. Findings emphasize the importance of examining individual subject variability.

Poor perceptual imagery: why? Weak top-down influences?

Unable to draw from memory, describe details, faces, notice changes, etc

# Visual top-down




- Normal perception requires top-down influences to form expectations.
- What if PC/FC feedback connections to visual/auditory areas are weak?

- This does not qualify as agnosia, but is a kind of imagery agnosia, something not yet identified!

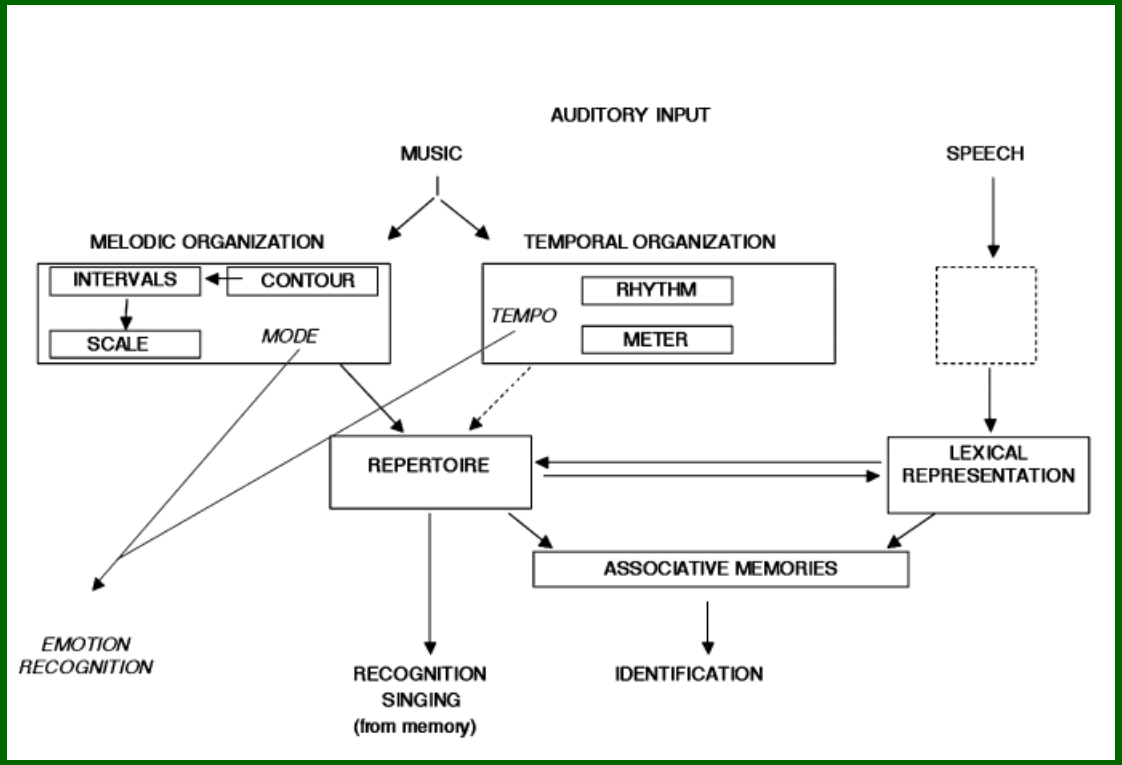
How will the weak top-down activations in visual modality manifest?

Attention problems? Only if top-down connections are very weak, then object recognition in poor lighting conditions may be impaired.
Otherwise: poor visual imagination & memory for visual features, inability to draw from memory, recall and describe faces and objects, notice changes, slow in making puzzles, difficulty to see 3D magic eye pictures, perhaps introvert?
More conceptual than perceptual thinking … recognition memory may work fine

At PC/FC level less interferences from sensory areas, so imagination, creativity, reasoning are fine, perhaps even better than average.

