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Brain Plasticity & Cochlear Implants: *from Fundamental Research to the Clinic*

Alexandre Lehmann, PhD

Assistant Professor, *McGill University, Faculty of Medicine*

Full Member, *Centre for Research on Brain, Language & Music*



Oct 21st 2015 CAA Workshop

Cochlear Implants – Emerging Advances in Clinical and Research Audiology,

Brain Plasticity & Cochlear Implants:

from Fundamental Research to Clinic

- Brain plasticity
- Why should you care ?
- Illustrations
- Take-home message

From Fundamental Research

RECENT RESEARCH ON PLASTICITY

Brain plasticity & sensory deprivation

[Crossmodal Plasticity for Auditory Processing in the Blind]

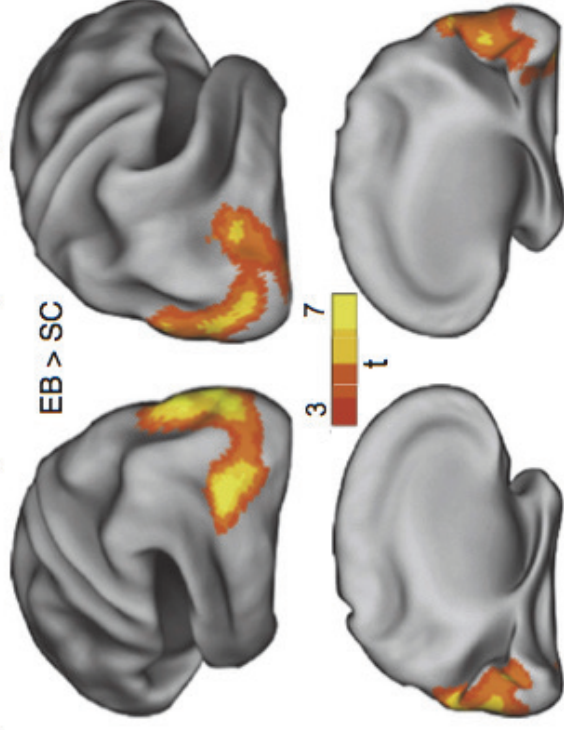


Fig. 1. Example of the massive activation elicited by sounds in the occipital cortex of blind adults. We created this figure using data from [Collignon et al. \(2011b\)](#): it depicts the activation obtained when contrasting early-blind individuals (EB) versus sighted controls (SC) when both groups of participants were exposed to auditory stimuli only.

Blind: Heimler et al. 2014

Brain plasticity & sensory deprivation

[Crossmodal Plasticity for Auditory Processing in the Blind]

