Selected topics in cognitive science and biomodeling

L9: Motor & auditory

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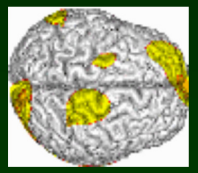
What it will be about

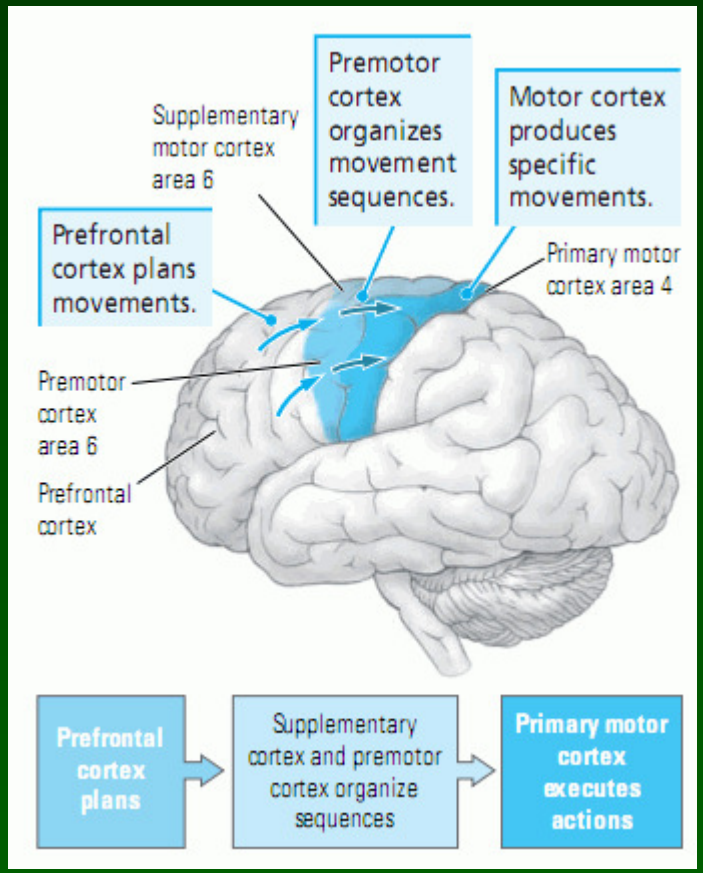


1. Information flow in the brain.
2. Sensory input coding - receptors.
3. Cortex functions.
4. Learning, coding sensory information.
5. Topographical maps and somatosensory perception.
6. Population coding – active perception.
7. Sound perception.
8. Vision.
9. Memory …

Motor control

On the other side of central fissure, opposite to the SI cortex the primary motor cortex MI has also topographical structure.

- Plans for movements are made in the prefrontal cortex;
- organized into sequences of primitive movements in the premotor (SMA) cortex with the help of basal ganglia;
- MI executes actions and cerebellum adds smooth control to many muscles.
- Information is sent to muscles using motoneurons, specialized motor fibers.
- To coordinate movement of many muscle units population coding is used.



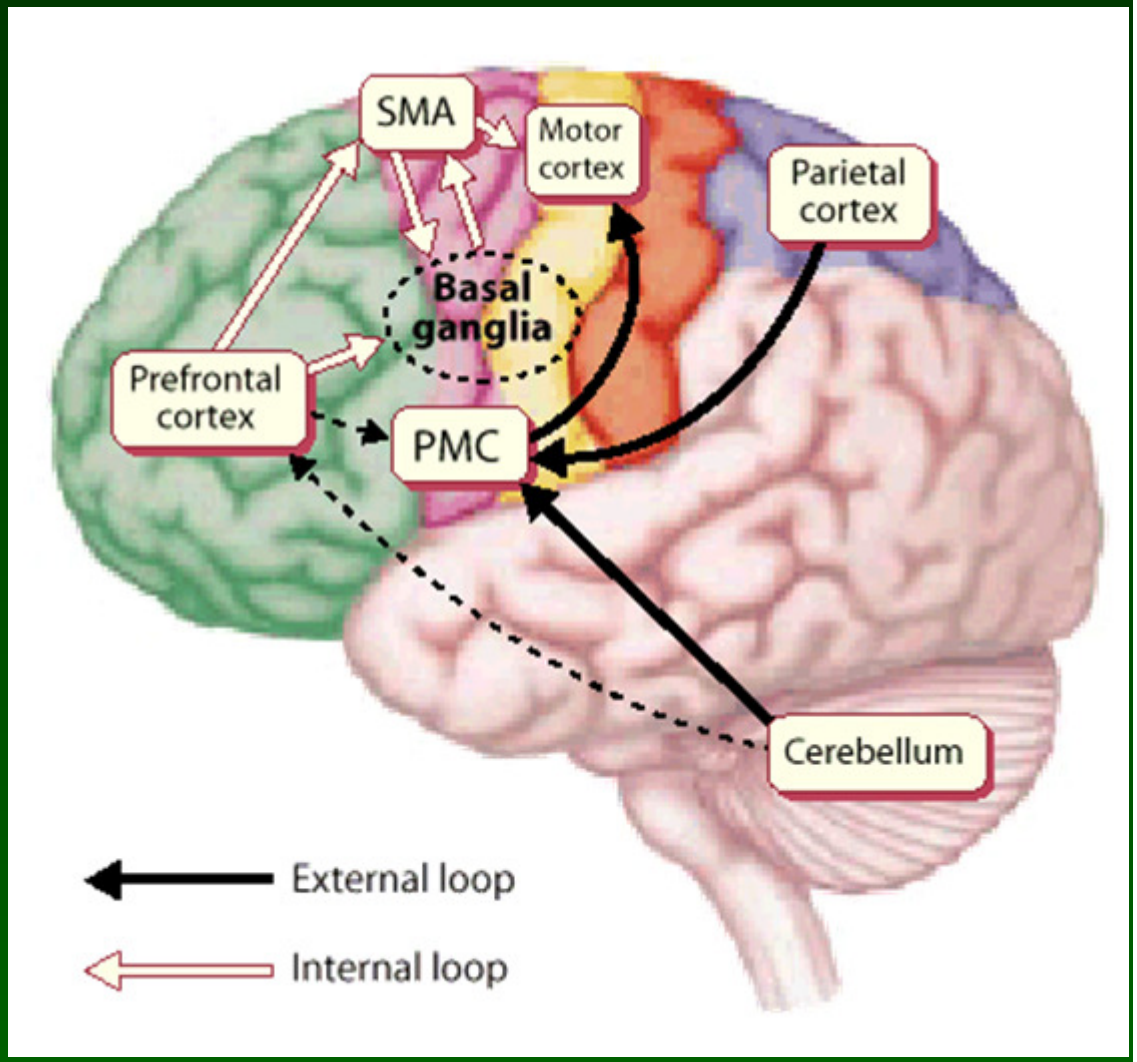
Motor control - overview

How can we learn about ourselves?

Some control information is internal but some comes from observations of the results of our actions.

External loop is needed to train the brain: play, watch and listen what happens.

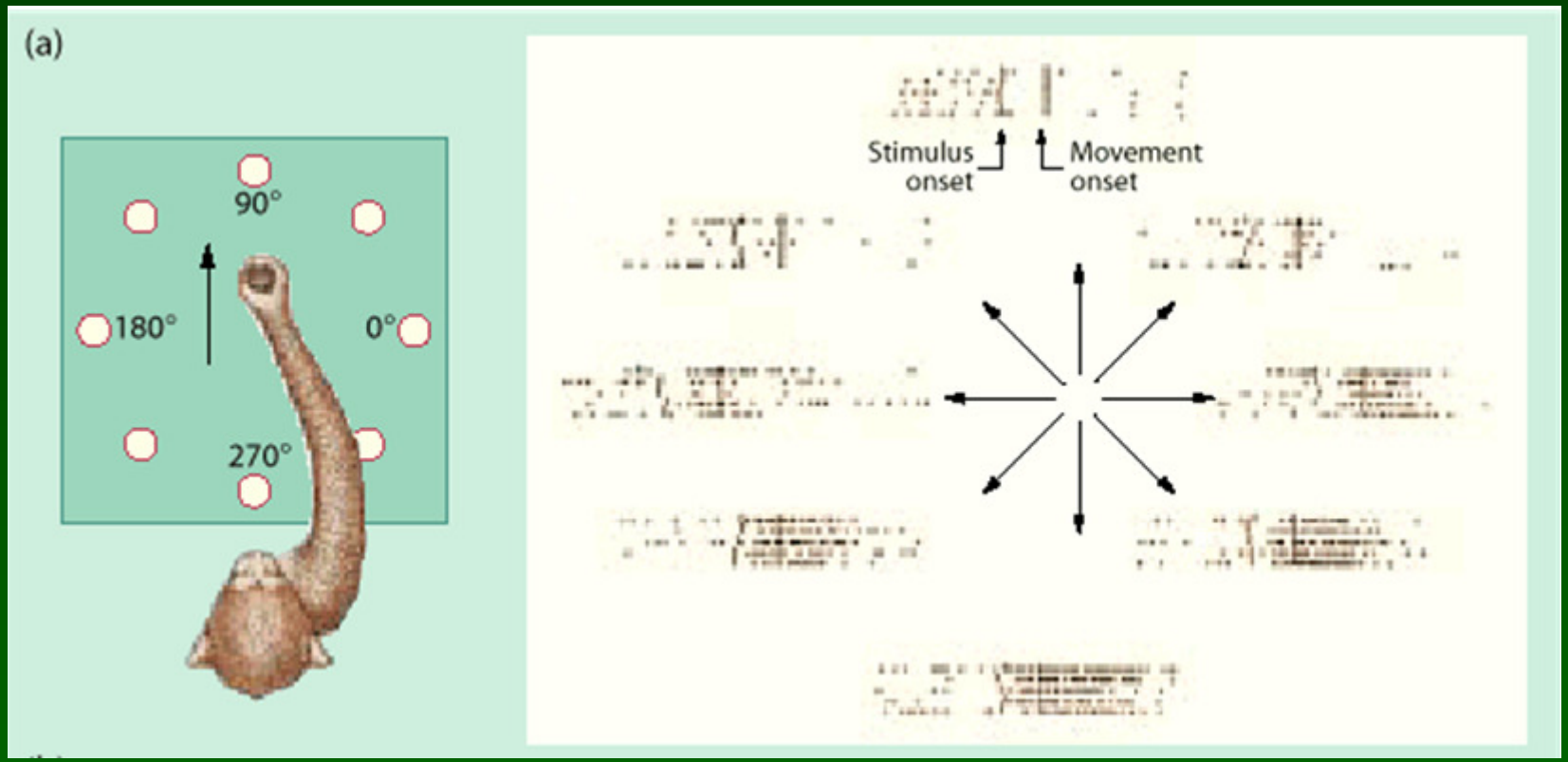
We know how to act because we have external feedback, not only internal.