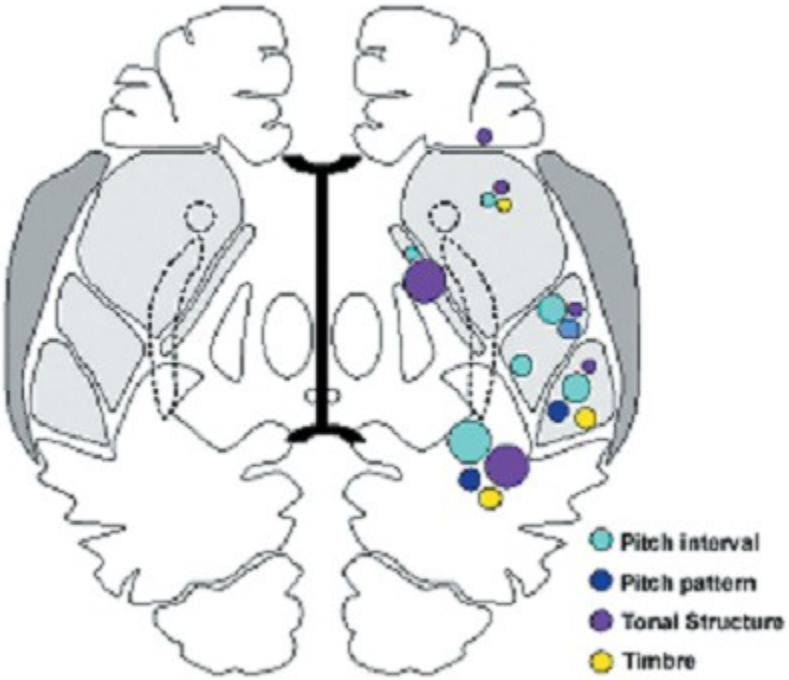
# Auditory Perception

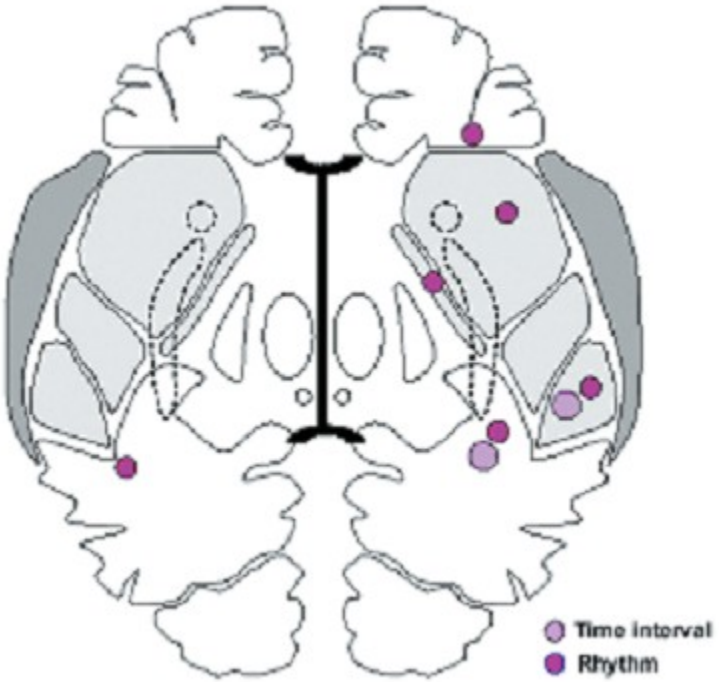
Much less research has been done with auditory perception.




Peretz, I., Champod, S. & Hyde, K, Varieties of Musical Disorders: The Montreal Battery of Evaluation of Amusia. Annals of the New York Academy of Sciences, 999, 58-75, 2003.

Model of music perception behind the MBAE test – no imagery.







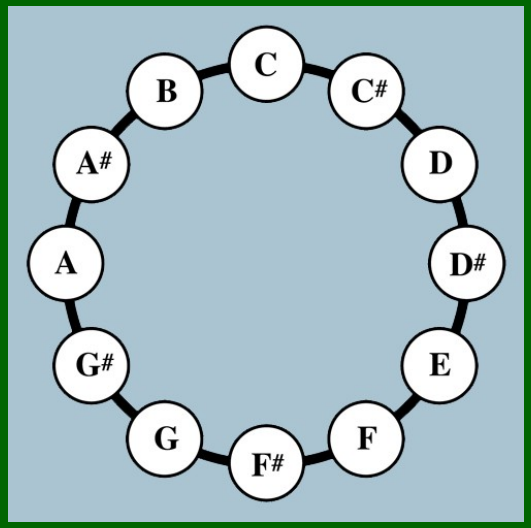
Books that teach improvisation encourage imaging and hearing the effect of playing internally.

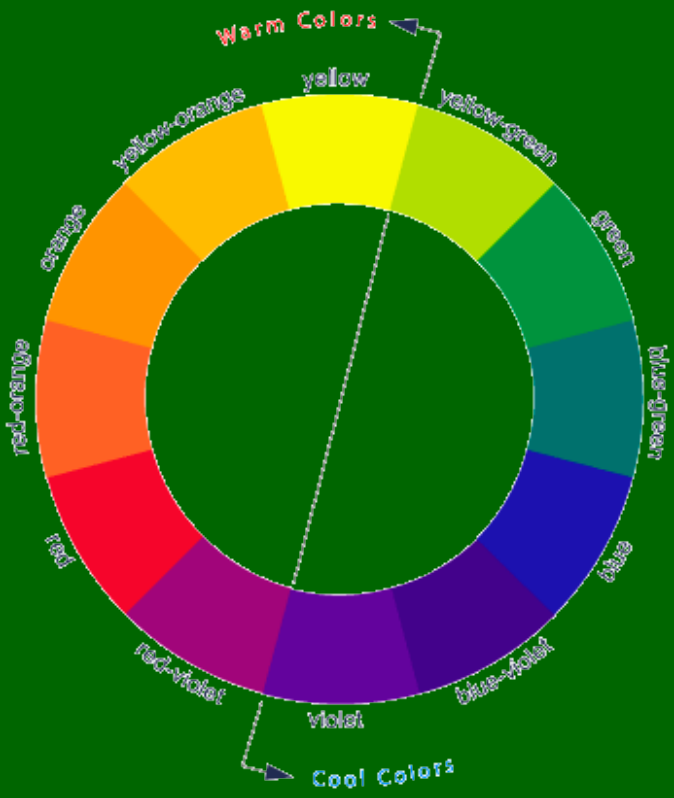
Existing cognitive model of music processing lack imagery and top-down processes, ex: Peretz I, Coltheart M, Modularity of music processing, Nature Neuroscience, vol. 6(7), 688-691, 2003; model also used in:
Stewart L. et al. Music and the brain: disorders of musical listening. Brain, 129, 2533-2553, 2006.