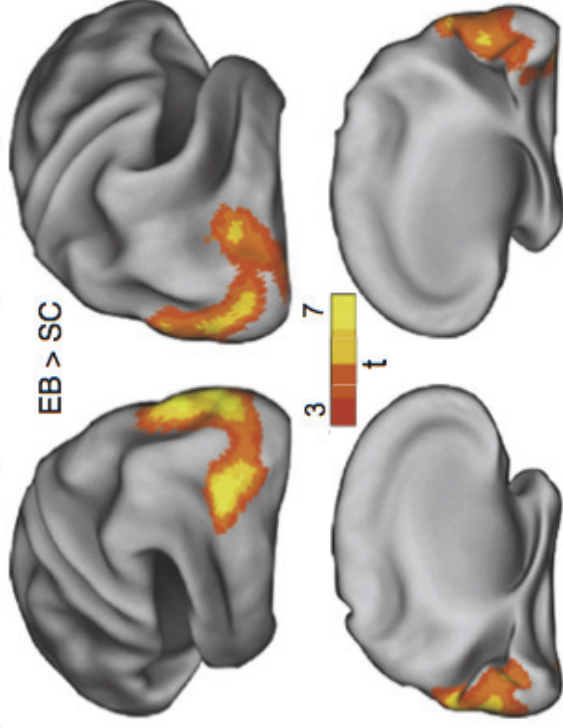


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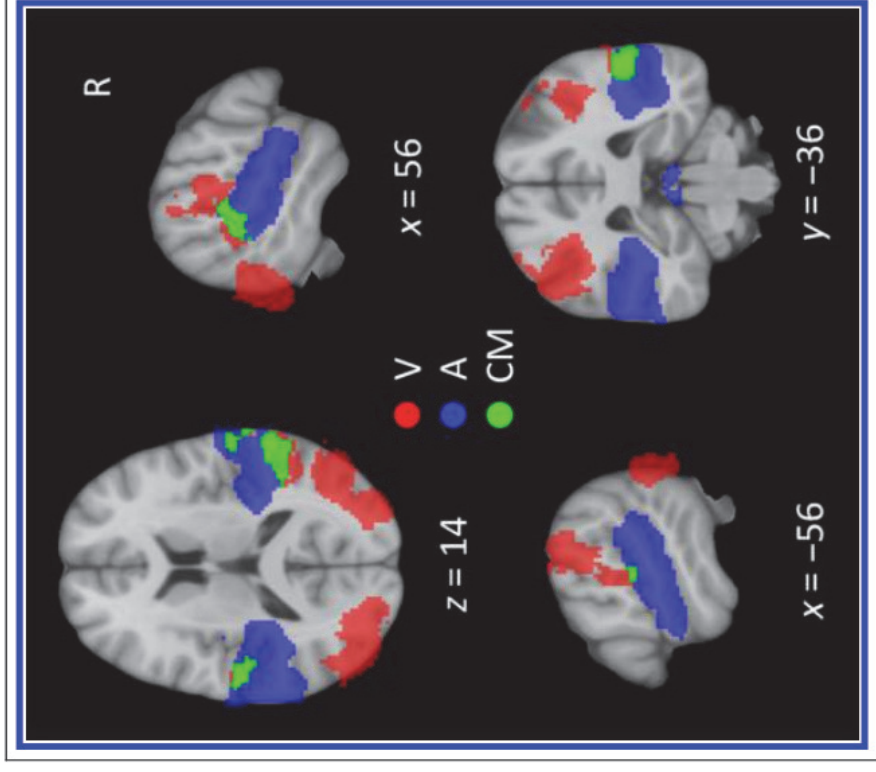


Figure 3. Cross-modal activity (green) in the deaf group, displayed in MNI152 standard space. In the RH posterior STG, visual motion-related activity in the deaf (red, $p < .05$) overlapped with the auditory localizer activity (blue, $p < .01$) from the hearing group. In the deaf group,

Deaf: Shiell et al. 2014

“Maladaptive” plasticity in CI users



Visual activation of auditory cortex reflects maladaptive plasticity in cochlear implant users

Pascale Sandmann,¹ Norbert Dillier,² Tom Eichele,^{3,4} Martin Meyer,⁵ Andrea Kegel,² Roberto Domingo Pascual-Marqui,⁶ Valentine Leslie Marcar,⁷ Lutz Jäncke⁸ and Stefan Debener¹

Cerebral Cortex April 2007;17:909-917
doi:10.1093/cercor/bhl001
Advance Access publication May 26, 2006

Cortical Activity at Rest Predicts Cochlear Implantation Outcome

- Visual activation in the auditory cortex is inversely related to speech recognition ability
- Incomplete reversal of this visual take-over might limit clinical benefit and help explain the high inter-subject variability in auditory speech comprehension.

Recent discoveries in brain plasticity

- The brain is plastic throughout the lifespan

Development/Plasticity/Repair

Training-Induced Brain Structure Changes in the Elderly

Janina Boyke,¹ Joenna Driemeyer,¹ Christian Gaser,² Christian Büchel,¹ and Arne May¹

¹Department of Systems Neuroscience, University of Hamburg, D-22046 Hamburg, Germany, and ²Department of Psychiatry, University of Jena, 07740 Jena, Germany

- Even subcortical structures are plastic !
 - Musicians, Bilinguals (Krishnan et al. 2009, Krizman et al. 2012)
 - Attention, Context (Lehmann et al. 2014, Skoe 2014)
 - Dyslexia, Amusia (Banai et al. 2008 , Lehmann et al. 2015)



Link between fundamental research and clinical outcomes

WHY SHOULD I CARE ?

Why should you care ?

Link between fundamental research and clinical outcomes

- How do we limit maladaptive plasticity ?
- How do we promote adaptive plasticity ?

Time matters for cochlear implantation

Nuno M. Gama^{1, 2, 3*}, Alexandre Lehmann^{1, 2, 4}

¹International Laboratory for Brain, Music and Sound Research (BRAMS), Canada, ²Center for Research on Brain, Language and Music (CRBLM), Canada, ³MRC Institute of Hearing Research, United Kingdom,

⁴Dept. of Otolaryngology Head & Neck Surgery, McGill University, Canada

Insights from human and animal literature

- Age at implantation
- Sensitive period 3.5 years
- Duration of deafness
- Language acquisition
- Benefit before 1 year ?
- One-day, one-week, one-month activation ?

To use or not to use hearing aids

- Functional reorganization of auditory cortex varies with hearing aid use,
- Continued hearing aid use may have protective effects for implant candidates, even if no benefit is perceived !