Population coding

Experiments in primates show that motor neurons in MI have preferred direction, with broad tuning curves around this direction.

Summing preferred directions over whole population gives overall direction of real movement (Georgopoulos, Science, 1986).



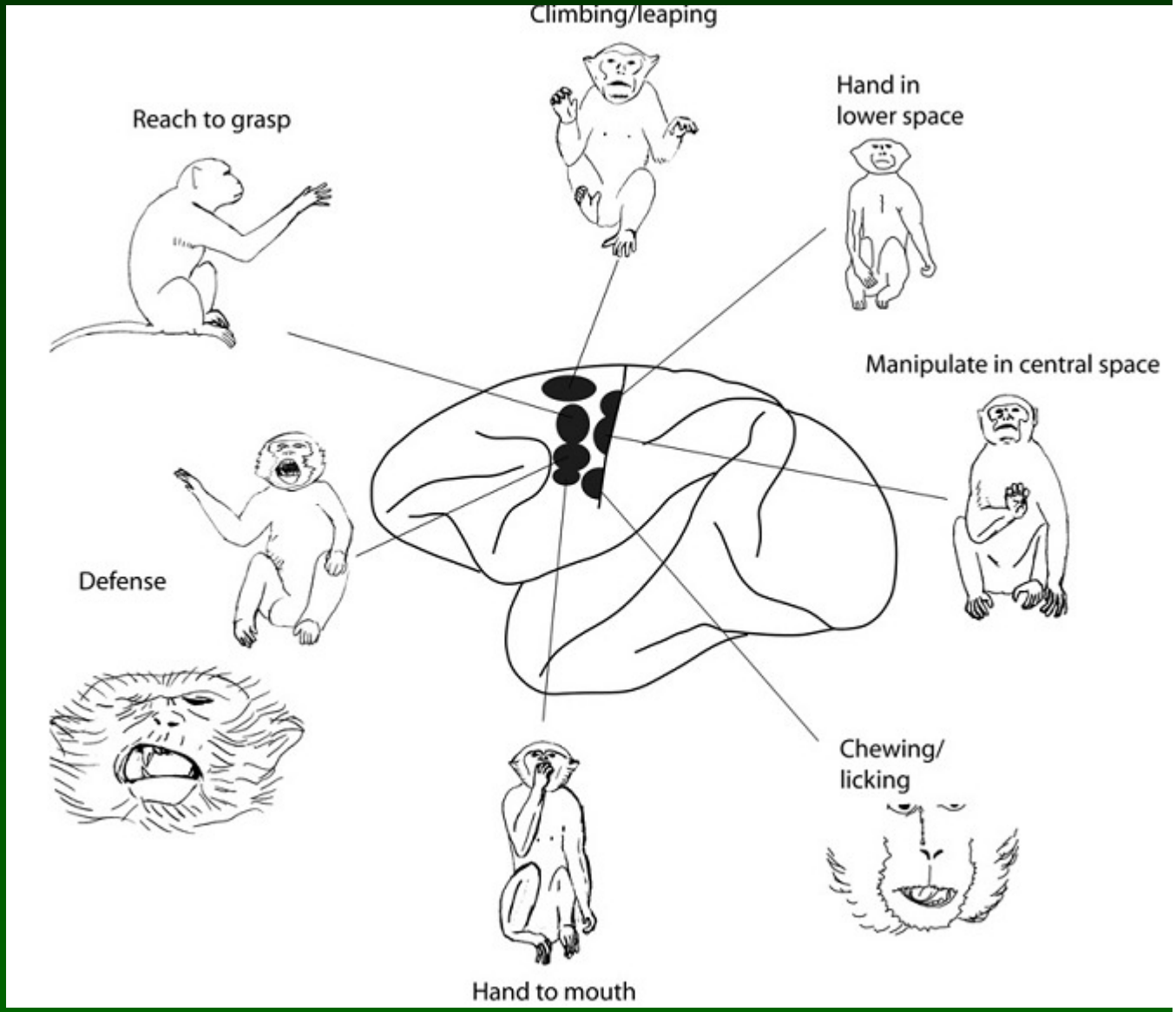
MII motor cortex

More complex movement patterns are coded in the SMA premotor areas, and the basal ganglia.

Stimulation with weak currents for 0.5 sec will elicit such movements.

Continuity of similar actions is preserved.

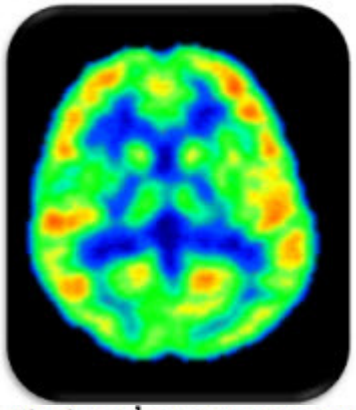
Graziano & Aflao 2007



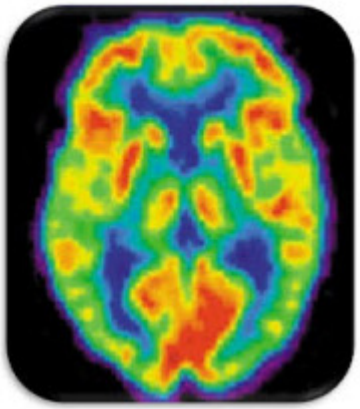

THIS MIND
INTENTIONALLY
LEFT BLANK

Sound in the brain

The brain at rest



The brain's reaction to music



Musical activities stimulate development in every area of the brain.

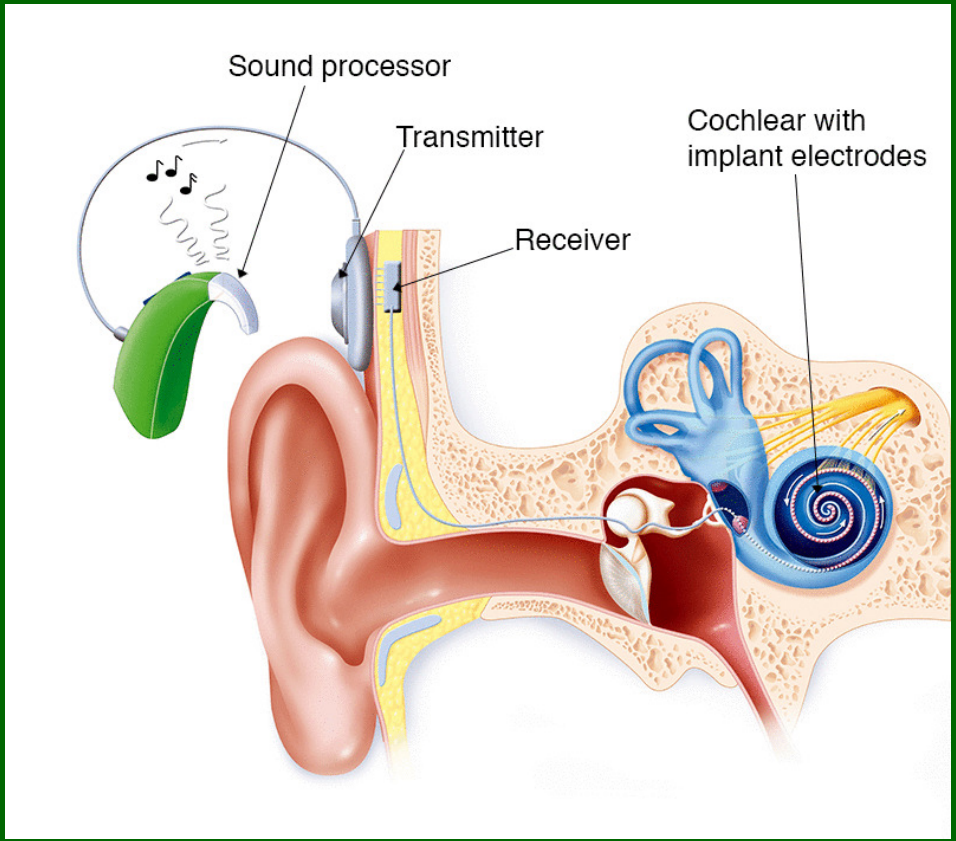
- Vision
- Sensation
- Balance
- Skill
- Speech
- Movement
- Behavior
- Emotion

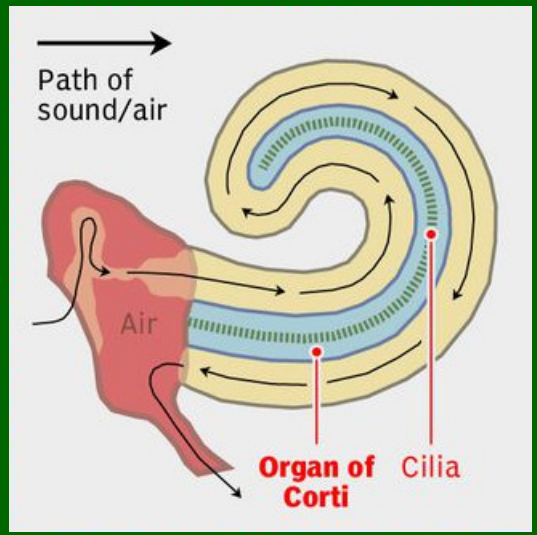
Kindermusik

Do we all hear the same things when we hear music?