# Pitch anomia

Color anomia is rare: most of us can name about 12 colors.
Pitch anomia is common: few have absolute pitch. Lack of training?


Absolute pitch in population of music students in the USA:
Caucasians 9%
Japanese 26%
Korean 37%
Chinese 65%.
In general Caucasian population < 0.01%

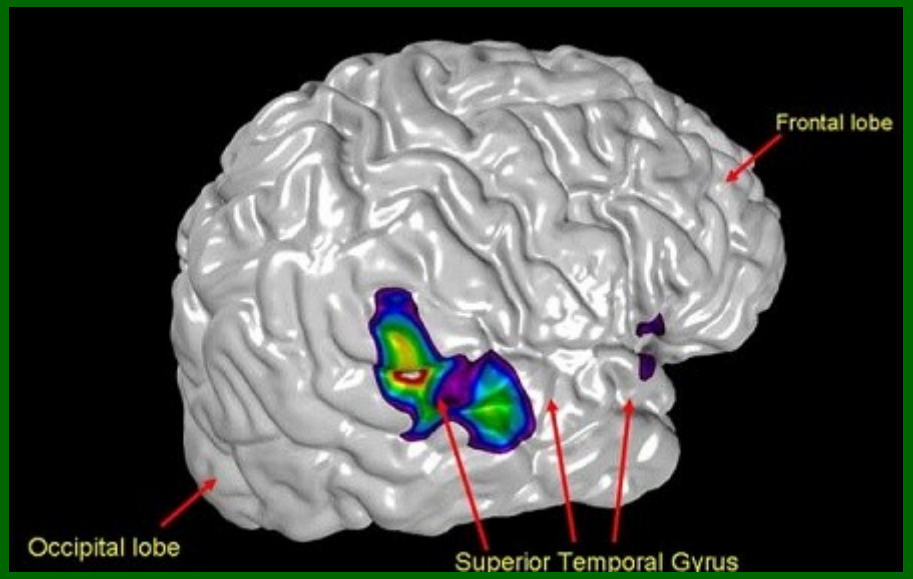


# Music Imagery

fMRI hemodynamic increase during an Auditory Imagery Task performed in silence, in the auditory cortex posterior superior temporal gyrus.

Zatorre & Halpern, Mental Concerts: Musical Imagery and Auditory Cortex, Neuron 47, 9-12, 2004.




Aural imagery or inner hearing is considered to be an important aspect of musical development. Musicians need to connect the sound they desire with a "feel" they know will produce that sound. The goal of music performance is the reproduction of the internal auditory image. (D.R. Allen musicology thesis, 2007)

“An anticipatory image of feedback from an action participates in the selection and initiation or that action. [...] In the closed-loop formulation, the image may serve as a template for comparison with current feedback and need not be activated prior to  performance.” A.G. Greenwald, Psych. Rev, 77, 73-99, 1970.

# Music deficits

Stewart et. al, Music and the brain: disorders of musical listening. Brain, 129, 2533-2553, 2006, long review discussing complex music perception.

Pitch change directions, intervals, melodic patterns, contours, tonal structure, timbre, temporal structures (intervals, rhythm and meter), memory and emotional responses due to neurological problems are described.

**Congenital amusia:** true perceptual agnosia, although hearing and cognition is normal perception of music is not. Usually due to the **deficit in pitch processing**.

