Marienhamn
April 23, 2014

Music education and brain science – dreams and realities

Prof. Mari Tervaniemi
Cognitive Brain Research Unit, Institute of Behavioural Sciences, University of Helsinki

www.cbru.helsinki.fi/~music

MONITIETEISEN MUSIIKINTUTKIMUKSEN HUIPPUYKSIKKÖ | FINNISH CENTRE OF EXCELLENCE IN INTERDISCIPLINARY MUSIC RESEARCH

Content of the talk

I Musical expertise in adult musicians

II Music training in childhood

III Methodological considerations

IV General conclusions

I Musical expertise in adult musicians is seen…

- In auditory modality
- In motor and somatosensory modalities
- In cross-modal functions

- Perceptually
- Cognitively
- Neurally
  - Functionally
  - Anatomically

Something more

and/or

something faster

Review: Tervaniemi 2009
Annals of the New York Academy of Sciences

Musical expertise: brain function and structure

Evidence for use-dependent changes in brain functions and brain structure in adult musicians when compared with individuals without formal training in music (”non-musicians”)

The comparisons based on **adult classical** musicians vs. non-musicians

Egg and Chicken – Chicken and Egg – Effects of training or differences prior to training?

Content of the talk

I Musical expertise in adult musicians

II Music training in childhood

III Methodological considerations

IV General conclusions

II: Music training in childhood

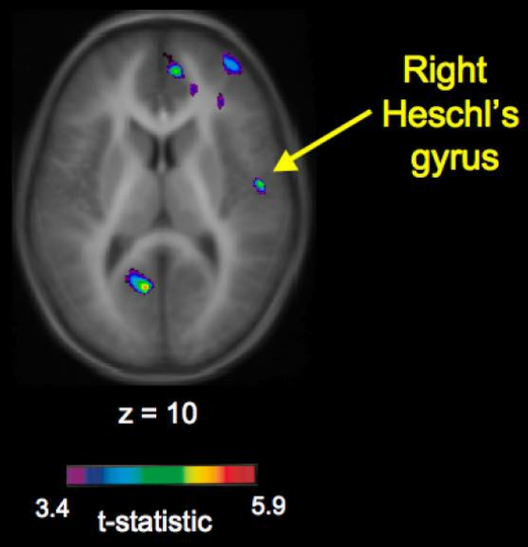
- By careful follow-up studies, specific effects of music training in children can be shown
- Pre-test, training, testing, training… (read: £ € $ etc)

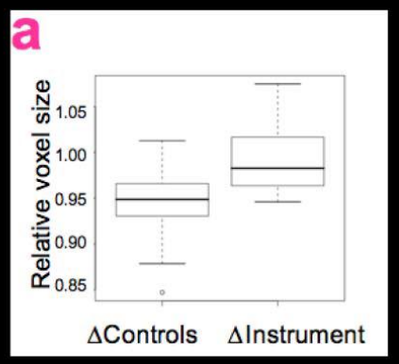
MONITIETEISEN MUSIIKINTUTKIMUKSEN HUIPPUYKSIKKÖ | FINNISH CENTRE OF EXCELLENCE IN INTERDISCIPLINARY MUSIC RESEARCH

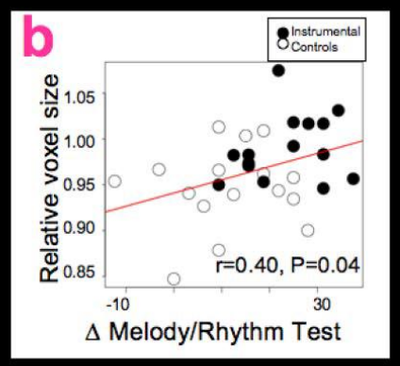
Effects of music training: Structural

- Individual piano lessons for 15 months vs. music lessons including singing and drums
- Mean age of the children: 6 yrs
- Structural changes with corresponding changes in motoric and perceptual functions
- No differences prior to training

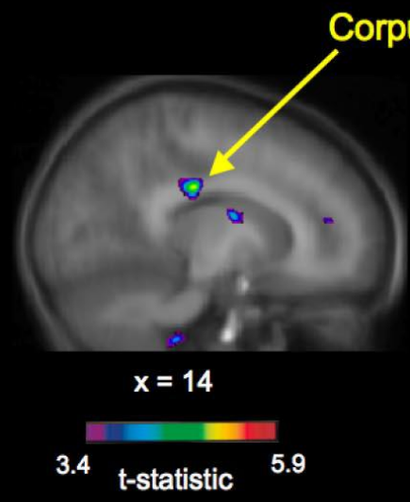
Primary auditory area
(Instrument > Controls)