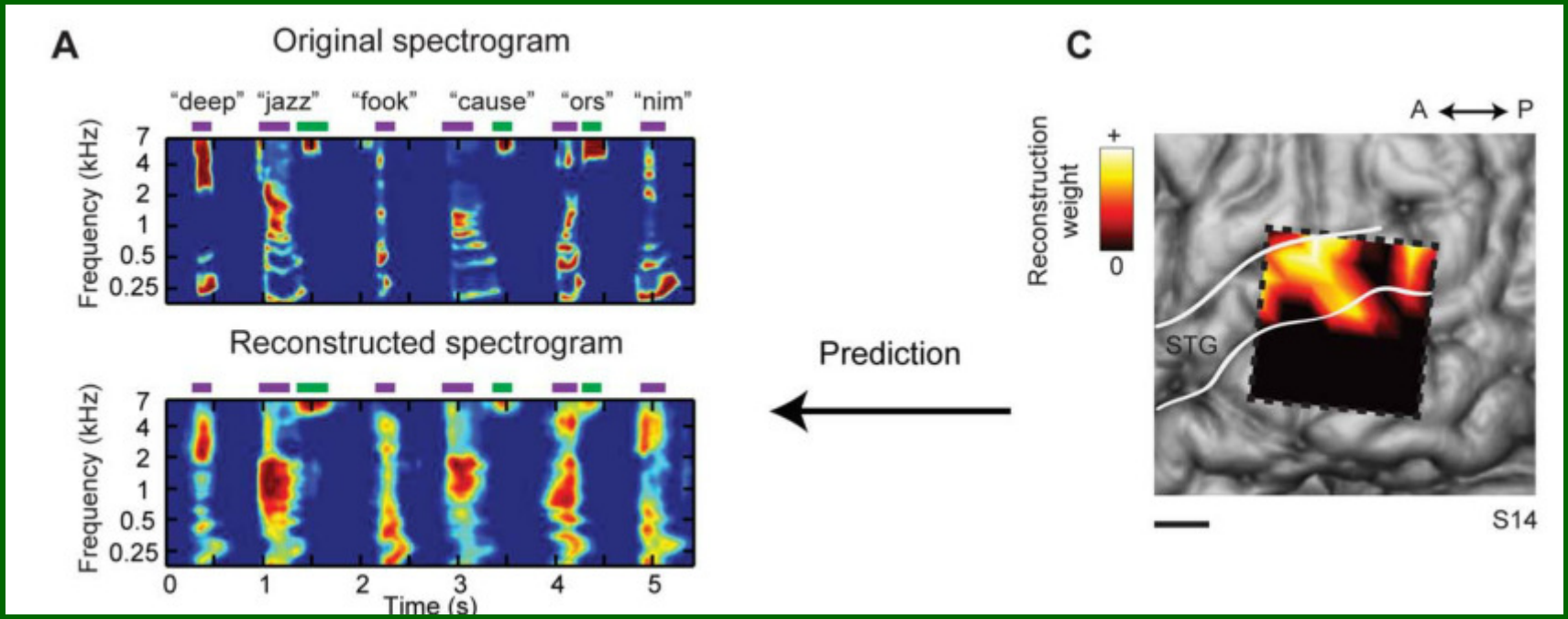
Sound into the brain

Acoustic pressure moves cilia (small hair) in the cochlea, mechanoreceptors attached to cilia generate impulses trasmitted by the auditory nerve to cortex.
Cochlear implants use many electrodes for stimulation of auditory nerve.
Limited: vibrotactile activations on skin, bone conduction.





Time, place, energy, frequency



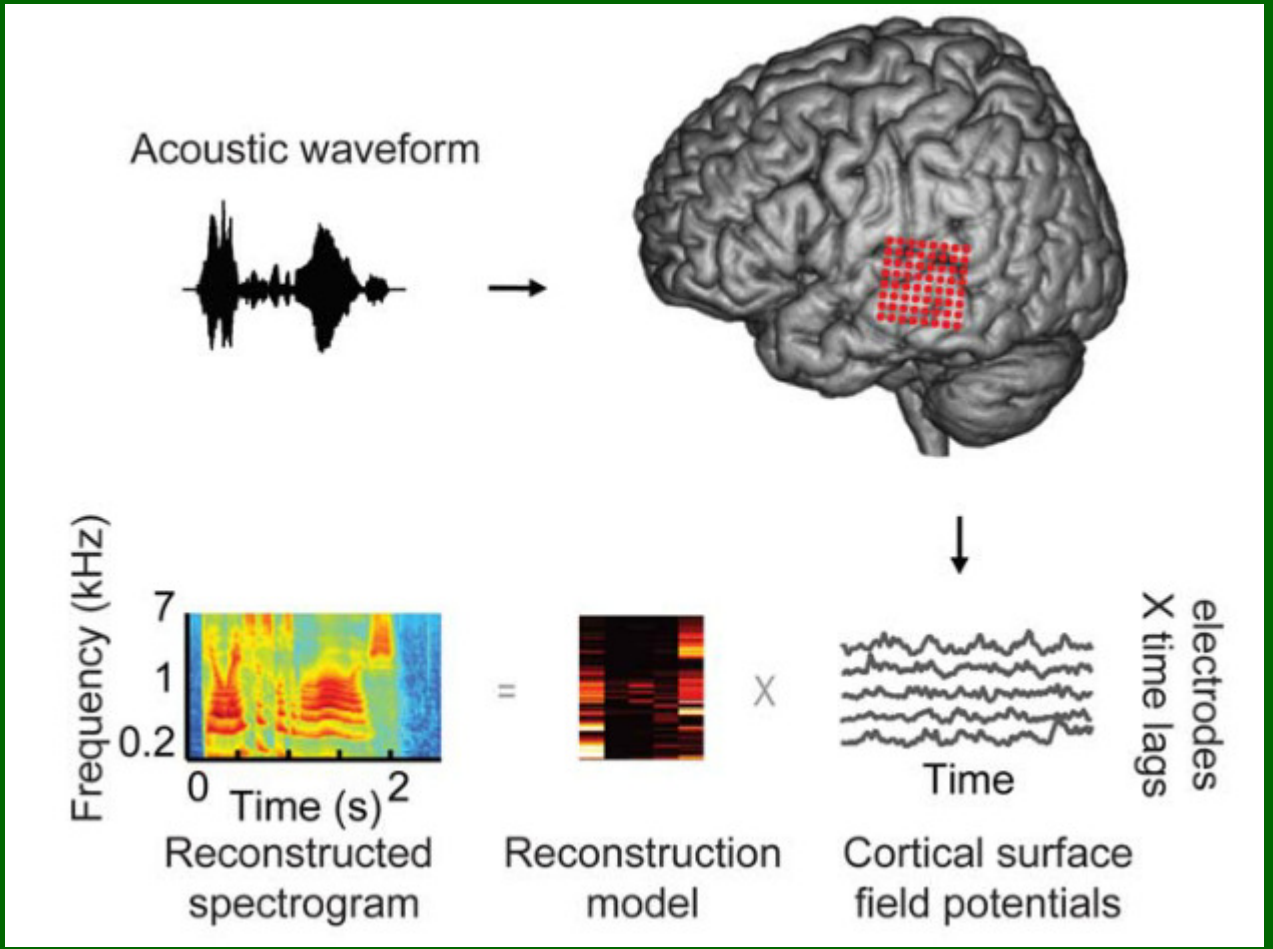
All brain activity is just trains of neural spikes and microcircuit oscillations.

Sounds can be recreated from neural representations using 4-dimensional spectrograms of the auditory cortex activity.

Pasley et al. Reconstructing Speech from Human Auditory Cortex. PLOS Biology 2012.

Sound from neurons

A mesh of electrodes measuring cortical electric field potentials allows for reconstruction of speech from measured brain activity.