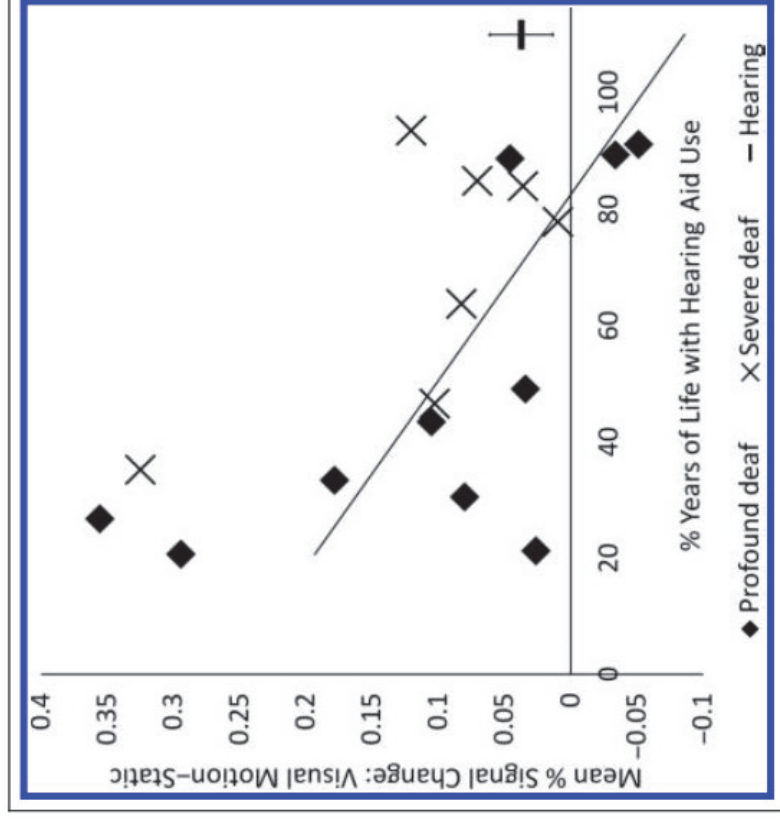


Figure 5. Correlation between duration of hearing aid use and cross-modal activity in RH posterior STG, with a regression line fitted to the profound deaf. This correlation was significant both with and without severely deaf participants included and while controlling for the effects of age of onset of hearing aid use (see Hearing Aid Use and Cross-modal Reorganization section). The horizontal bar represents the mean for the hearing group, with standard error bars.

Musical training can benefit speech

- Musical training in children, adults and the elderly improves behavioral and neural markers of speech perception
- By placing higher constraints on the auditory system, music drives plastic changes in the auditory pathway, from cortex to brainstem, with benefit speech processing
- Musical training could improve speech outcomes in CI users (Patel 2014, Lehmann & Skoe, in press)

Extra-ordinary skills ?

International Journal of Audiology 2013; 52: 424–432

informa
healthcare

Clinical Note

A cochlear implant user with exceptional musical hearing ability

Mohammad Maarefvand^{*,†}, Jeremy Marozeau^{*} & Peter J. Blamey^{*,†}

^{*}Bionics Institute, East Melbourne, Victoria, Australia, and [†]Department of Audiology and Speech Pathology, The University of Melbourne, Parkville, Victoria, Australia

Abstract

Although the perception of music is generally poor in cochlear implant users, there are a few excellent performers. *Objective:* The aim of this study was the assessment of different aspects of music perception in one exceptional cochlear implant user. *Design:* The assessments included pitch direction discrimination, melody and timbre recognition, relative and absolute pitch judgment, and consonance rating of musical notes presented through the sound processor(s). *Study sample:* An adult cochlear implant user with musical background who lost her hearing postlingually, and a normally-hearing listeners with musical training participated in the study. *Results:* The CI user discriminated pitch direction for sounds differing by one semitone and recognized melody with nearly 100% accuracy. Her results in timbre recognition were better than average published data for cochlear implant users. Her consonance rating, and relative and absolute pitch perception were comparable to normally-hearing listeners with musical training. *Conclusion:* The results in this study showed that excellent performance is possible on musical perception tasks including pitch perception using present day cochlear implant technologies. Factors that may explain this user's exceptional performance are short duration of deafness, pre- and post-deafness musical training, and perfect pitch abilities before the onset of deafness.

Key Words: Pitch direction discrimination; melody recognition; timbre recognition; absolute pitch; relative pitch; consonance rating; cochlear implant; music perception



Current research illustrating the fundamental / clinical articulation with
brain plasticity in mind

ILLUSTRATIONS

Emotion Perception

- Accurately perceiving emotions in language and music plays an important role for social development, interpersonal communication and maintaining quality of life.



frontiers
in Neuroscience | Auditory Cognitive Neuroscience

3.7
IMPACT FACTOR

Cross-domain processing of musical and vocal emotions in cochlear implant users

 Alexandre Lehmann^{1,2,3*} and  Sébastien Paquette^{2,3}

¹Department of Otolaryngology Head and Neck Surgery, McGill University, Montreal, QC, Canada
²International Laboratory for Brain, Music and Sound Research, Center for Research on Brain, Language and Music, Montreal, QC, Canada
³Department of Psychology, University of Montreal, Montreal, QC, Canada

