Coherence Analysis of Brain Activity Associated with Tinnitus

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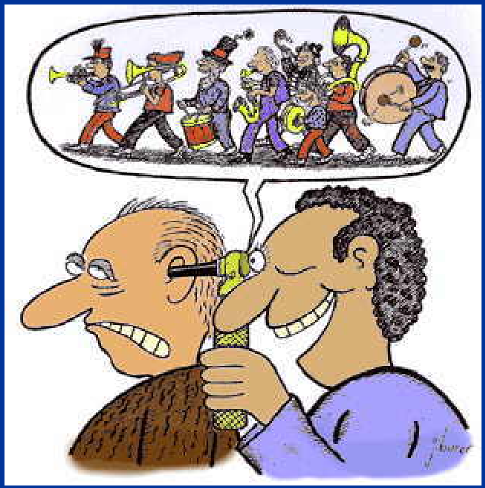
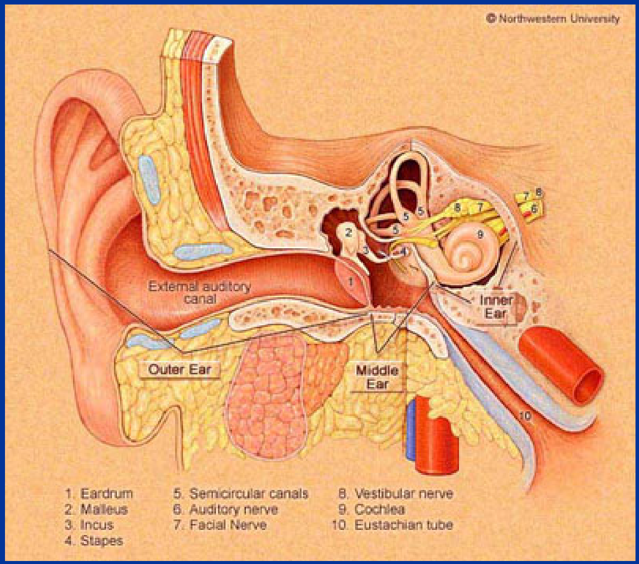
WEB site:

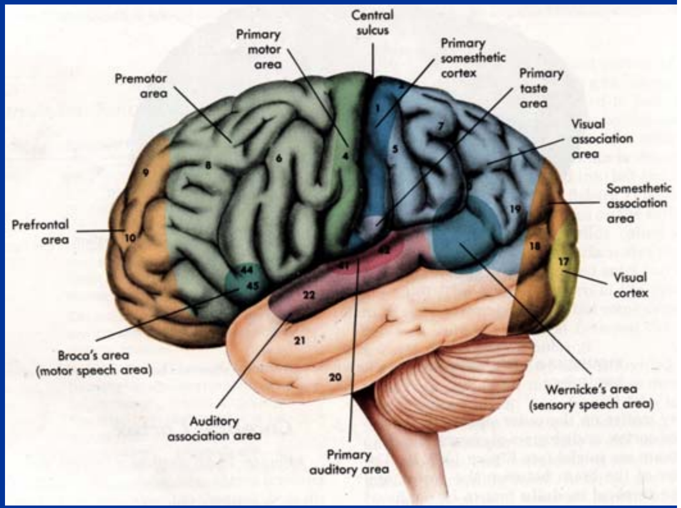
http://www.megimaging.com

Objective

To determine if MEG can detect cortical sources in the auditory cortex correlated with severity and location of Tinnitus.







Tinnitus

- Tinnitus is ringing, buzzing or any sound perceived to be coming from the head or ears without an external sound source (Seidman, 2008).

- Tinnitus is a distressing symptom affecting up to 30% of the population (300 million world wide), with 2 to 4% severely debilitated (Seidman, 2003).

- Tinnitus is a subjective phenomenon, that is difficult to measure. The Tinnitus Handicap Inventory is often used to quantify the impact of tinnitus on daily living.

- Although no cure for tinnitus exists there are many treatments, most of which provide only limited relief.

Imaging Studies of Tinnitus

- For many years it was thought that the buzzing or ringing sounds heard by people with tinnitus ONLY originated in the ear, but a functional imaging study using PET demonstrated that these phantom auditory sensations originated somewhere in brain, not in the ear. Increased activity of the primary auditory cortex that correlated with site of tinnitus. (Langguth 2006).