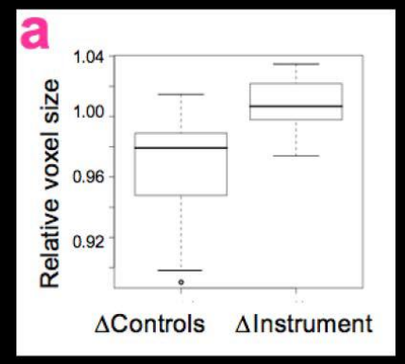


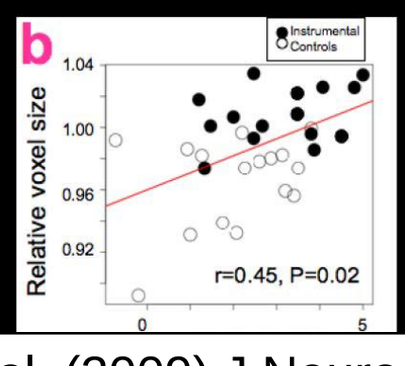




Corpus callosum
(Instrument > Controls)





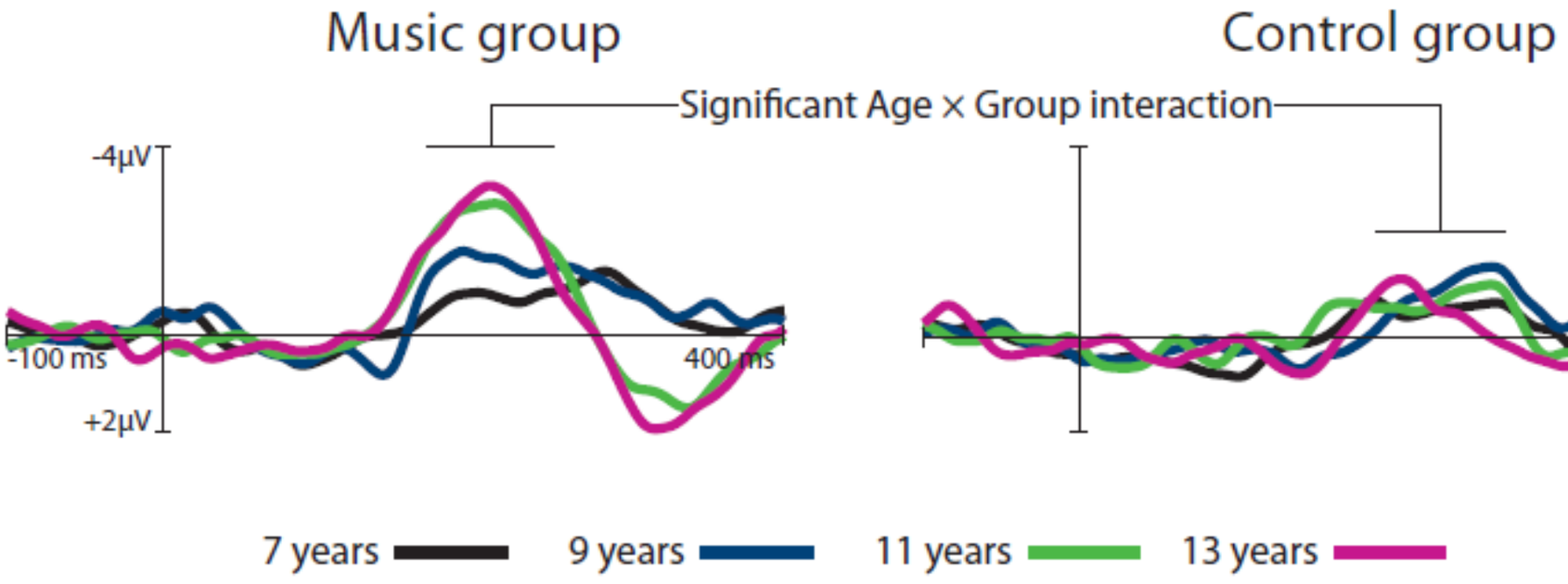


Hyde et al. (2009) J Neurosci

Effects of music training: Functional

- EEG measurements every second year
  - 7 yrs, 9 yrs, 11 yrs, 13 yrs
  - Music training within regular school curriculum
  - Control children with other hobbies
- To investigate the development of auditory memory functions in
  - Basic sound discrimination with non-musical sinusoidal sounds
  - Chord discrimination

