BRAIN IMAGING IN AUDIOLOGY, RESEARCH AND CLINICAL PRACTICE: Introduction

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Conflict of Interest Declaration

Have provided lectures and seminars at hearing instrument manufacturer sponsored symposia or educational workshops
Neuroimaging, Auditory Function and Auditory Disorders: looking into the structure, function and metabolism of the brain

(Kamarajan and Porjesz, 2015)
Purpose

- Insight into different neuroimaging approaches to study auditory function and disease/disorders.
- Show relationship between different measures and behaviour helps understand normal and abnormal auditory processing.
Selected a number of examples:

- Use of electrophysiological approaches to study auditory behaviour (object recognition): **Claude Alain**

- Understanding disease/disorders:
  
  • Tinnitus and role of brain networks: **Larry Roberts**
  
  • Animal studies of development and effect of transient hearing loss: **Dan Sanes**
Looking inside the brain: Neuroimaging Approaches

- Non-invasive structural, functional, physiological, metabolic imaging of brain structures and pathways
- Correlation with behaviour
- Offers insights into processes underlying normal and abnormal auditory processing
- Clinical and diagnostic use in Audiology strong in EPs, developing in other modalities
Neuroimaging Approaches

Magnetic Resonance Imaging (MRI)

Positron Emission Tomography (PET)

Wiki commons and Ahveninen et al. 2006, 10.1073/pnas.0510480103

https://commons.wikimedia.org/w/index.php?curid=4467244
Functional Imaging

Identify location of brain activity associated with functional tasks

• BOLD-fMRI measures change in blood oxygen ratio as index of function

• PET uses radioactive tracers to measure blood flow or metabolic activity as indicators of function
Neuroimaging Approaches

• MRI and PET powerful tools to image brain structure, function, metabolism

• Identify structural features and enable tracing of nerve fibre tracts and assessment of integrity

• Interaction of brain regions as networks, connectomics (eg tinnitus)
Neuroimaging Approaches

- Possible in animals as pre-clinical studies of auditory function and disorders

Small brain imaging with BOLD fMRI

Measure hemodynamic response to sound

Gao et al., 2015
Small brain imaging with BOLD fMRI

7 Tesla Scanner

3D rendered brain

Correlation coefficient map

Gao et al., 2015
Neuroimaging Approaches

Physiology: **ElectroEncephaloGraphy (EEG, AEPs)**

Zendel and Alain 2008
Neuroimaging Approaches

Physiology: MagnetoEncephaloGraphy (MEG)

Non-invasive techniques for functional neuroimaging

- Positron Emission Tomography (PET)
  - High spatial resolution, poorer temporal resolution
- Functional Magnetic Resonance Imaging (fMRI)
- Electroencephalography (EEG)
  - Poor spatial resolution (esp EEG), higher temporal resolution
- Magnetoencephalography (MEG)
Inner Ear Imaging: structure and function
Blood Labyrinth Barrier in Meniere’s Disease

Plumat et al., in preparation

Meniere’s background signal

Meniere’s post vascular Gd
Round Table Presentations
Claude Alain: "The Object-Related Negativity: A Neural Metric to Assess Concurrent Sound Segregation from Infancy to Old Age"

– Event-related potentials (ERP) to look at how we segregate sounds occurring simultaneously.

– Use to study concurrent sound perception and to assess hearing difficulties in noise.

– Research and clinical opportunities to objectively quantify deficits in concurrent sound segregation and perception.
Larry Roberts: "Electrophysiological and metabolic imaging of tinnitus from cochlea to brain"

- Metabolic and electrophysiological imaging of brain network activity to look at neural basis of tinnitus
- Changes in primary auditory cortex relate mostly to tinnitus percept while those in other brain regions reflect the cognitive and emotional consequences
- Application to improved methods for treatment.
Studies of Auditory Disorders using Animal Models

Dan Sanes: “Can transient hearing loss harm the developing nervous system?”

– Transient hearing loss in children causes deficits in perception, speech, or language skills.
– Animals studies help to understand neurological basis
– Show irreversible functional impairments to auditory cortex synapses
– Learning deficits maybe due to long-lasting impairment in brain areas downstream of auditory cortex.
Non-invasive recording from human brain (Functional brain imaging)

Electromagnetic techniques

Hemodynamic techniques

Positron emission tomography (PET)

Excellent spatial resolution (~1-2mm)
Poor temporal resolution (~1sec)

Functional magnetic resonance imaging (fMRI)

Electro-encephalography (EEG)

Poor spatial resolution (esp. EEG)
Excellent temporal resolution (<1msec)

Magneto-encephalography (MEG)
Probing Primary Auditory Cortex with EEG and MEG

2000 Hz tone AM @ 40 Hz

40-Hz Auditory Steady State Response

Change carrier frequency to probe different tonotopic regions

MEG: Pantev Roberts Ross et al. (1996)
EEG: Gander Bosynak & Roberts (2010)
Inner Ear Imaging

- Imaging techniques not just confined to auditory brain but imaging approaches improving and developing for studying inner ear disease
Neuroimaging Approaches

• Together (MRI, PET with behavioural and electrophysiological techniques) very powerful approaches that have helped advance our understanding of:
  – Normal and abnormal auditory processing
  – Brain plasticity with cochlear implantation
  – Tinnitus
  – Speech production and recognition
Programme

Claude Alain: "The Object-Related Negativity: A Neural Metric to Assess Concurrent Sound Segregation from Infancy to Old Age"

Larry Roberts: "Electrophysiological and metabolic imaging of tinnitus from cochlea to brain"

Dan Sanes: "Can transient hearing loss harm the developing nervous system?"

Panel discussion/QA
LORETA: Low resolution electromagnetic tomography

- Projects current densities per voxel of brain space from EEG and MEG data
- Interregional connectivity: time series coupling between regions in various frequency bands
- Cross-frequency coupling: time series coupling between frequencies


Inner Ear Functional Imaging

Use of Manganese MRI to study neural function in animals: Mn taken up by active neurons, such as with tinnitus, and shows high signal in MRI

Jung et al., 2014
Neural activity associated with concurrent sound segregation

Alain, Arnott, & Picton (2001) JEP:HPP