Mandell J, Schulze K, Schlaug G, Congenital amusia: An auditory-motor feedback disorder? Restorative Neurology and Neuroscience 25, 2007

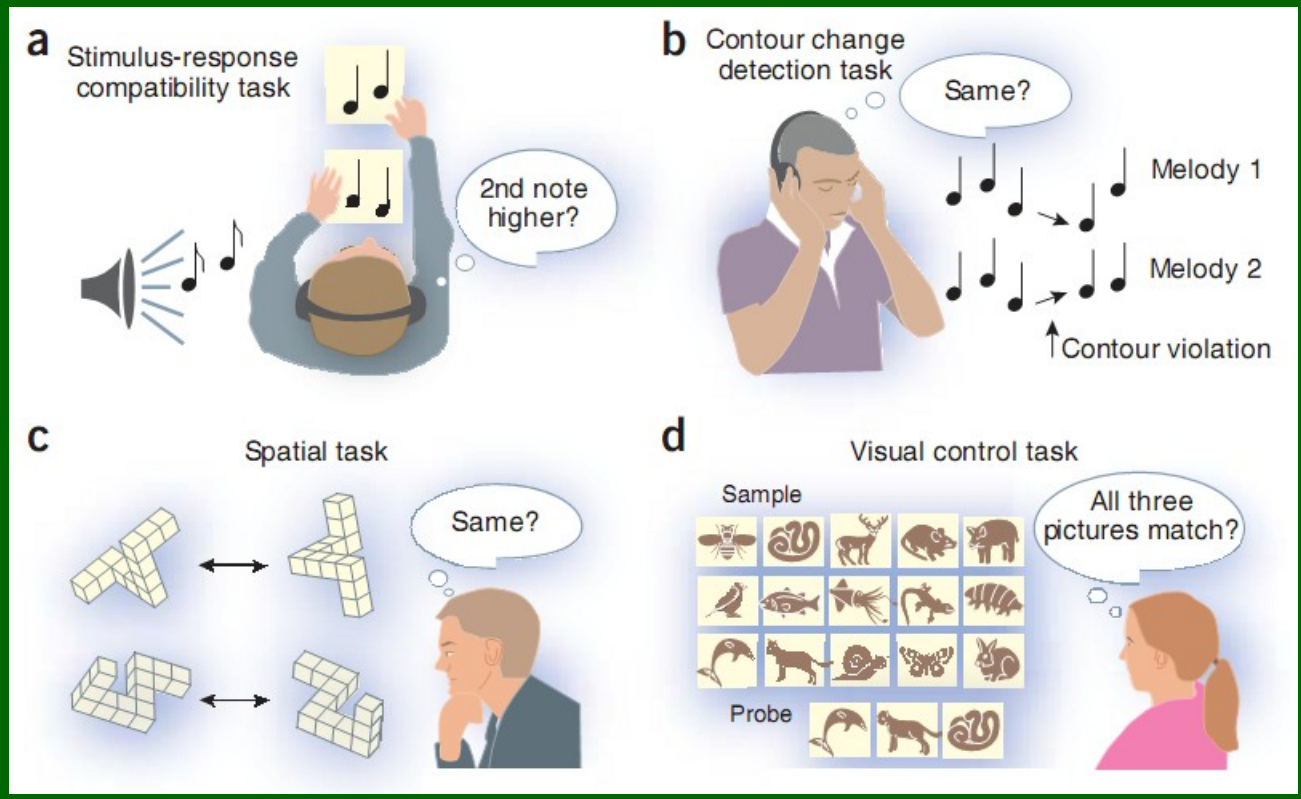
"Thus, it is conceivable that individuals with congenital amusia, or the inability to sing in tune, may actually have an impairment of the auditory-motor feedback loop and/or auditory-motor mapping system."

**Conceivable, but some may have simply poor top-down feedback.**
This seems to be a condition that has not been clearly identified, a new kind of imagery amusia, the inability to imagine sounds.

# Amusia and spatial processing

Anatomical locus of amusia, neuroimaging/lesion studies: auditory areas along the superior temporal gyrus in pitch discrimination and melodic contour processing.

But **amusics** show deficits relative to musicians and nonmusicians, in tasks that involve spatial processing.




Douglas, K.M. & Bilkey, D.K. Nature Neurosci. 10, 915-921 (2007)

There is no evidence for morphological correlates of amusia in parietal regions.

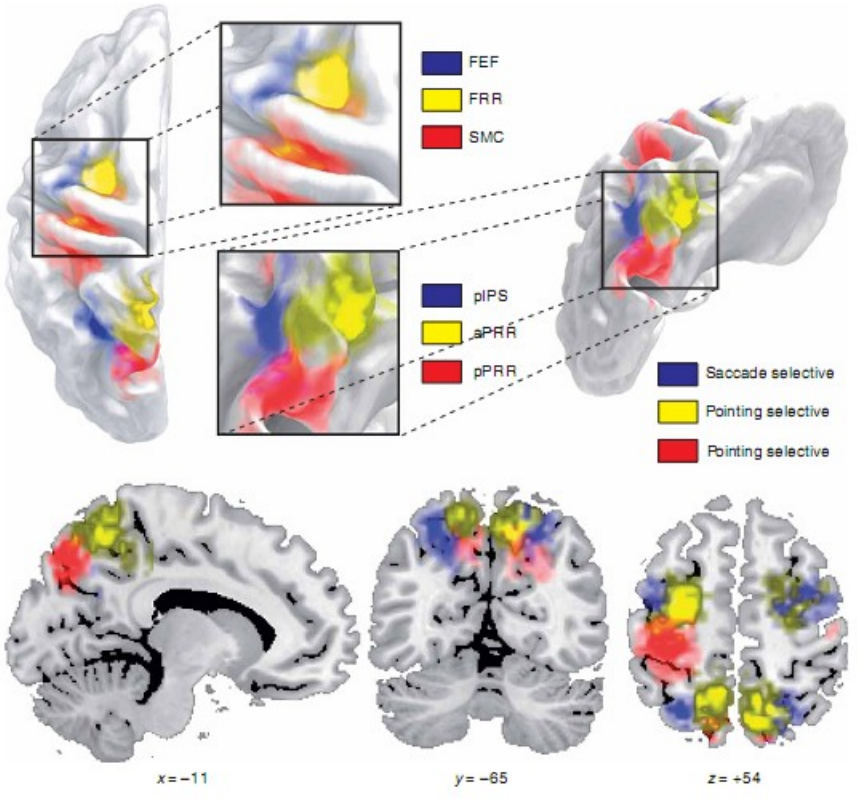
"The deficit may derive from **changes in neural functioning** that are **invisible** to the tools that have been applied to date."