Chord paradigm - Results



No group differences prior to training

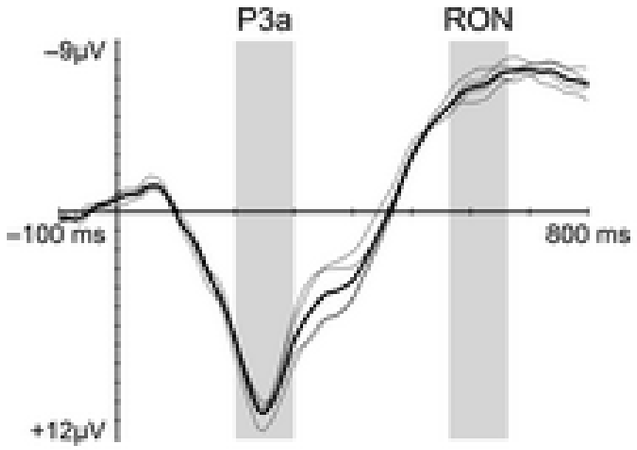
No group differences when non-musical sounds were used

Putkinen et al. (in press)
Developmental Science

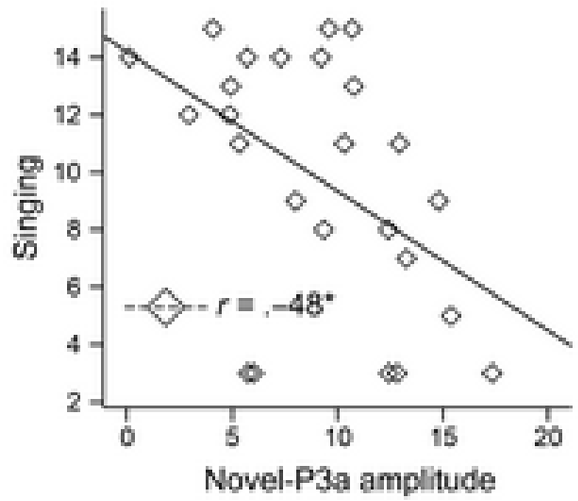
Correspondence between informal music activities and brain function

- 25 children, 3 yrs of age
- Participants of music play school
- Singing and Music activities at home associated with less distractability – more music, better attention

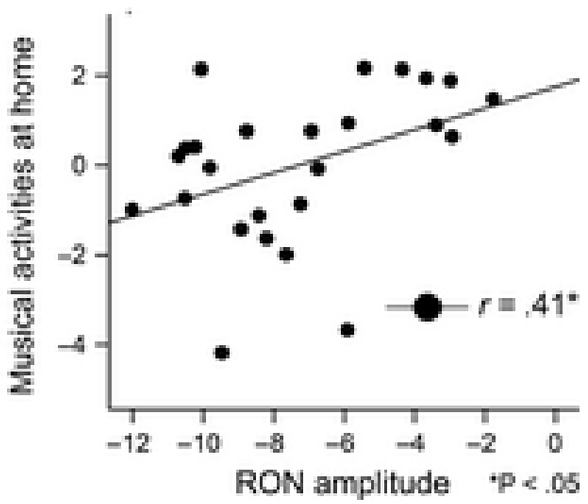
ERPs



Singing vs. P3a



Music activities vs. RON



Putkinen et al. (2013)
Eur J Neuroscience

Auditory learning before birth?

- Fetuses hear during the last trimester of pregnancy
- Fetal learning may result in formation of neural memory traces in the brain for sounds which the fetus has been exposed to during pregnancy.
- The formation of neural memory traces should be seen as strong neural activity in conditions where newborns need to discriminate small changes in sounds they have learned during pregnancy.
- Alternatively, the learning effects should be seen as stronger neural activity to familiar sounds.

Auditory learning before birth?

- In our studies
  - Pregnant women were given a CD and instructed to play the sounds daily from the last trimester of pregnancy until giving birth.
  - After birth the newborn’s EEG was recorded and brain activity elicited by the sounds was compared to that of naïve controls.