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Impaired recognition of emotions in music and speech

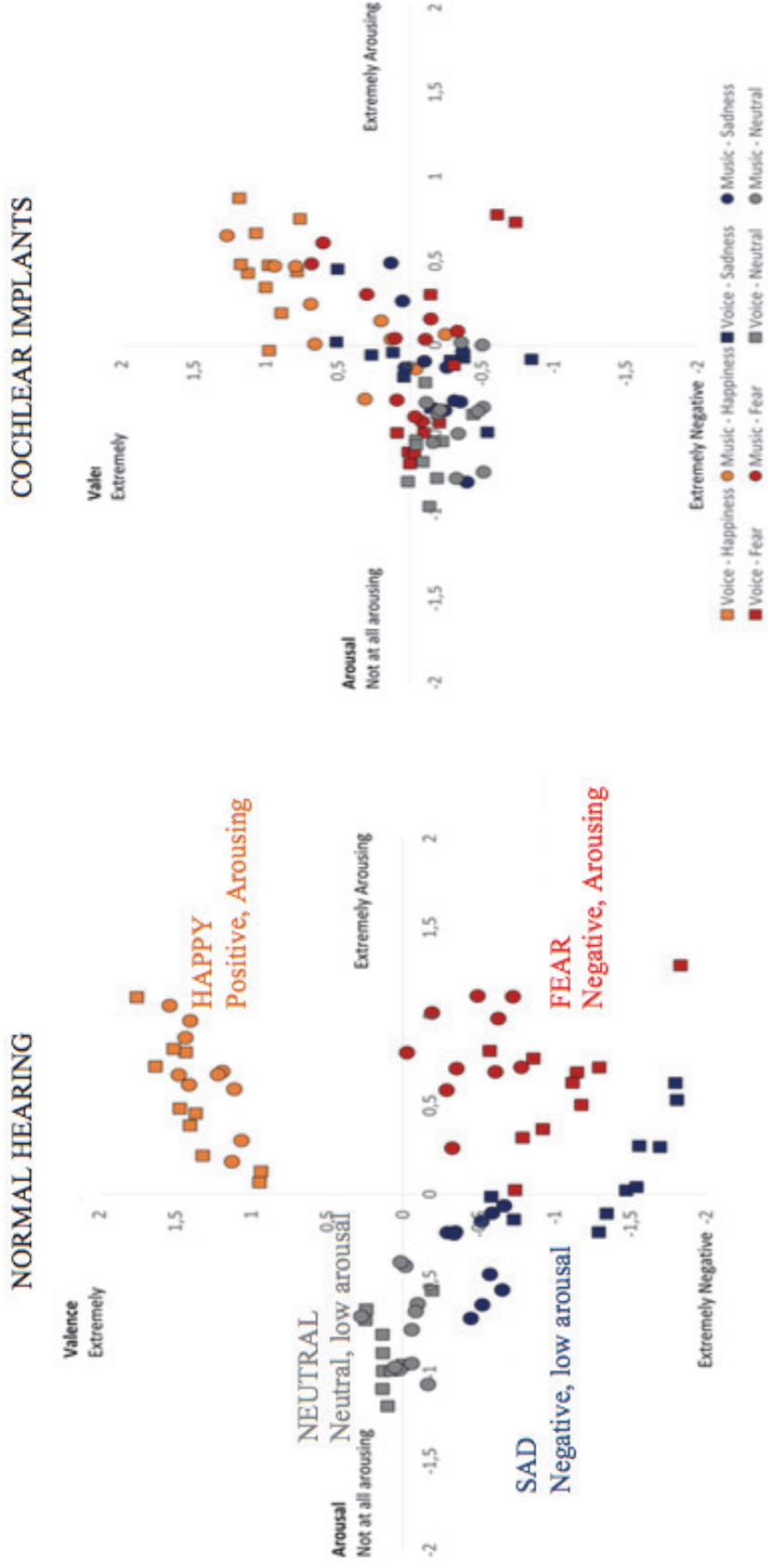
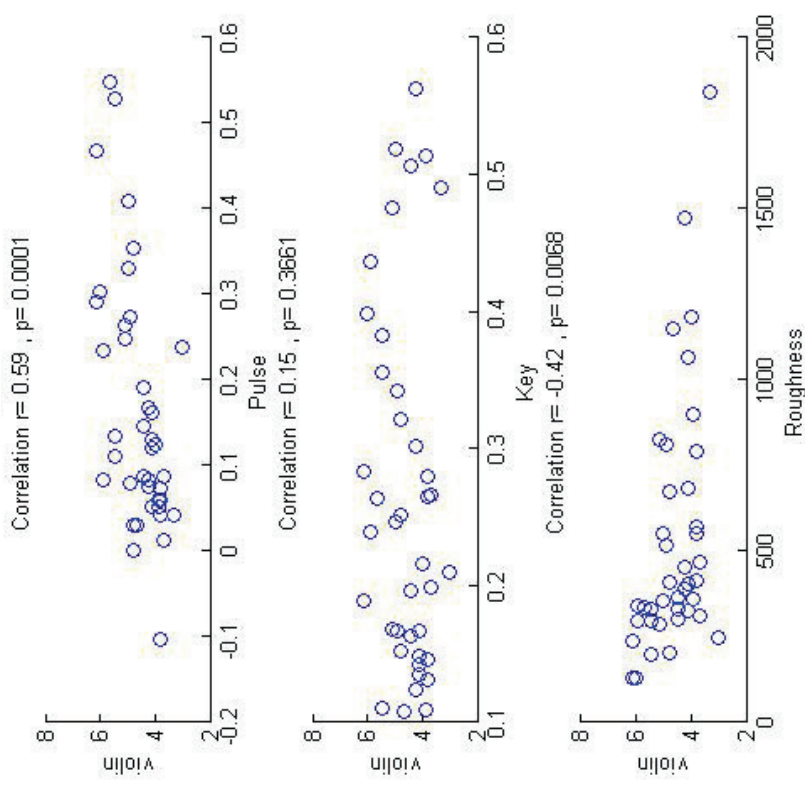