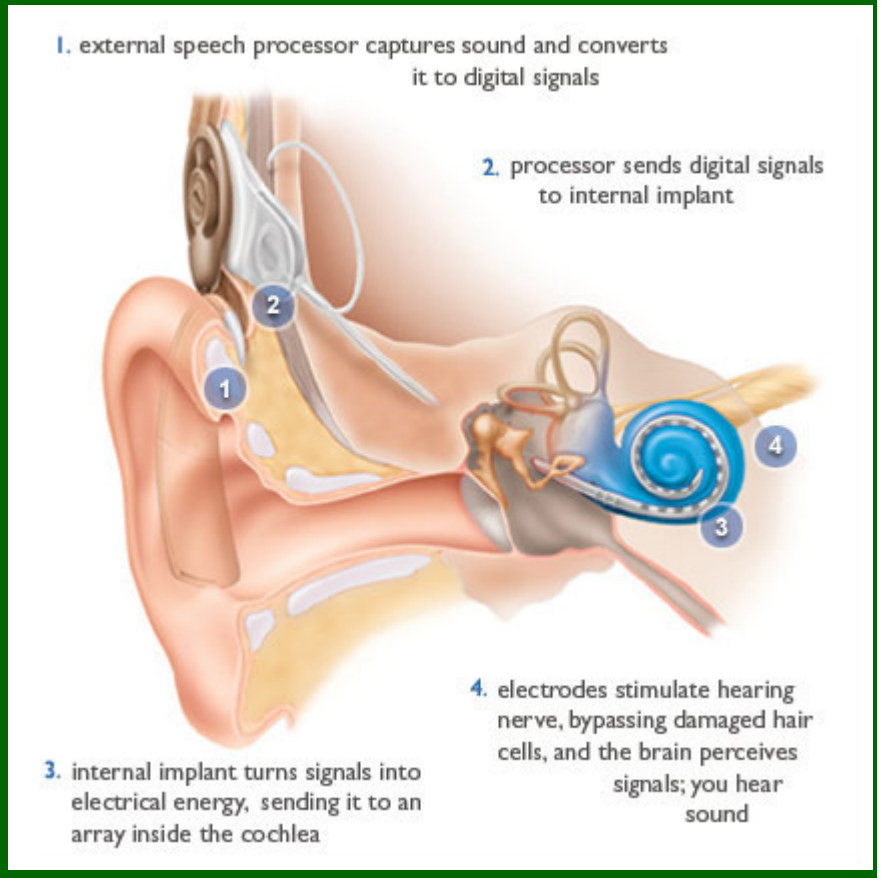
Music perception with implants

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

"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.

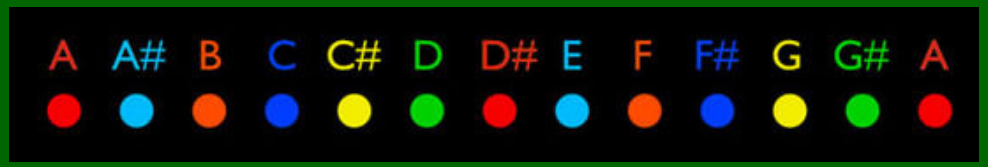
The current behavioral and EEG findings highlight the **residual neural skills for music processing** even in CI users who have been implanted in adolescence or adulthood."

„Beats of Cochlea Music Festival" of implanted people in Warsaw!



Special talent or agnosia?

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



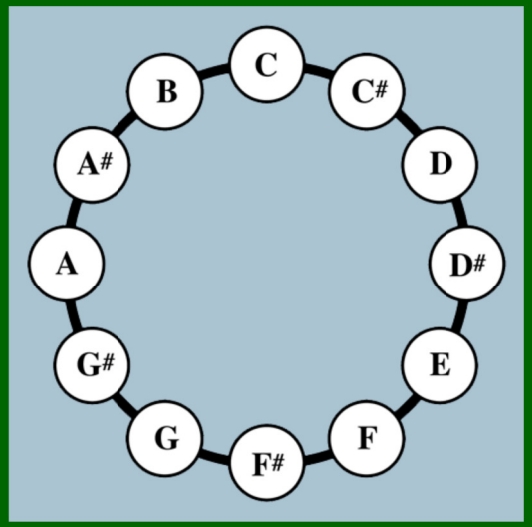
Special gift?
Or lack of training?

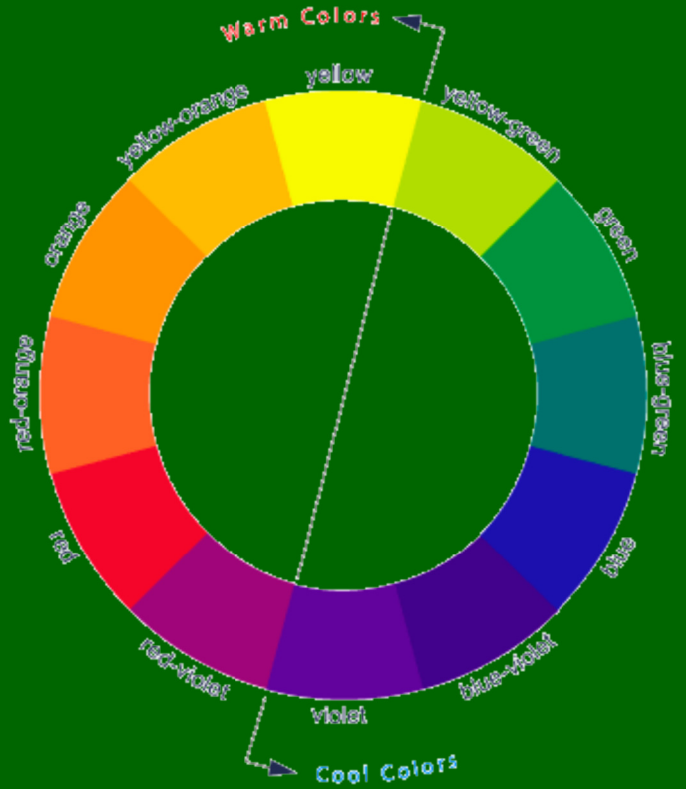
Absolute pitch in population of music students in the USA:
Caucasians 9%
Japanese 26%
Korean 37%
Chinese 65%
In general Caucasian population < 0.01%

Agnosia of synesthesia.

Grapheme-color synesthesia has been induced.

Induced color-pitch synesthesia?





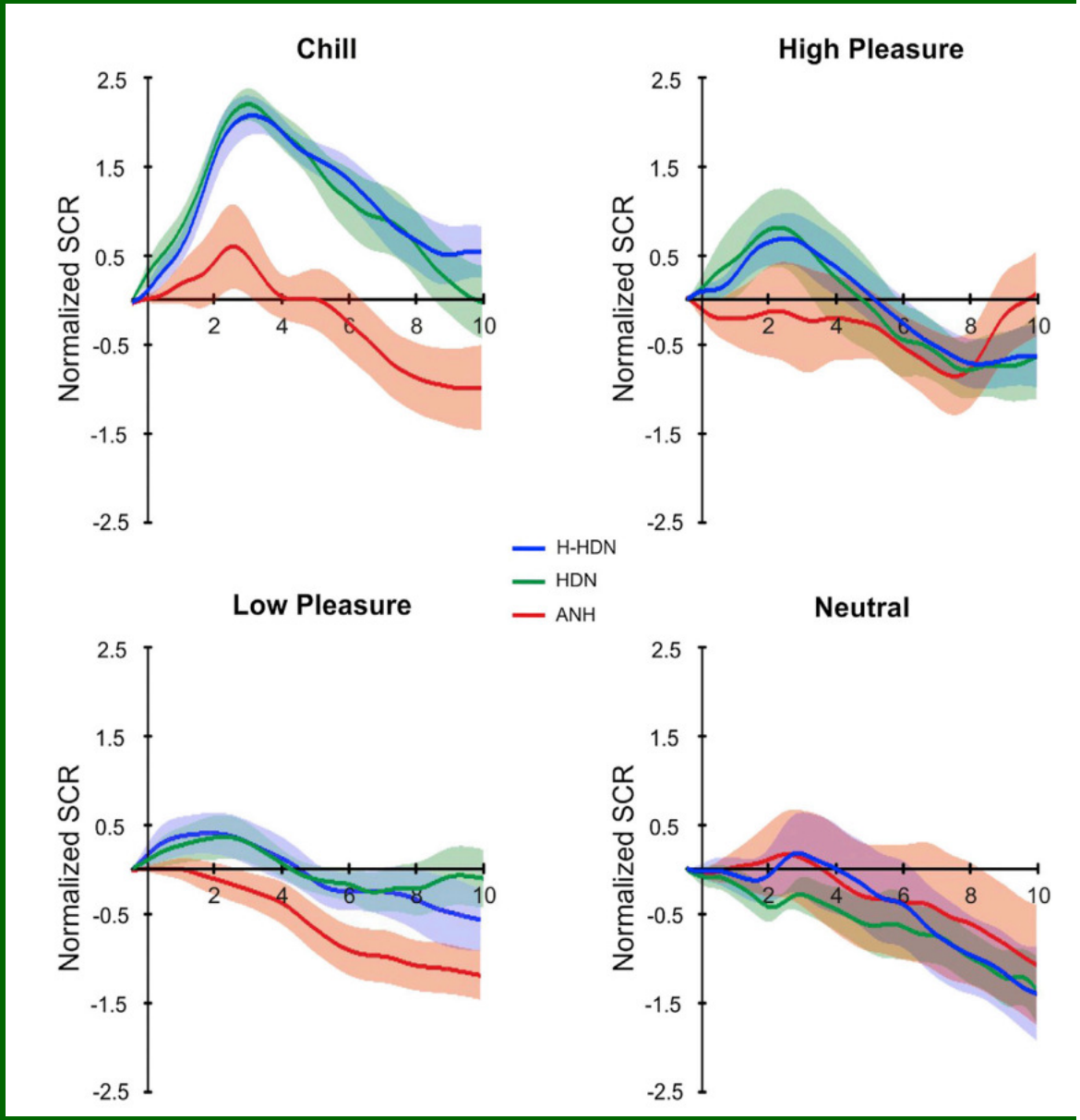
Specific musical anhedonia

An example of musical pleasure agnosia.