Auditory learning before birth, part I

- Here, fetuses were exposed to trisyllabic pseudoword [tatata] and its' two variants with either pitch or vowel identity changes in the middle syllable.
- After birth, newborns had stronger responses to pitch increments than naïve controls
- The responses were stronger the more often fetuses had heard the sounds before birth.
- Both groups could discriminate the vowel changes, a very common type of change in Finnish. Processing of vowels was not improved by fetal learning.

Partanen et al., 2013
PNAS

Auditory learning before birth, part II

- Here, fetuses listened to Twinkle twinkle little star for the last trimester of pregnancy.

- After birth and at the age of four months, infants' heard a modified version of the melody. In the modified version, some notes were changed but were in key with the melody.

- Both at birth and at the age of four months, the newborns exposed to the melody had stronger neural responses to unchanged notes. Furthermore, the responses were larger the more often fetuses were exposed to the melody before birth.

Partanen et al., 2013
PLoS ONE

I and II: Interim conclusions (shortest-cut)

- Music training is reflected
  - as functional and structural brain changes
  - in adults and children
    - auditory exposure being seen even in newborns
    - together formal and informal music activities
- Ongoing studies to determine
  - transfer effects of music training in children to other cognitive domains (attention, language)
  - different auditory profiles in adult musicians with different backgrounds

Content of the talk

I Musical expertise in adult musicians

II Music training in childhood

III Methodological considerations

IV General conclusions

Methodological limitations

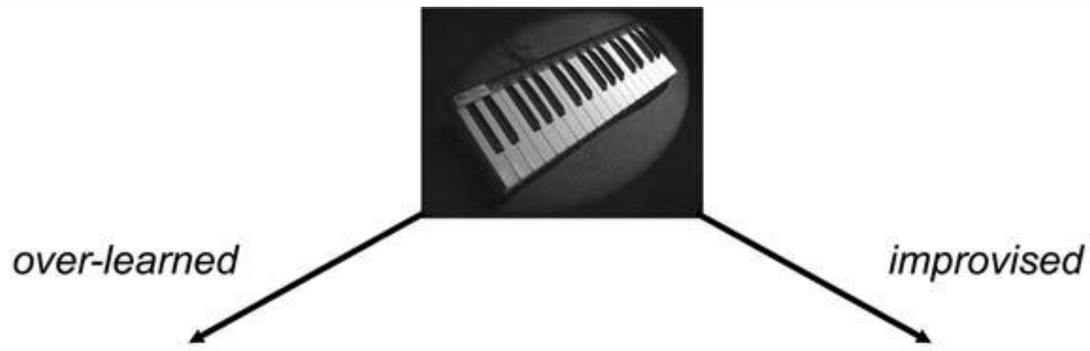
- Your brain, my brain, our average brain
  - Anatomical and functional differences not taken into account in analyses
- Your music, my music, our average music
  - How to make a study in which music has the same meaning for all participants?
  - Too often same music is played to all participants
- Studies only in the laboratory
  - without movements
  - without metal objects around

EEG outside the laboratory

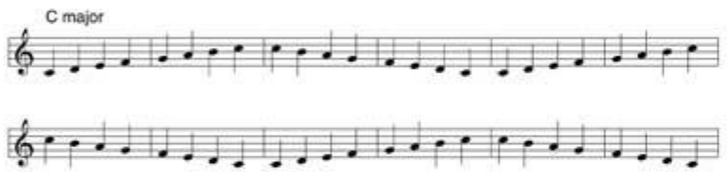
EEG while playing

Babiloni et al. 2012
NeuroImage

Playing in fMRI scanner (special keyboard without metal)