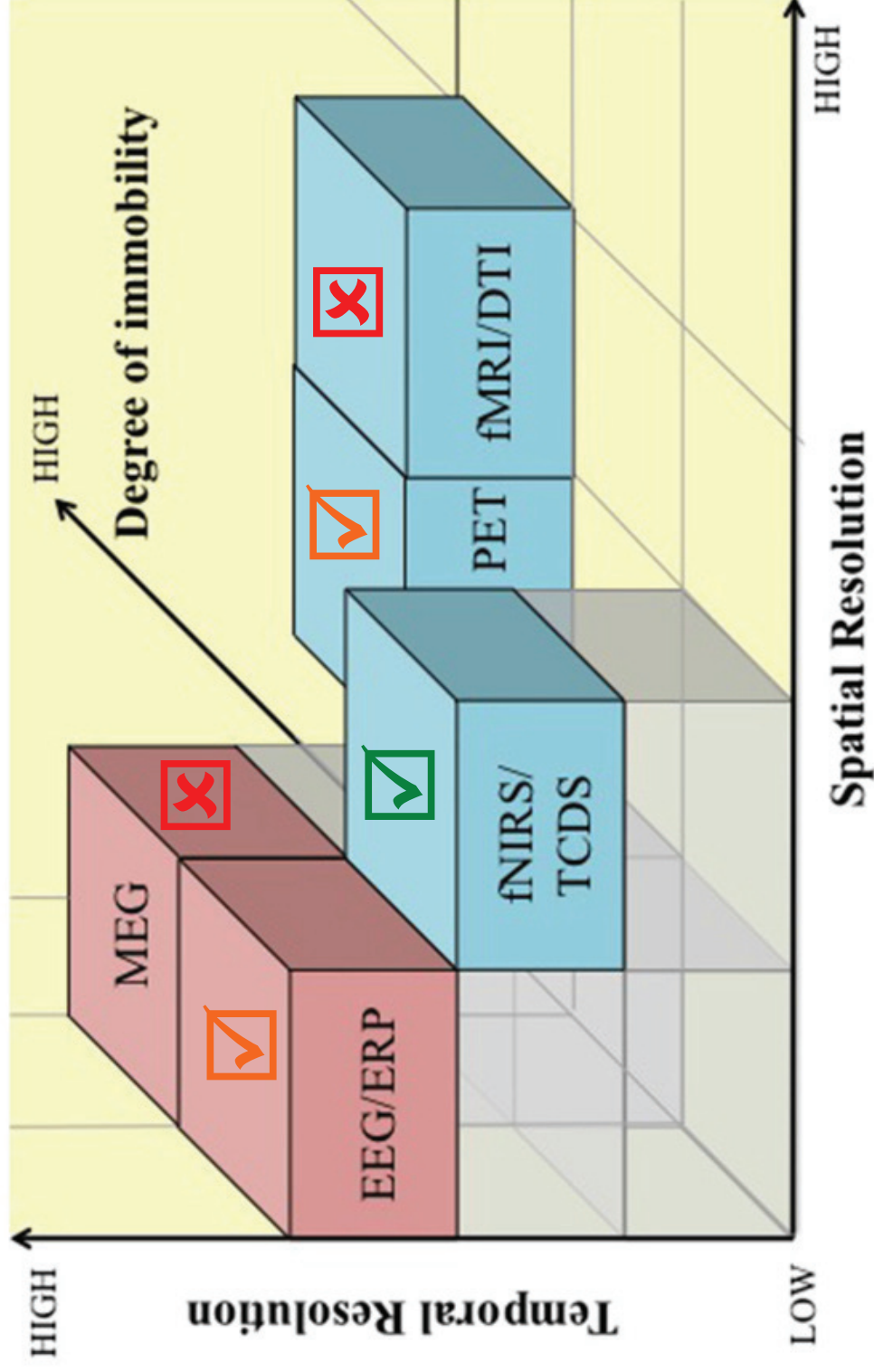
Figure 3. **Hearing through a cochlear implant impairs perception of emotion in music and voice.** Happy, sad and fearful sounds, which normally occupy distinct regions of the valence / arousal bidimensional scale (orange, blue and red symbols, panel A) become similar to neutral sounds (grey symbols) through a cochlear implant (panel B). Only happy sounds are discriminated slightly above chance in this condition.