Barcelona Musical Reward Questionnaire (BMRQ) is a reliable indicator of interindividual variability in music-induced reward.

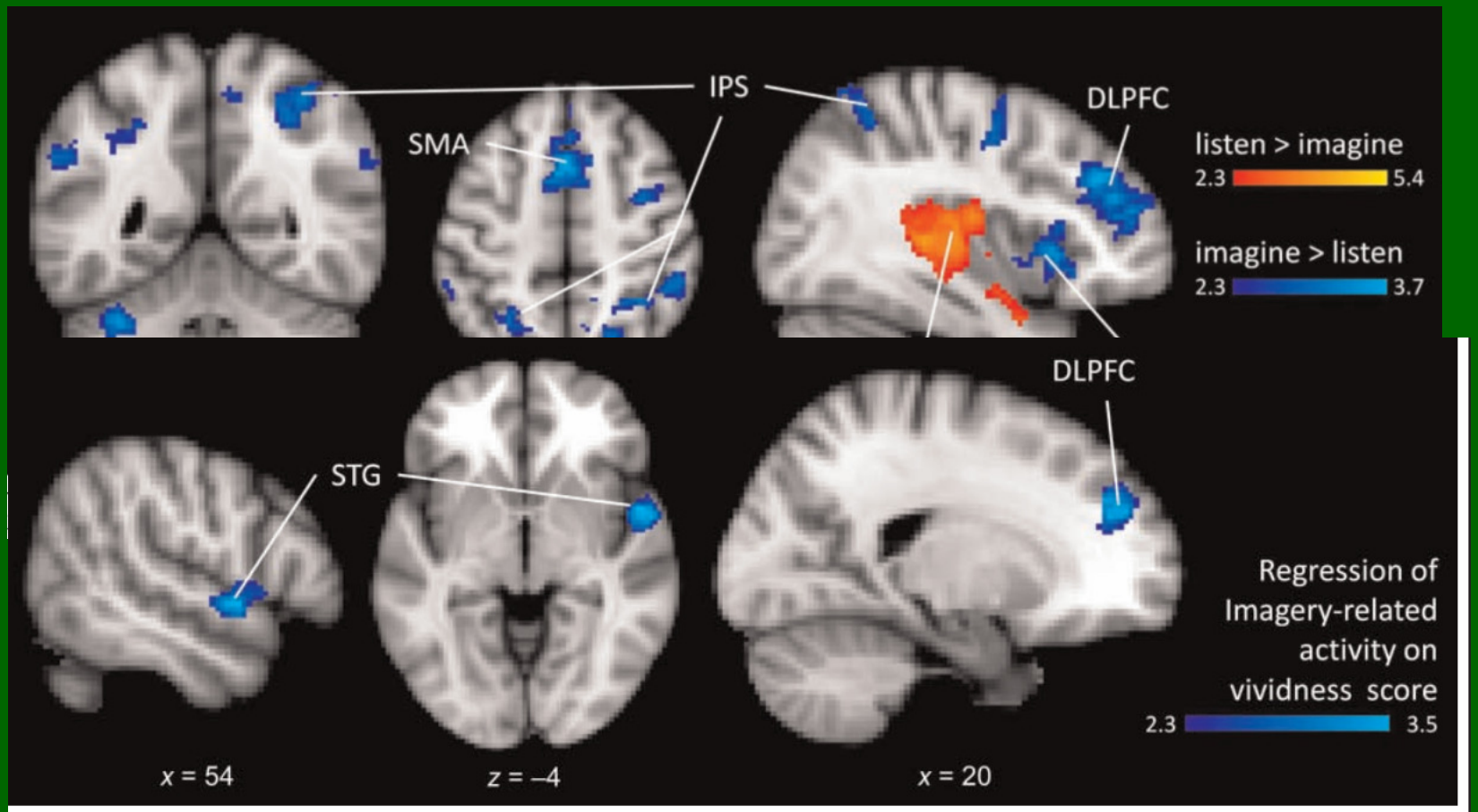
SCR = Skin Conductance Response

Mas-Herrero, Zatorre et al. (2014). Dissociation between musical and monetary reward responses in specific musical anhedonia. Current biology, 24(6), 699.



Listen vs imagine

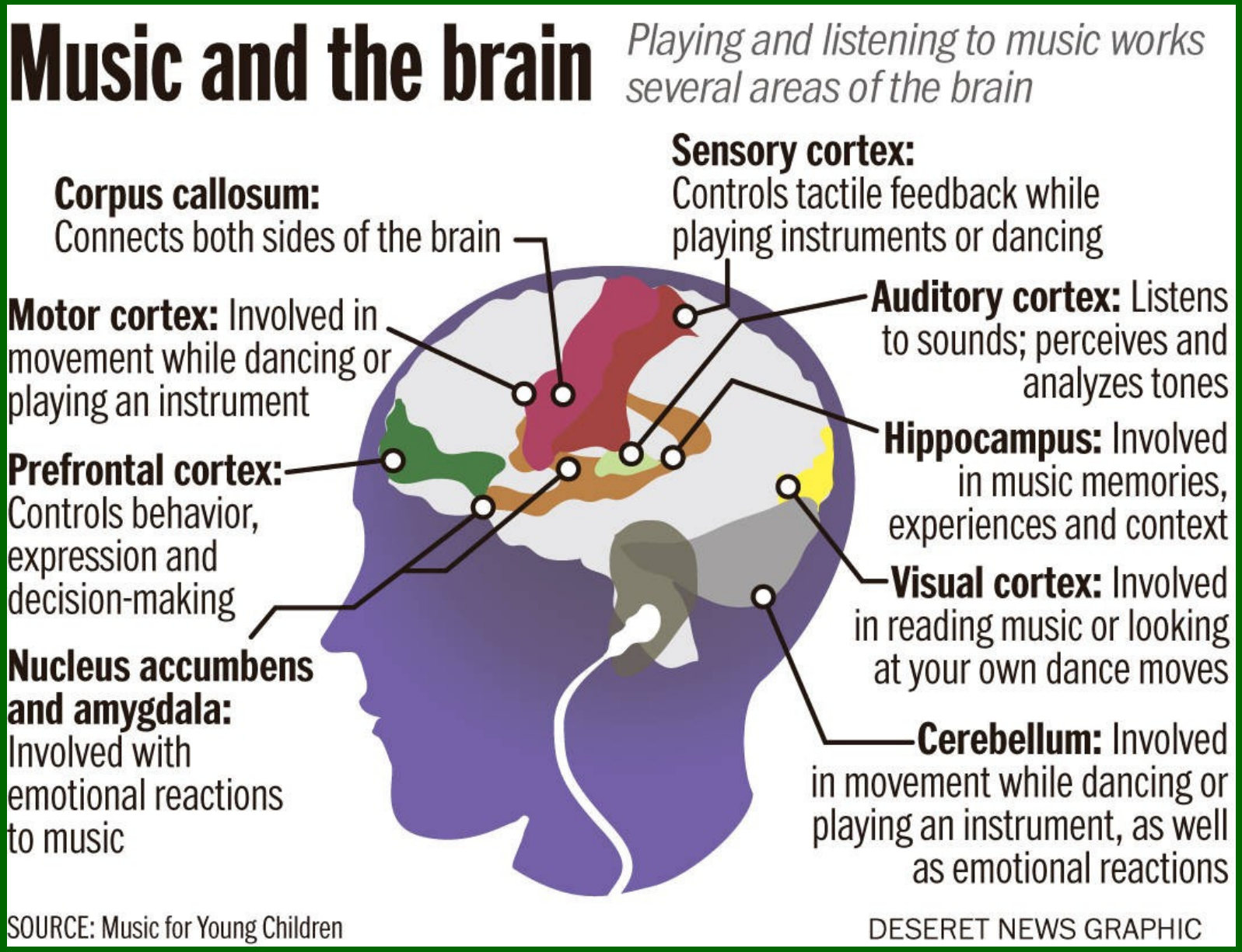
Question: how precisely can episodic memory be recreated?