# Parietal c

A. Tosoni et al, Nature Neuroscience 11, 1
mechanisms in human parietal cortex unc

In arbitrary association of visual stimuli wi
effector-specific regions in human posteri
sensory stimuli per se, but to **integrated s**
outcome, triggered by contextual stimulu

**Hypothesis**: normal perception requires t
expectations. What if feedback connectio

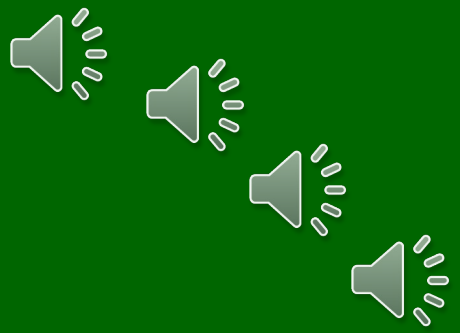



C. Gilbert, M. Sigman, Brain States: Top-Down Influences in Sensory Processing. Neuron 54, 677-696, 2007.

"New findings on the diversity of top-down interactions show that cortical areas function as adaptive processors, being subject to attention, expectation, and perceptual task. Brain states are determined by the interactions between multiple cortical areas and the modulation of intrinsic circuits by feedback connections. ... Disruption of this interaction may lead to behavioral disorders."

# Window of perception

In auditory domain perception is localized in a window of a few seconds:



- It was found that the *eel was on the axle.
- It was found that the *eel was on the shoe.
- It was found that the *eel was on the orange.
- It was found that the *eel was on the table.

People asked what did they hear say:
wheel, heel, peel, meal, depending on the context.

- Noise adds energy (stochastic resonance effects).
- Context adds structure to neural activation.
- Neurodynamics is interpreted internally as perceptual experience.

# What goes on in my brain?

I do have little access to perceptual imagery, visual, auditory, tactile or gustatory.

I am not more privileged to have conscious insight into my own brain then external observer! I have no idea what will come out before I play and hear it.

I am a listener, like everyone else, listening to what my brain tries to say.
Learning to play music without imagery is difficult – **how far can one go**?

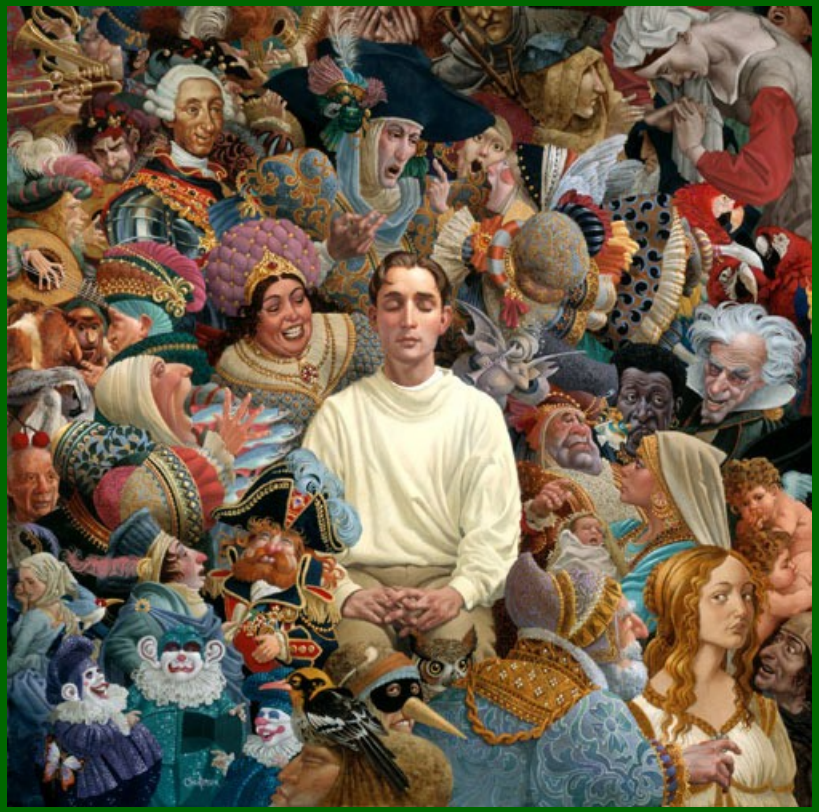
Recognition memory is fine, but **without inner ear** how will I know what to play? No recall, I cannot repeat simple melody, but can read music and improvise. Conscious mental rehearsal is not possible. Without **internal feedback** the only way to learn about plans formed by my brain is to act and observe results.