Implications

- Behavior
 - Role of context and other confounding factors
 - Effect of language acquisition
 - Impact on rehabilitation strategies
- Computational
 - Which acoustic features best convey emotion through implants ?
 - Impact on processor design, rehabilitation and user choices
- Neural measures
 - Which neural stages are affected ?
 - Target mechanisms at stake



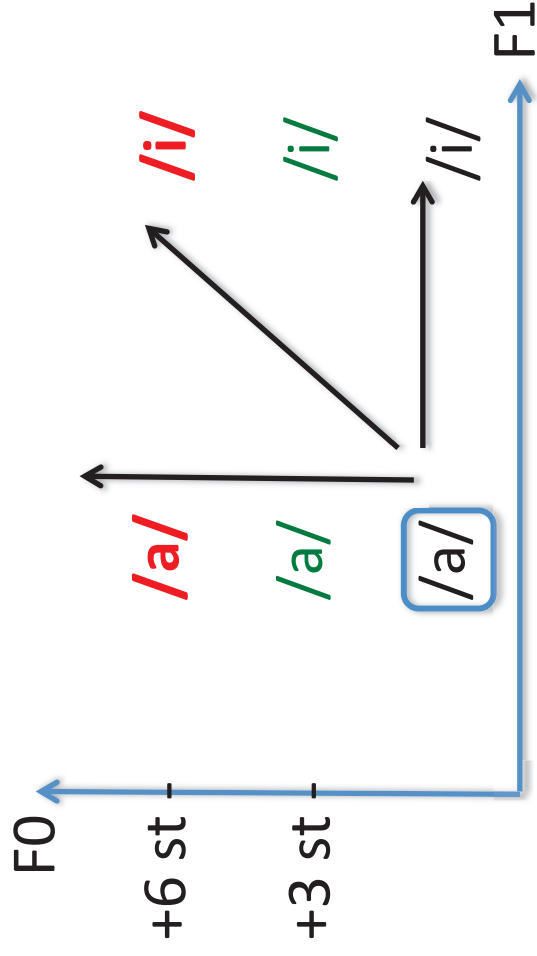
Brain imaging with CI users



EEG studies of plasticity

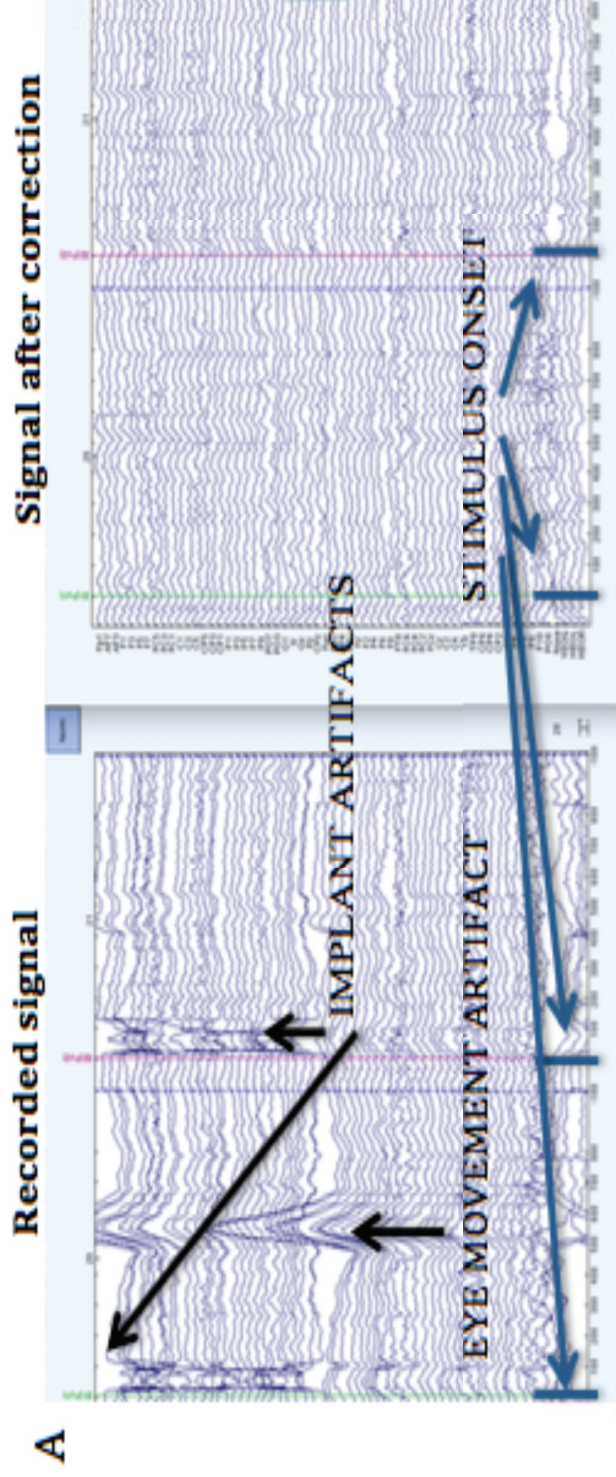
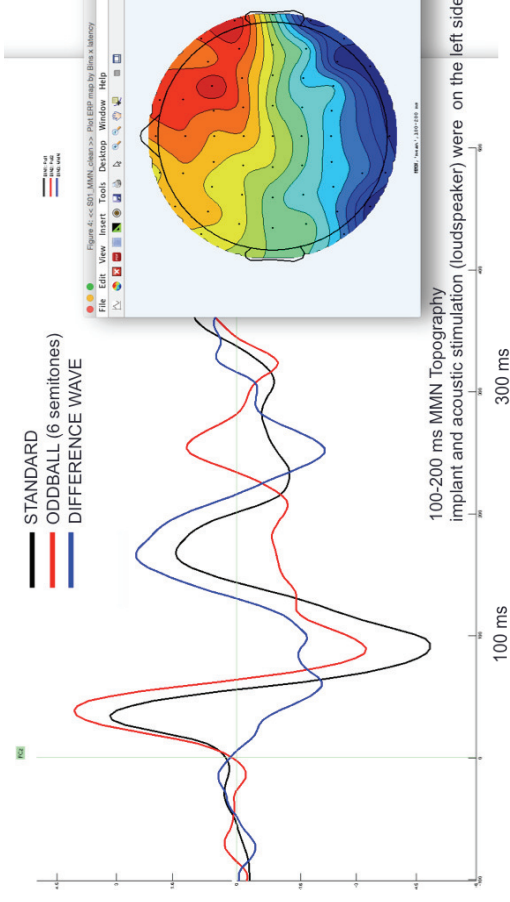
Residual Neural Processing

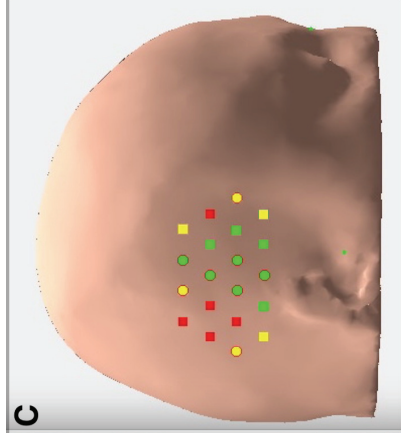
Is there a residual neural discrimination capacity and can it be utilized ?