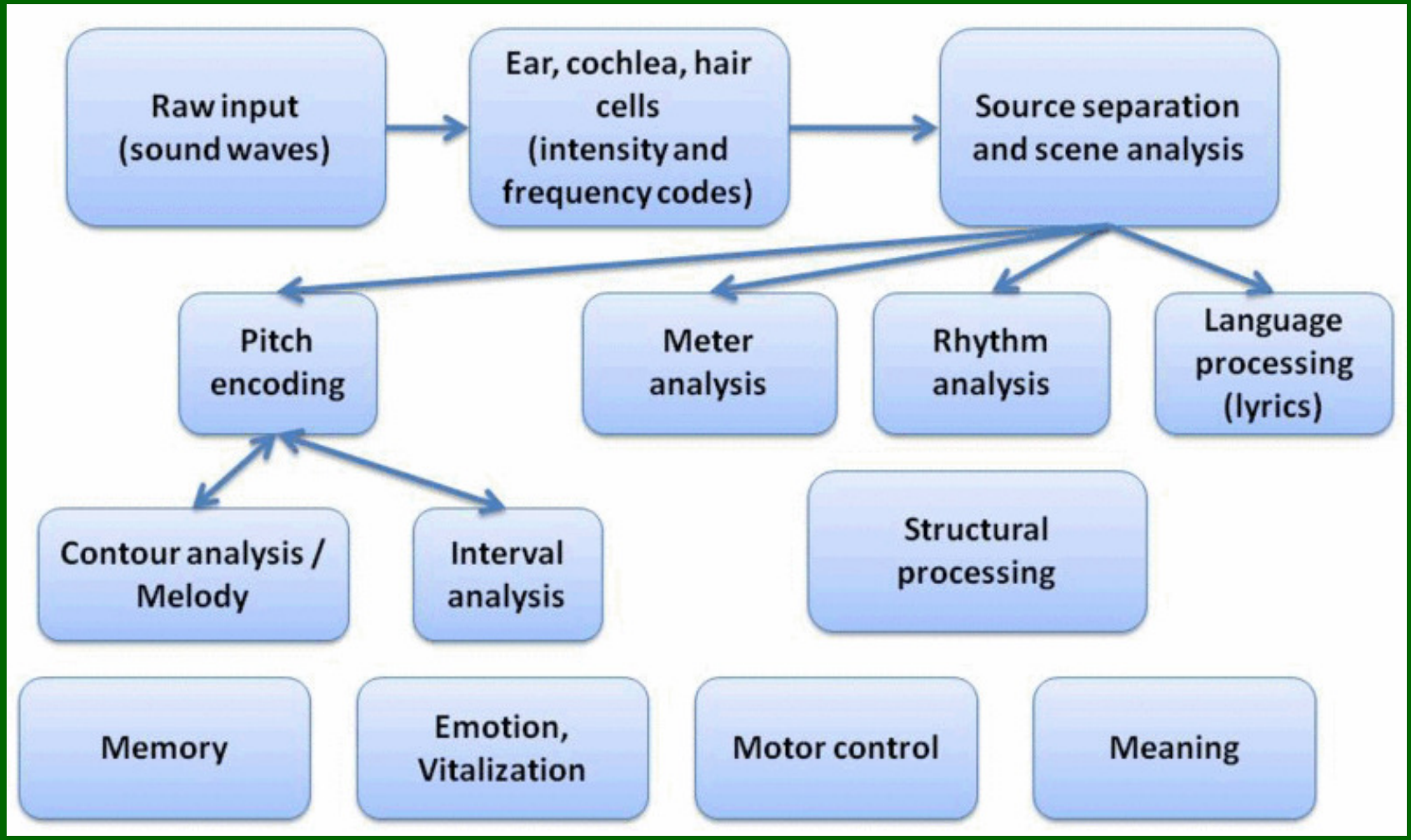
gure 4. Regression of activity during imagery compared with baseline during the encoding phase of the experiment on the vividness of imagery

Herholz, S.C, Halpern, A.R, Zatorre, R.J. (2012) Neuronal correlates of perception, imagery, and memory for familiar tunes. JCN 24

Music perception



How brains are analyzing sound?



S. Koelsch, Toward a neural basis of music perception – a review and updated model. Front. in Psychology 2 (110), 1-20, 2011

Neurocognitive model

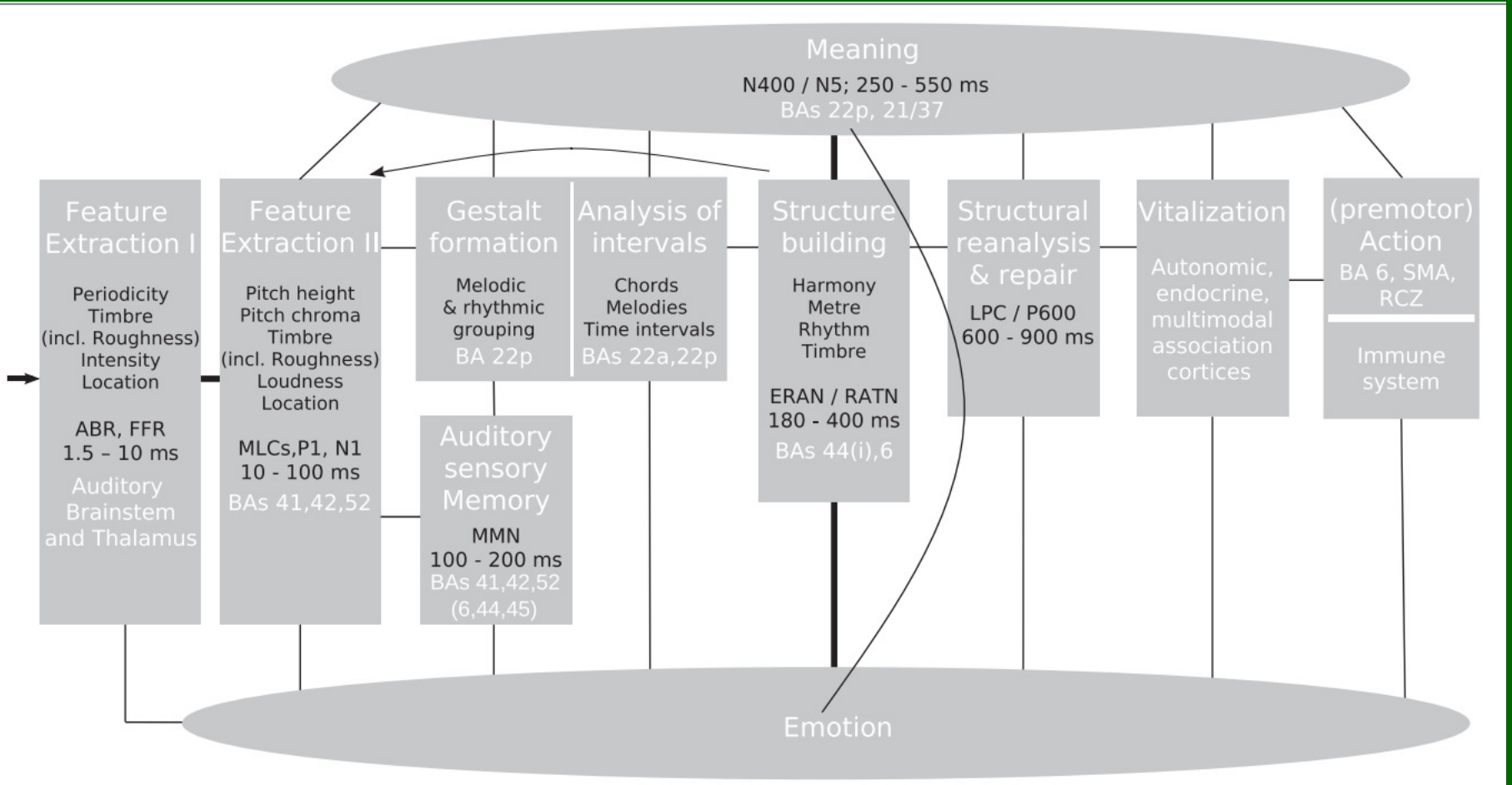
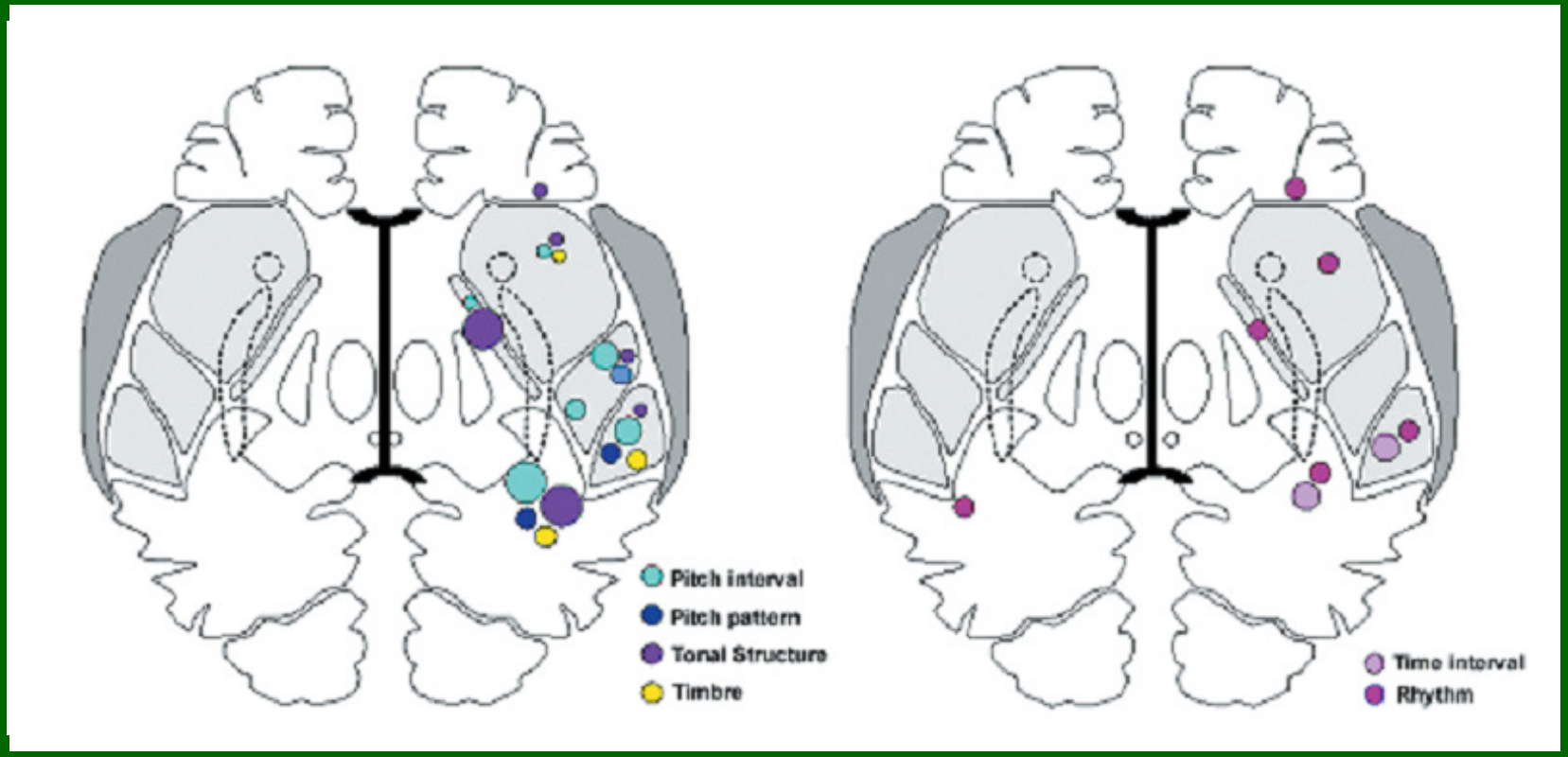