"We know ourselves only in so far as we have been tested" (W. Szymborska).

Inability to consciously interpret our own **brain states** leads to the need to **express and recognize** them through various **bodily actions**.

I scratch my head, make gestures, repeat myself, add irrelevant words just to slow down, because the brain needs more time to parse/associate.
"We are not masters of our own house"(S. Freud).

# The Listener



James C. Christensen

# Many questions

To understand talent in its many forms it would be good to know:

**Statistics** on clear visualizers/auditory/taste imagery ect. How clear is it?
Is there correlation between lack of different types of imagery?
15% of population has difficulty in singing, but only 5% congenitial amusia.

High-level processes, such as imagery, planning & creativity, do not have to be conscious – **when is consciousness essential**?

**Interpretation** of many experiments may be **wrong**, **mixing brains** that work in quite different styles (like statistics for cognitive decline).
**Spatial deficits** are correlated with amusia; distinguish between imagery and other types of amusia and find people with amusia without spatial deficits!

Possible applications:

**Education**: need for simple giftedness tests – ERPs for imagery?
How to develop personalized education styles? Music/art education?
**BCI** (with Klonowski, Perovic, Jovanovic) – for those that have imagination?
How many states can be distinguished by pitch? Timbre? Rhythm?

# Music perception with implants

L. Timm et al. Residual neural processing of musical sound features in adult cochlear implant users. Front Hum Neurosci. 2014 Apr 3;8:181

The musical **multi-feature paradigm** involves deviant sound features (such as pitch, timber, intensity, and rhythm) embedded in the "Alberti bass," where three different pitches alternate in a four-note pattern changing over the 12 keys.

"Our results suggest that even though cochlear implant (CI) users are not performing at the same level as normal hearing controls in neural **discrimination of pitch-based features**, they do possess potential neural abilities for music processing. However, CI users showed a **disrupted ability** to automatically **discriminate rhythmic changes** compared with controls.

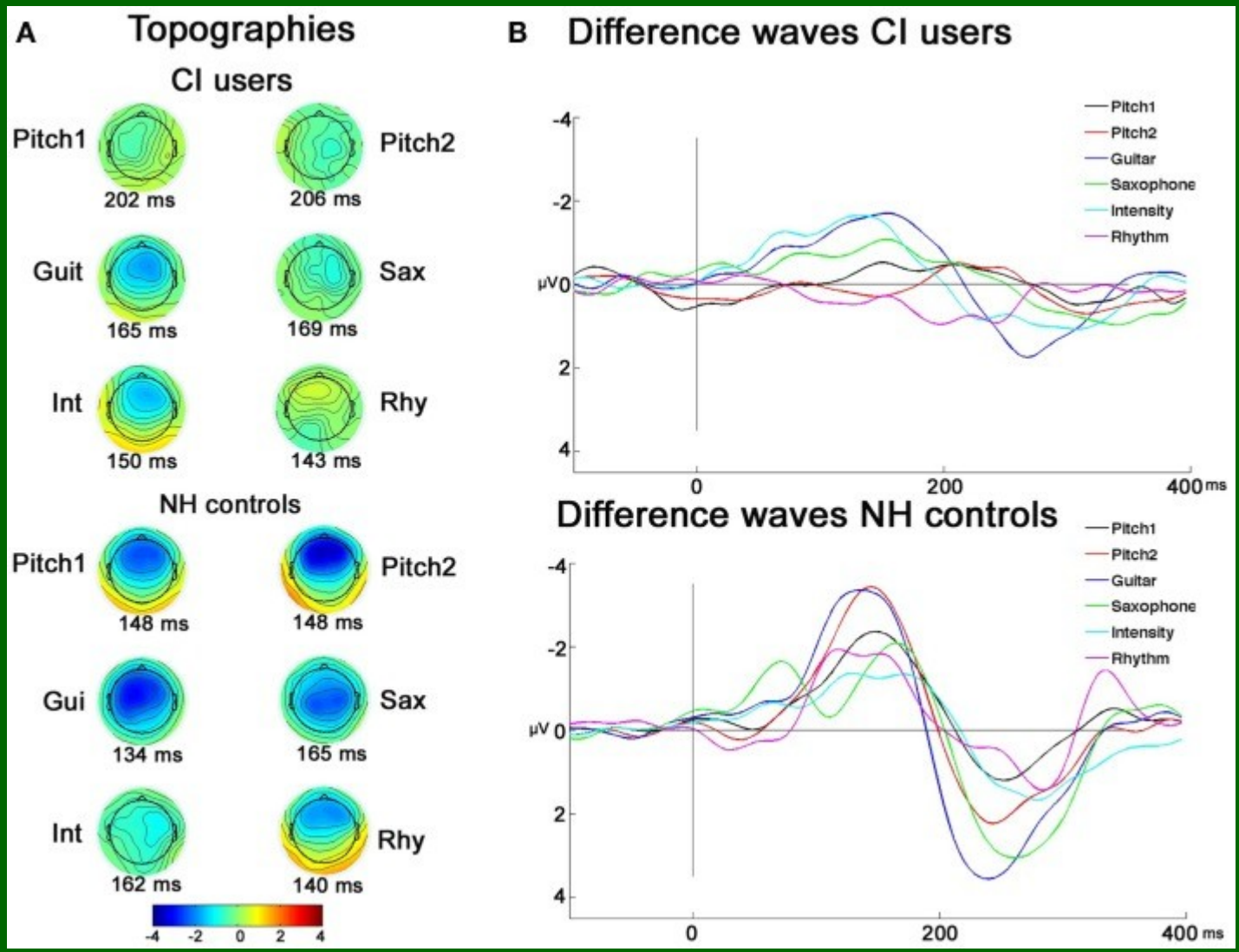
The current behavioral and mismatch negativity findings highlight the **residual neural skills for music processing** even in CI users who have been implanted in adolescence or adulthood."