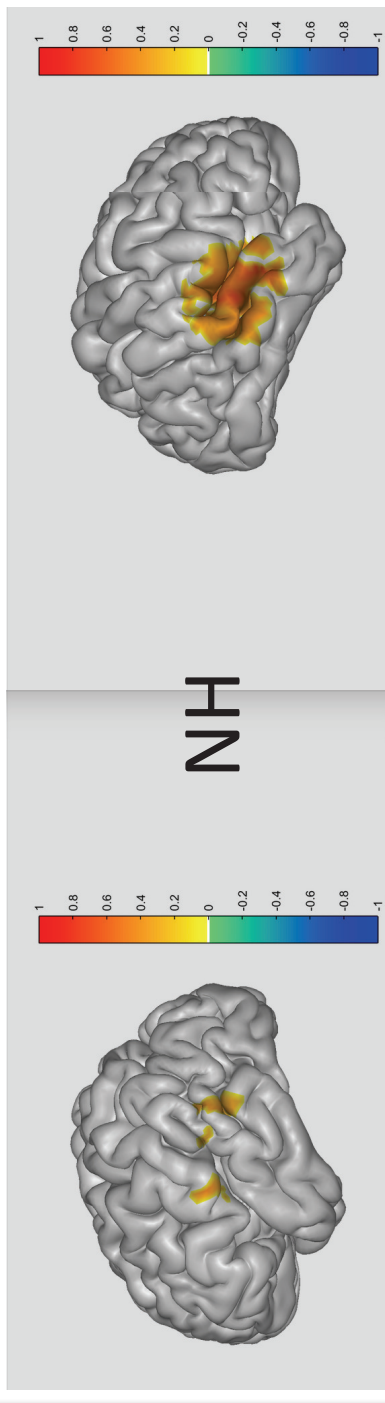
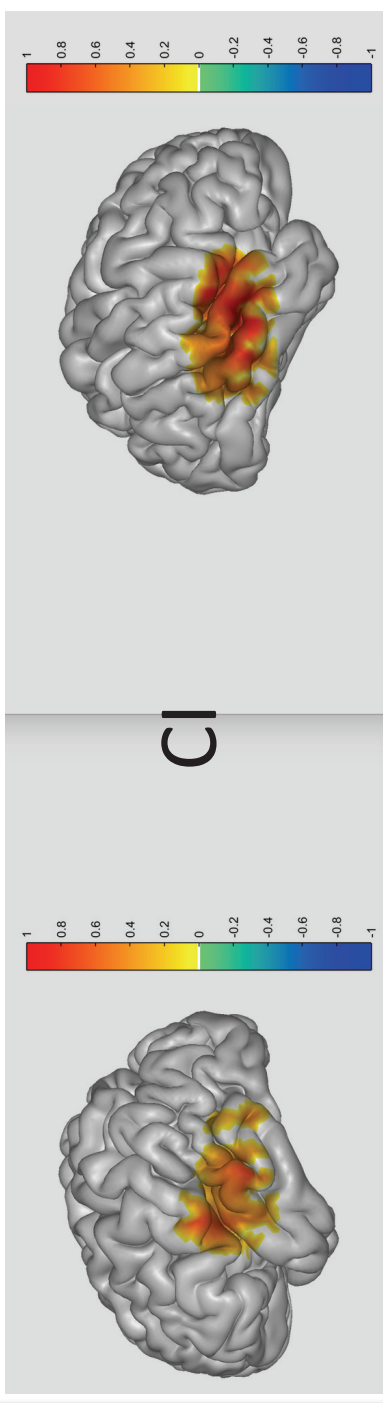
Audio-visual integration markers

Cleaning EEG with ICA





fNIRS, the future of imaging ?



LEFT

RIGHT

Towards personalized rehabilitation ?

- *In order to achieve the best level of speech comprehension, **optimal rehabilitation programs should be individualized**. In the future, **clinical neuroimaging, coupled with behavioral investigations might provide insight into the type of rehabilitation strategy that is best suited for an individual with significant hearing loss.***

(Champoux 2009)

- *The multisensory data are of importance to the development of appropriate therapeutic strategies that maximize speech rehabilitation based on visual and auditory interactions. It is likely that **rehabilitation strategies built on visual and audiovisual training will not only improve but also fasten the recovery of** auditory speech comprehension in CI users.*

(Barone & Deguine 2011)

Holy grail for objective measures

Predicting outcomes & Guiding personalized interventions

- How close are we to it ?
- Is it realistic, feasible, practical ?
- Is it in line with clinical priorities ?
- How do you integrate feedback from clinic into research designs ?

4. The missing link

- From the clinic to the research laboratory
 - Time constraints
 - Different incentives
 - Different languages
- Complementary viewpoints
 - Critical insights
 - Direct feedback from implant users
 - Relevance / Feasibility
- How can it be established / strengthened ?

Take home message

- The brain is plastic across the lifespan, at all hierarchical levels of the auditory system
- Neural plasticity can both promote and impede outcomes in cochlear implant users
- Music-based training can drive plastic changes that have benefits beyond the musical domain
- Optimal counseling, rehabilitation and research directions can only emerge from joint work and exchanges between all actors, from fundamental research to the clinic, and back !

Thanks a lot to:

- You !
- CAA and conference organizers, especially Salima Jiwani and Stephanie Laros
- Rehabilitation centers
 - Institut Raymond Dewar & MAB-Mackay
 - Center for Interdisciplinary Research on Rehabilitation
- Collaborators and students :
 - Isabelle Peretz, Marc Schönwiesner, Nina Kraus, Erika Skoe, John Oghalai, Anthony Zeitouni, François Prevost, Sébastien Paquette, Marie-Anne Prudhomme, Joe Saliba, Duha Ahmed



alexandre.lehmann@mcgill.ca