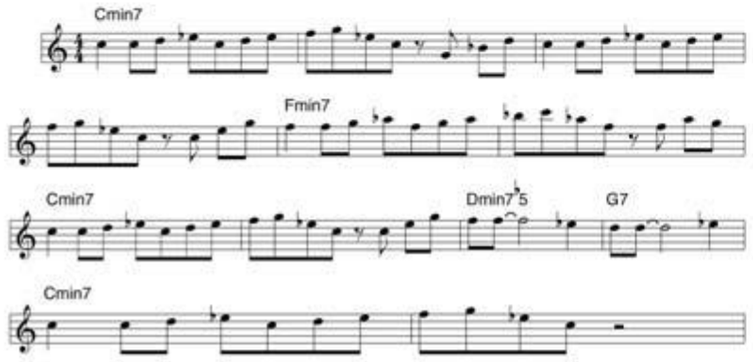


ScaleCtrl

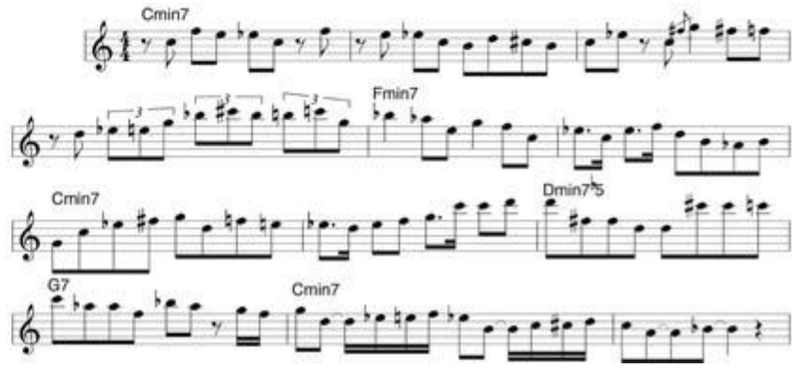


ScaleImprov *(example)*

JazzCtrl



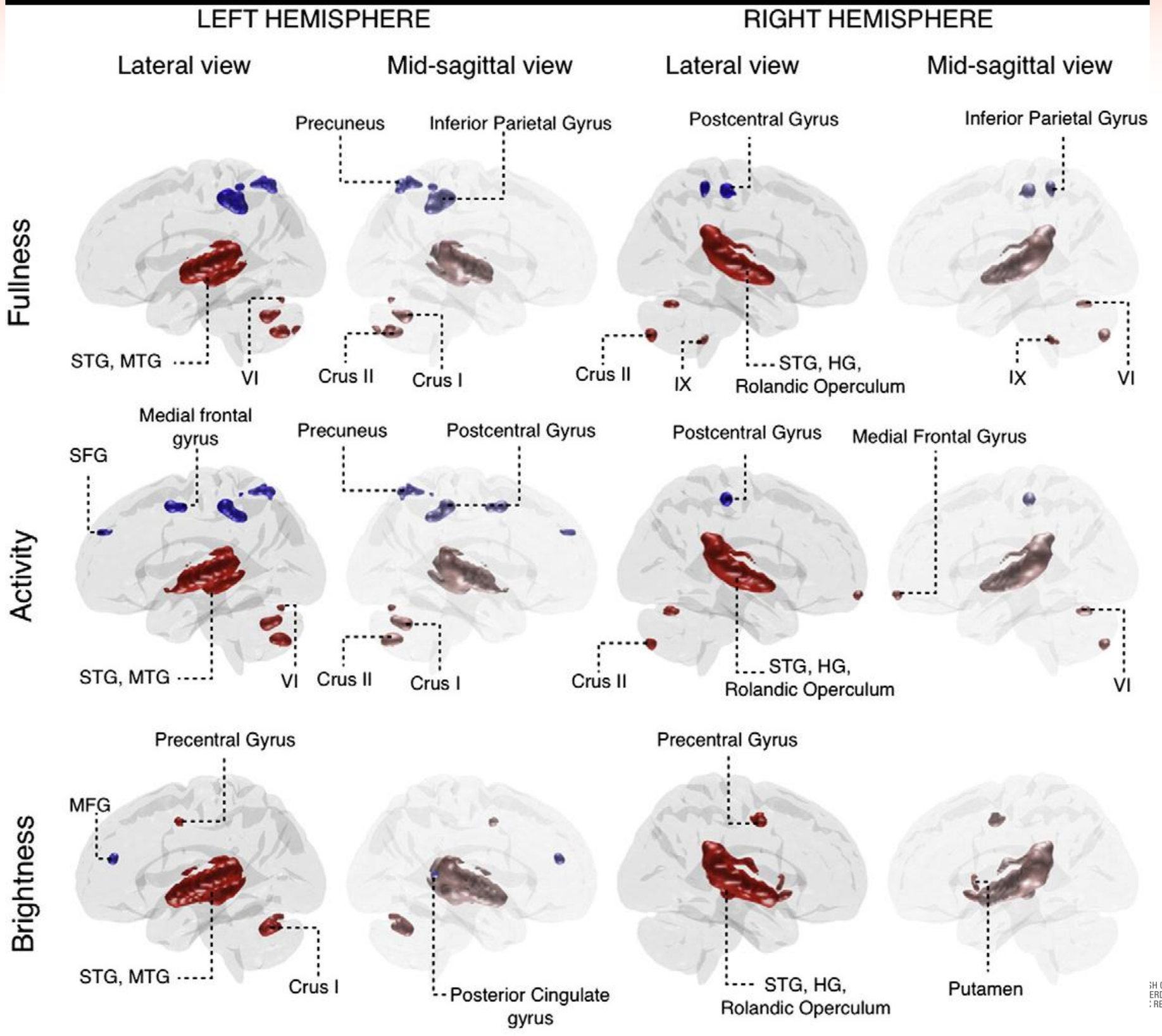
JazzImprov *(example)*



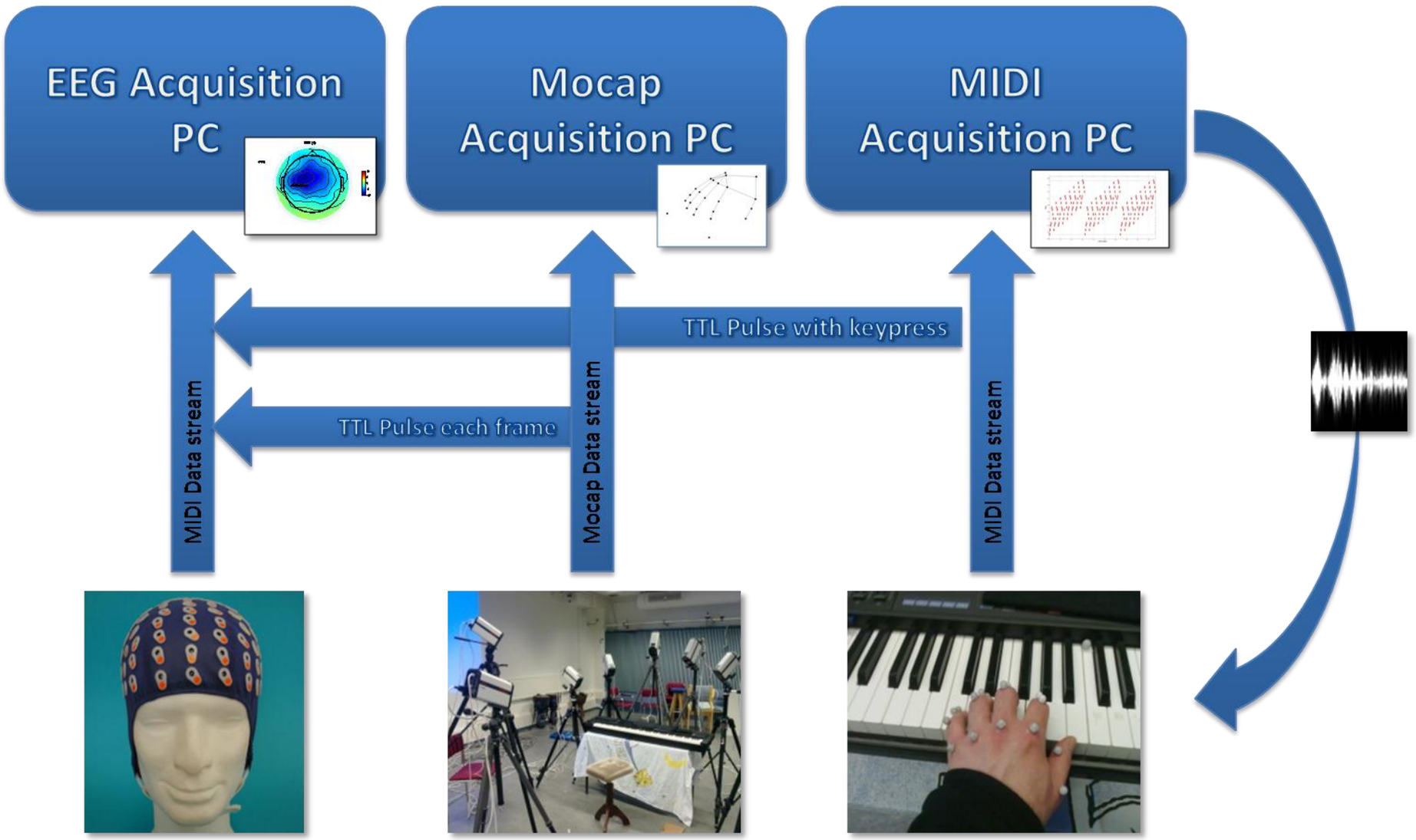
Limb & Brown 2008
PLoSONE

Brain reactions to real music