Challenge: how to automatize improvements of correct discrimination of all features? Neurofeedback on filtered EEG for automatic adaptation?

# Timm et al results

(A) EEG maps, responses to deviants minus standards around maximal peak amplitudes

(B) Grand-average difference-waves of CI users and NH controls.



# The expanded OPERA hypothesis

A.D. Patel, Can nonlinguistic musical training change the way the brain processes speech? The expanded OPERA hypothesis.
Hearing Research 2014 Feb;308:98-108.

Musical training benefits speech processing (e.g. hearing of speech in noise, and prosody perception). Listening to rap is a good exercise.

The expanded OPERA hypothesis:
- music and speech share sensory & cognitive processing mechanisms;
- music places higher demands on cognitive mechanisms;
- higher demands + the emotional rewards of music + frequent repetition during musical training + the focused attention required

results in
- neural plasticity, changes in brain structure/function that impacts also speech processing.

Pilot study has been done on the impact of musical training with melodic contours played by cochlear-implant users on their speech perception, with promising results.

# Involuntary musical imagery (INMI)

Involuntary musical imagery (INMI), internal perception of spontaneous melodies, repetitive musical sounds.

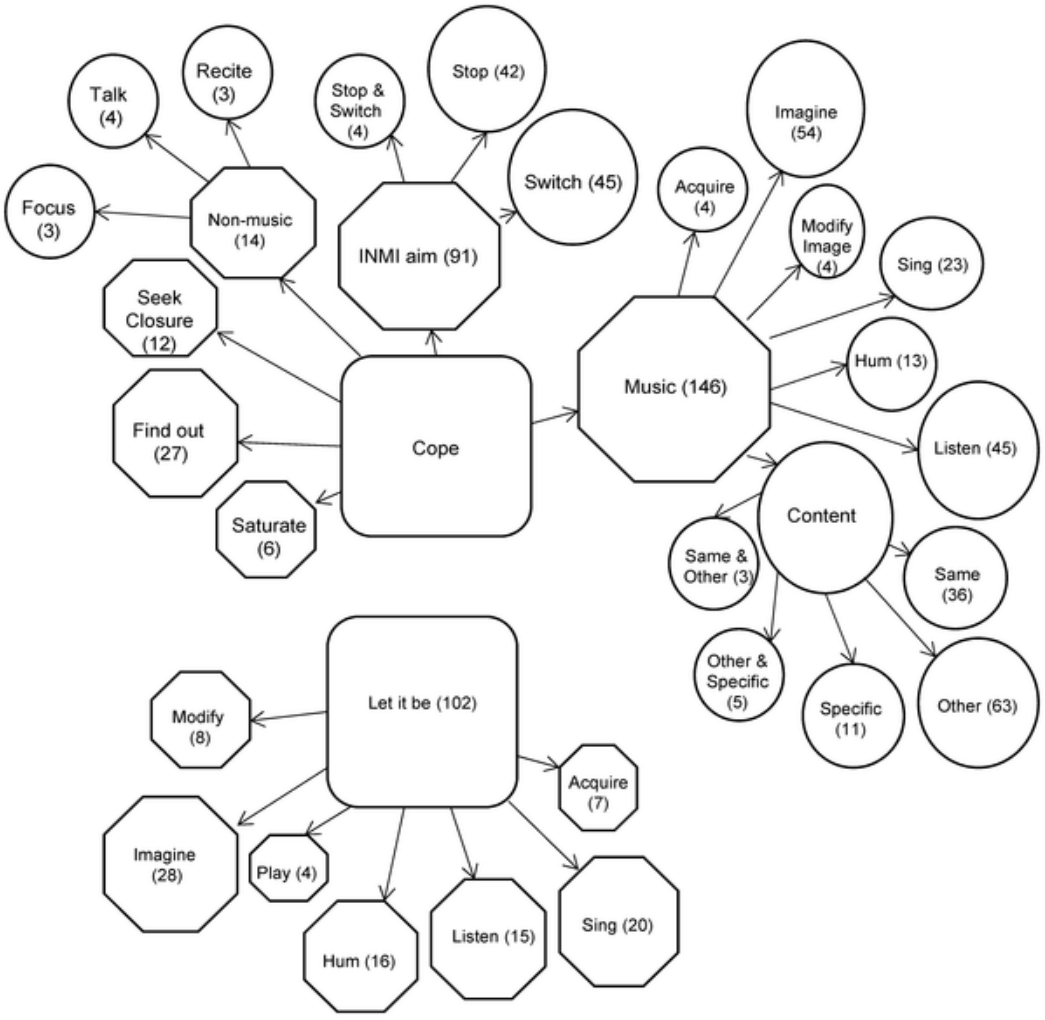
How common is INMI? How people react to INMI? Can they control it?