- MEG, using a noise free environment, is better suited to detect functional activation arising from tinnitus.

- MEG has also been applied to the investigation of a limited number of tinnitus studies and has been used to detect differences in the auditory responses in tinnitus patients [Hoke 1989,Muhlnickel 1998 and Wienbruch 2006].

- Recently Kahlbrock and Weisz, 2008 used MEG to detect delta band changes after residual inhibition treatment in patients with tinnitus.

- Posters by Mueller "The impact of different TMS protocols on neuronal activity in tinnitus patients revealed by MEG" and Schlee "Directed Coherence in the Resting Tinnitus Brain" show the use of MEG for detecting tinnitus.

- Our lab has been using MEG to determine areas in the brain that are coherent with all other areas. The synchronized activity within a neuronal network can be detected and imaged using Coherence analysis of MEG data (Salmelin 2006).

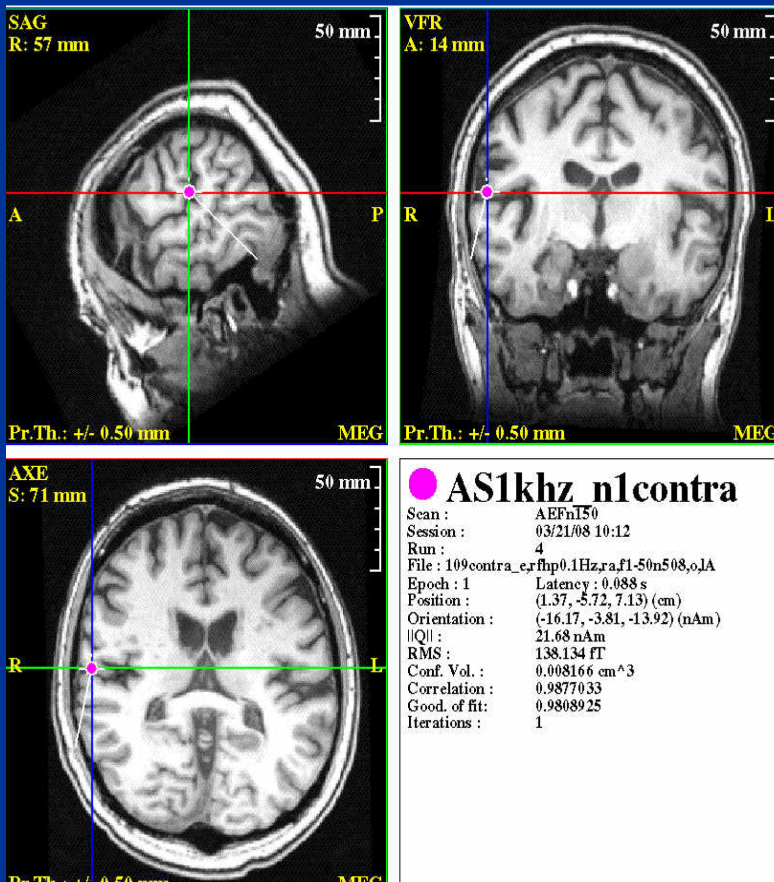
Methods

- Four Patients with Tinnitus (ages 50 $\pm$ 10: All Males)
- Five normal controls (aged 14-45, 2 females)
- 148 channel MEG: Magnetometers
- Spontaneous brain activity was measured while the patients lay still with ear plugs in their ears. Brain response to 1kHZ tone and tones frequency matched to the individual patients tinnitus were also recorded.
- Data was filtered 1-50Hz, then source localization results were imaged on to their anatomical MRI scan.