Click at http://becs.aalto.fi/bml/

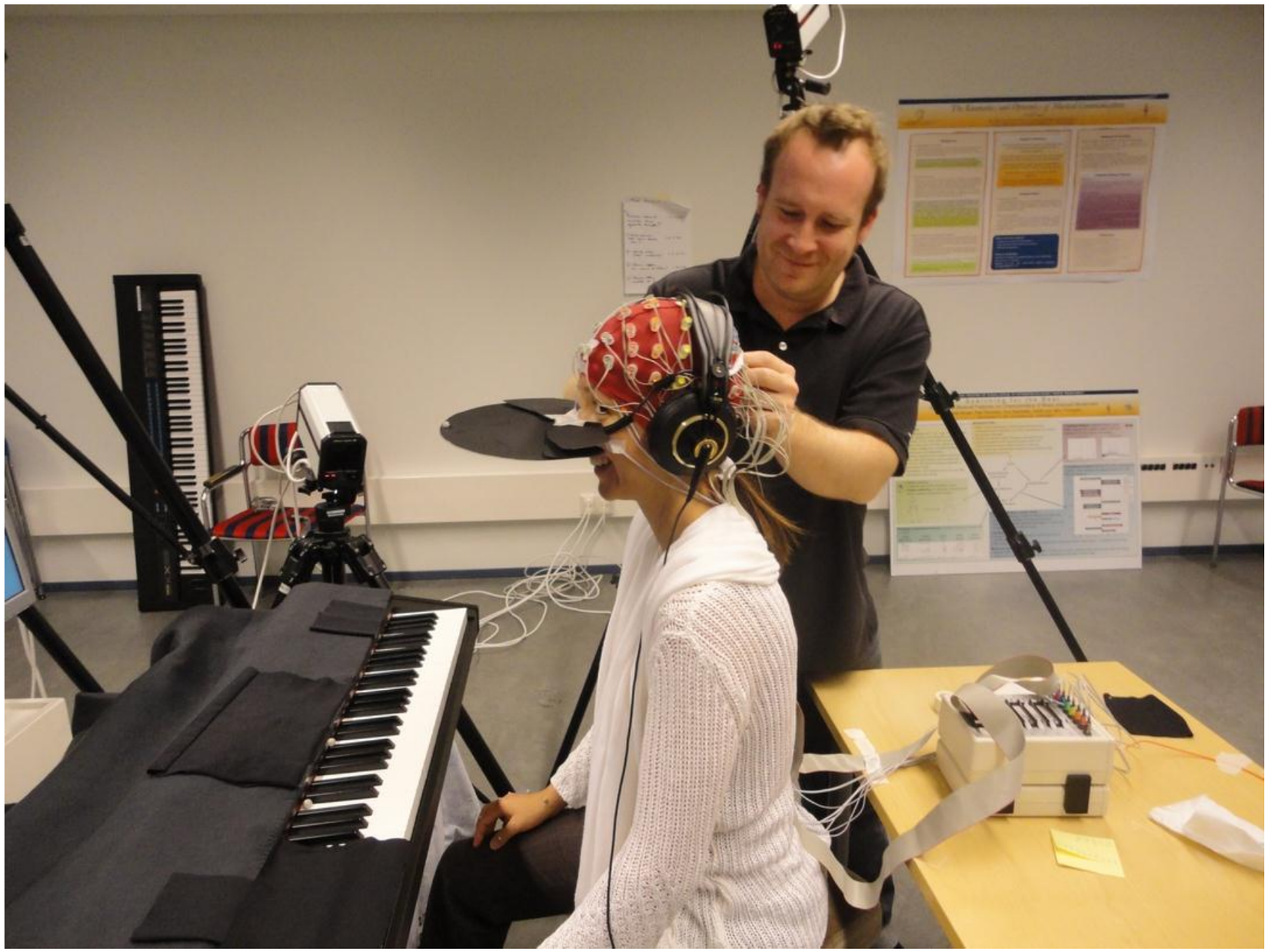


Simultaneous recording of finger movements, MIDI, and EEG



Maidhof et al. 2013
Frontiers in Human Neuroscience

Error signal in the brain before a wrong key press



Maidhof et al. 2013
Frontiers in Human Neuroscience

IV General conclusions

- Research on brain in the context of music education is challenging
  - Limitations of the methodology
  - Personal characteristics of music
  - Need of long follow-up times in longitudinal studies
- Solutions to these challenges are emerging => Well-controlled studies are emerging