Analysis of 1046 reports in Finland and the UK:  many INMI episodes were considered neutral or pleasant, with passive acceptance and enjoyment being among the most popular response behaviours. A significant number of people, however, reported on attempts to cope with unwanted INMI.

Activity and context situation => the experience of mind wandering
=> enables INMI. It happens at different time of the day, subjective evaluation of the INMI experience depends on the context situation.

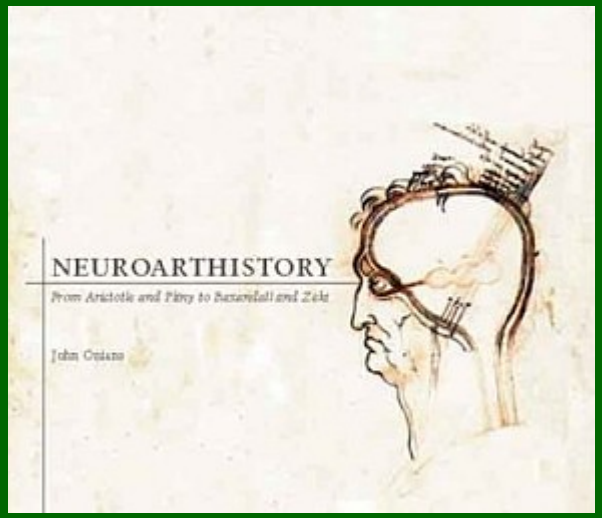
Frequency of INMI was related to cortical thickness in regions of right frontal
and temporal cortices as well as the anterior cingulate and left angular gyrus. Affective aspects of INMI (wish to suppress or enjoy it)  were related to gray matter volume in right temporopolar and parahippocampal cortices.
INMI is a common internal experience recruiting brain networks involved in perception, emotions, memory and spontaneous thoughts.

**Figure 1. Visual model of all Involuntary Musical Imagery (INMI) reactions including evaluations and behaviors (Finnish Study).**




Williamson VJ, Liikkanen LA, Jakubowski K, Stewart L (2014) Sticky Tunes: How Do People React to Involuntary Musical Imagery?. PLoS ONE 9(1): e86170. doi:10.1371/journal.pone.0086170
http://127.0.0.1:8081/plosone/article?id=info:doi/10.1371/journal.pone.0086170

# Neurohistory?




Speculations based on Zeki and Ramachandran neuroestetics applied to art history:

John Onians „Neuroarthistory: From Aristotle and Pliny to Baxandall and Zeki"; Yale University Press, Yale University Press 2008

Why and how art has changed in the history?

Why particular music forms have appeared around the world?
Why some musical forms have become popular at certain times?
Why some stayed and other vanished?

How is this related to perception mechanism? Technical developments in construction of instruments? Social millieu?

Is neurohistory of music possible and worth developing?

# Summary

- Individual differences in musical imagery is an interesting subject for study.
- Various forms of imagery agnosia have not yet been studied but may be important in understanding talent.
- Music training may influence various aspects of speech perception.
- Neurofeedback techniques combined with filtering of EEG artifacts and optimization techniques (evolutionary algorithms have been patented for such applications) may lead to significant improvements of adaptation to implants.

**Thank you for lending your ears ...**

Google: W. Duch => Papers/presentations/projects