FIGURE 1 | Neurocognitive model of music perception. ABR, auditory brainstem response; BA, Brodmann area; ERAN, early right anterior negativity; FFR, frequency-following response; LPC, late positive component; MLC, mid-latency component; MMN, mismatch negativity; RATN, right anterior-temporal negativity;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

S. Koelsch, Toward a neural basis of music perception – a review and updated model. Front. in Psychology 2 (110), 1-20, 2011

Processing Music



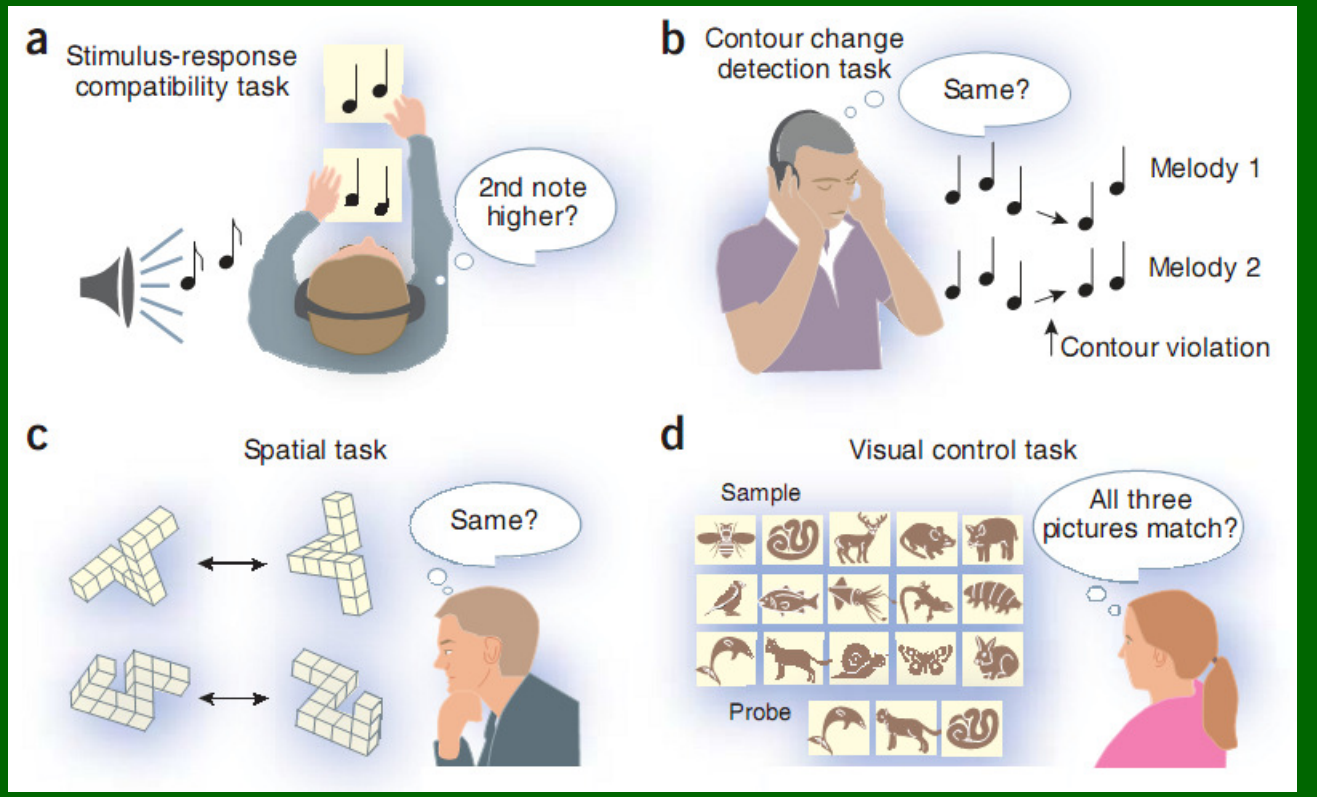
Cognitive model of music processing point to a widely distributed network, focused on pitch and rhythm processing: pitch in lateral Heschl's gyrus, timbre in posterior superior-temporal lobes, rhythm in motor/mesiolimbic areas.

Conscious hearing requires activation of the auditory cortex (temporal gyrus). **We do not have names** for internal aspects of music processing in the brain.

Amusia and spatial processing

Anatomical locus of amusia, neuroimaging/lesion studies: auditory areas along the STG in pitch discrimination and melodic contour processing;

Douglas, K.M. & Bilkey, D.K. Amusia is associated with deficits in spatial processing. Nature Neuroscience 10, 915-921 (2007)

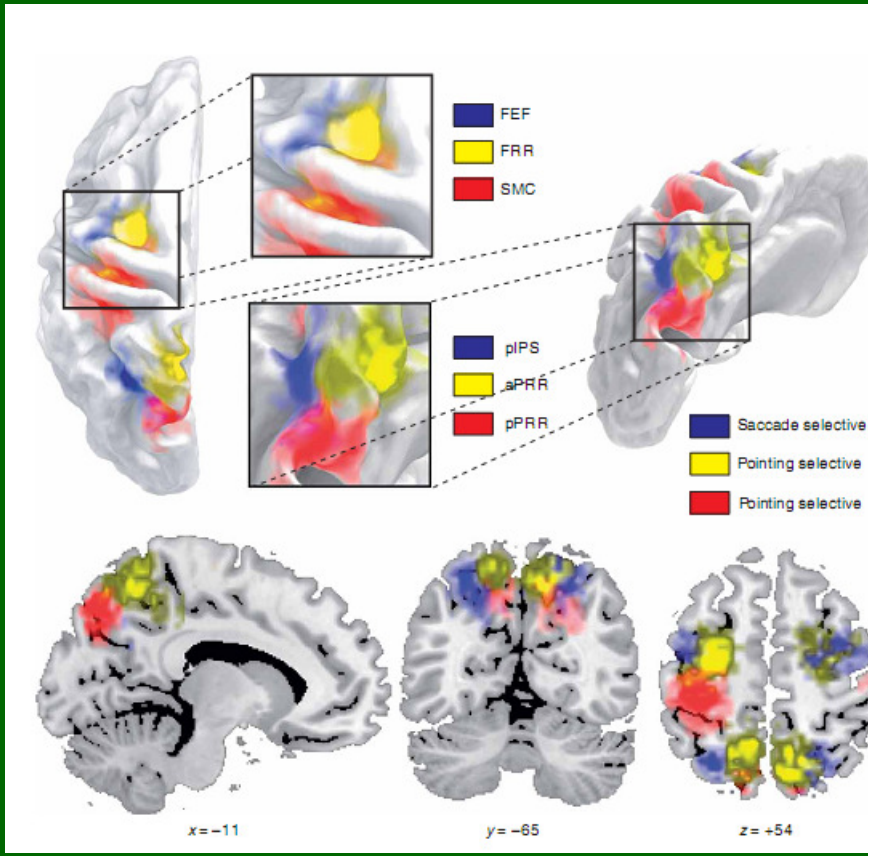


There is no evidence for morphological correlates of amusia in parietal regions. "The deficit may derive from **changes in neural functioning** that are **invisible** to the tools that have been applied to date."

Parietal cortex

A. Tosoni et al, Nature Neuroscience 11, 1446 - 1453 (2008) . Sensory-motor mechanisms in human parietal cortex underlie arbitrary visual decisions.

In arbitrary association of visual stimuli with different actions, activity of effector-specific regions in human posterior parietal cortex did not respond to sensory stimuli per se, but to **integrated sensory evidence** toward the decision outcome, triggered by contextual stimulus-response associations.