IV General conclusions

- Music interventions can modulate the brain function in a dynamic and useful manner
  - Music development and skill learning as evidenced in adult musicians and children active in music
  - Music listening and music making in neurological and psychiatric music rehabilitation and therapy (not discussed today)

Recent reviews from Helsinki

Särkämö, T., Laitinen, S., Tervaniemi, M., Numminen, A., Kurki, M., Rantanen, P. (2012). Music, emotion and dementia: Insight from neuroscientific and clinical research. *Music and Medicine,* **4**, 153–162.

Särkämö et al. (2013) Music perception & cognition: Development, neural basis and rehabilitative use of music. *WIREs Cognitive Science,* **4**, 441–451. doi:10.1002/wcs.1237

Putkinen et al. (2013) Do informal musical activities shape auditory skill development in preschool-age children? *Frontiers in Psychology,* **4**, 572. doi: 10.3389/fpsyg.2013.00572

Maidhof C. (2013) Error monitoring in musicians. *Frontiers in Human Neuroscience*, **7**, 401. doi: 10.3389/fnhum.2013.00401

More at www.cbru.helsinki.fi; pdf's of the Särkämö papers by contacting mari.tervaniemi@helsinki.fi (the others are online available)

PhD theses from Helsinki team on music and brain (2006 onwards)

- Elvira Brattico – Examined by prof. Trainor https://helda.helsinki.fi/handle/10138/19812 - Pitch perception
- Titia van Zuijen – Prof. Münte https://helda.helsinki.fi/handle/10138/19775 - Musical expertise
- Nikolai Novitski – Prof. Rauschecker https://helda.helsinki.fi/handle/10138/19738 - Effects of fMRI noise on auditory processes
- Riia Milovanov – Prof. Besson http://www.doria.fi/handle/10024/50249 - musical expertise and foreign language learning
- Tuomas Teinonen – Prof. Kuhl https://helda.helsinki.fi/handle/10138/23000 - statistical learning
- Teppo Särkämö – Prof. Zatorre https://helda.helsinki.fi/handle/10138/24940 - rehabilitation of stroke patients by music listening
- Veerle Simoens – Prof. Kreutz https://helda.helsinki.fi/handle/10138/37608 - stress (also stage fright)
- Miia Seppänen – Prof. Gaab https://helda.helsinki.fi/handle/10138/39470 - interplay between long-term and short-term learning in audition
- Eva Istok - Prof. Altenmüller https://helda.helsinki.fi/handle/10138/38316 - Behavioural and neural determinants of music emotions and preferences
- Eino Partanen – Prof. Jacobsen https://helda.helsinki.fi/handle/10138/41668 - Auditory learning across life span (including fetal learning)
- Vesa Putkinen - Prof. Penhune – https://helda.helsinki.fi/handle/10138/42756 - Development of music skills (formal, informal settings)

Recent very good reviews from other lab's

These two important review pdf's available at http://www.zlab.mcgill.ca

- Zatorre, R.J., Fields, R.D., and Johansen-Berg, H. (2012) Plasticity in gray and white: Neuroimaging changes in brain structure during learning. Nature Neuroscience, 15, 528-536.
- Zatorre, R.J. (2013) Predispositions and plasticity in music and speech learning: Neural correlates and implications. Science 342 (6158), 585-589
- See also Koelsch S. (2014). Brain correlates of music-evoked emotions. Nature Reviews Neuroscience,15(3), 170-180 and http://www.soc.northwestern.edu/brainvolts/

MONITIETEISEN MUSIIKINTUTKIMUKSEN HUIPPUYKSIKKÖ | FINNISH CENTRE OF EXCELLENCE IN INTERDISCIPLINARY MUSIC RESEARCH