Hypothesis: normal perception is goal-directed, requires top-down influences to form expectations. What if feedback connections to visual/auditory areas are weak? No imagery without activation of secondary sensory cortex!

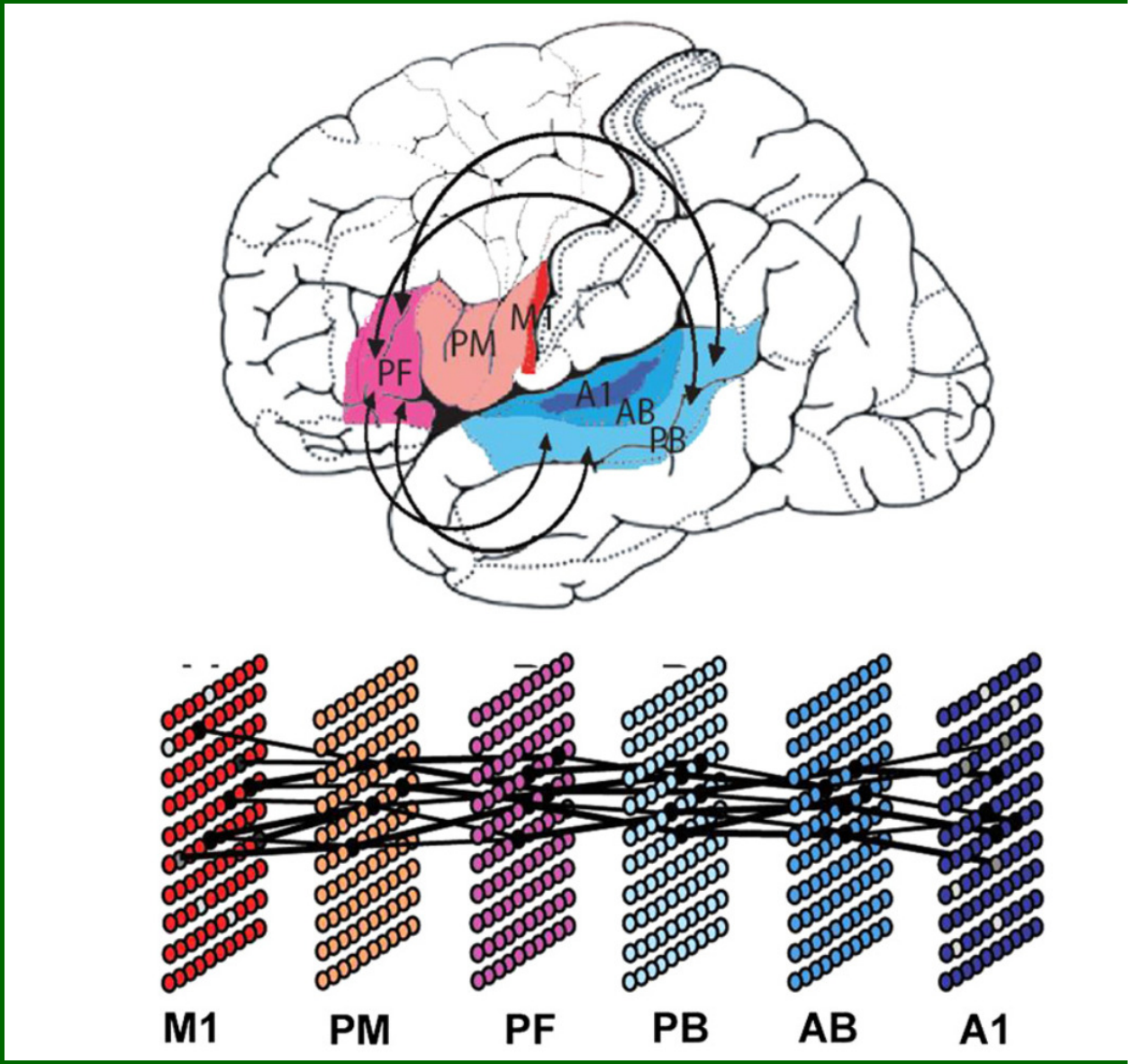
Speech perception

Sound is converted into activity of network that binds many brain areas.

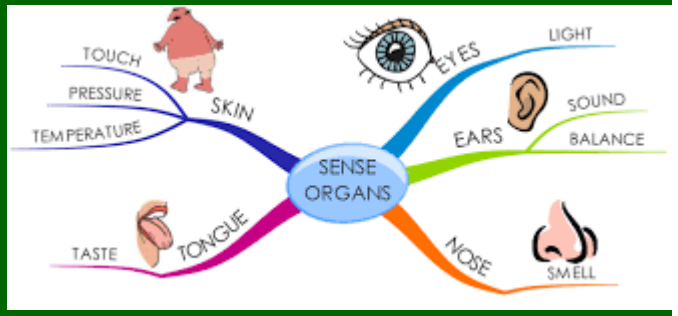
In case of speech at least 6 areas are involved, in temporal and frontal lobes, usually in the left hemisphere.

Many others areas are activated before meaning of a word is understood.

From: Garagnani et al, 2006



Sensory substitution

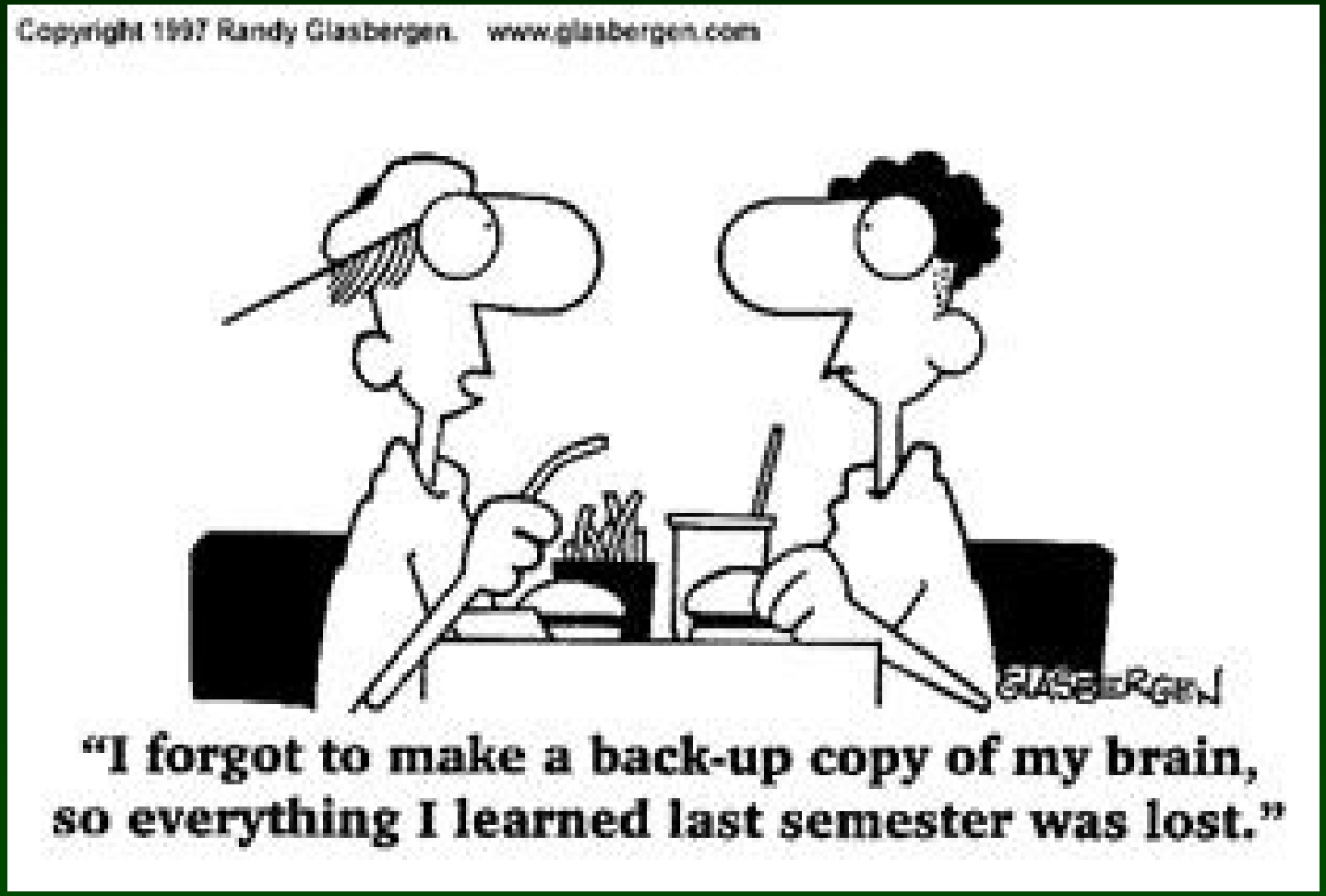


Auditory => vision,
tactile => visual, auditory, vestibular.
Vibrotactile stimulation: change sound to vibrations on skin or tongue.
Sense Organ synthesizer patent.
Magnetic=>vibrotactile, new sense.

The **Sound Shirt** connected to a computer system picks up audio signals from microphones and converts it into vibrations delivered by actuators, little motors placed around the shirt, high violins sounds in sleeves, low double-bass on the waist level.

A German orchestra, the Jungen Symphoniker Hamburg, organizes concerts for deaf people that “feel” the music through Sound Shirts.

Back-up your memory!



"I forgot to make a back-up copy of my brain, so everything I learned last semester was lost."