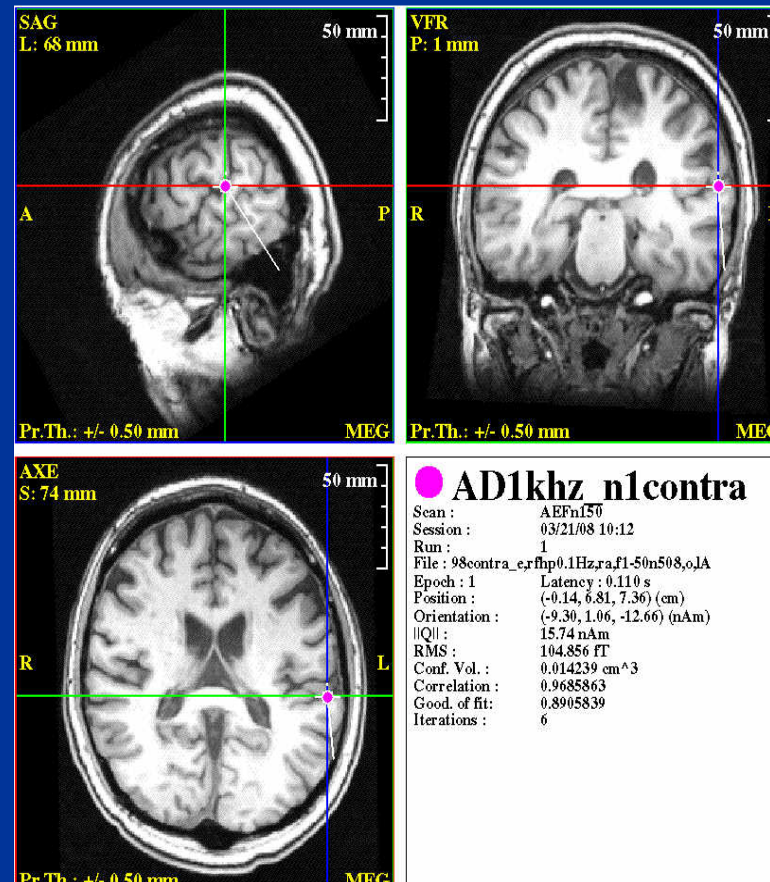
Source Localizations

- Equivalent single current dipole analysis (ECD) was used to determine the location of the N100m response to the 1kHz tone and the tones matched to the tinnitus.
- MR-FOCUSS, a current distribution mapping technique was also used to localize the cortical sources for the N100m from the tones (Moran et al, 2005).
- Coherence analysis was performed on the 10 minutes of spontaneous brain activity where no tones were presented.

AEF 1k Hz tones presented monaurally to each ear in a patient with Unilateral tinnitus (ECD)

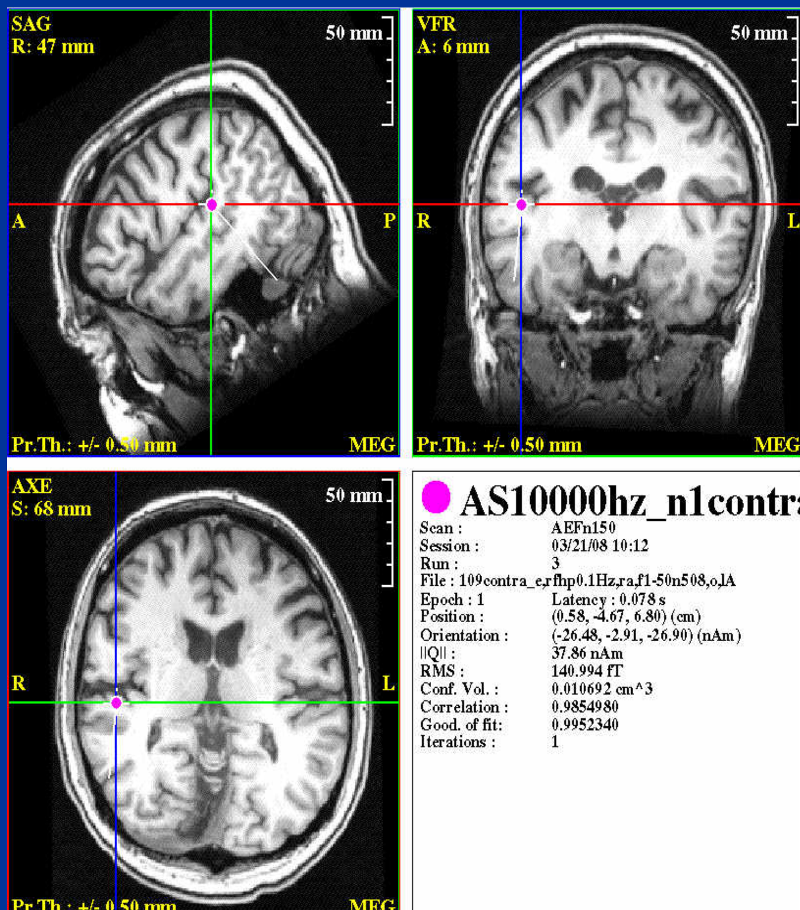


Tones presented to left ear

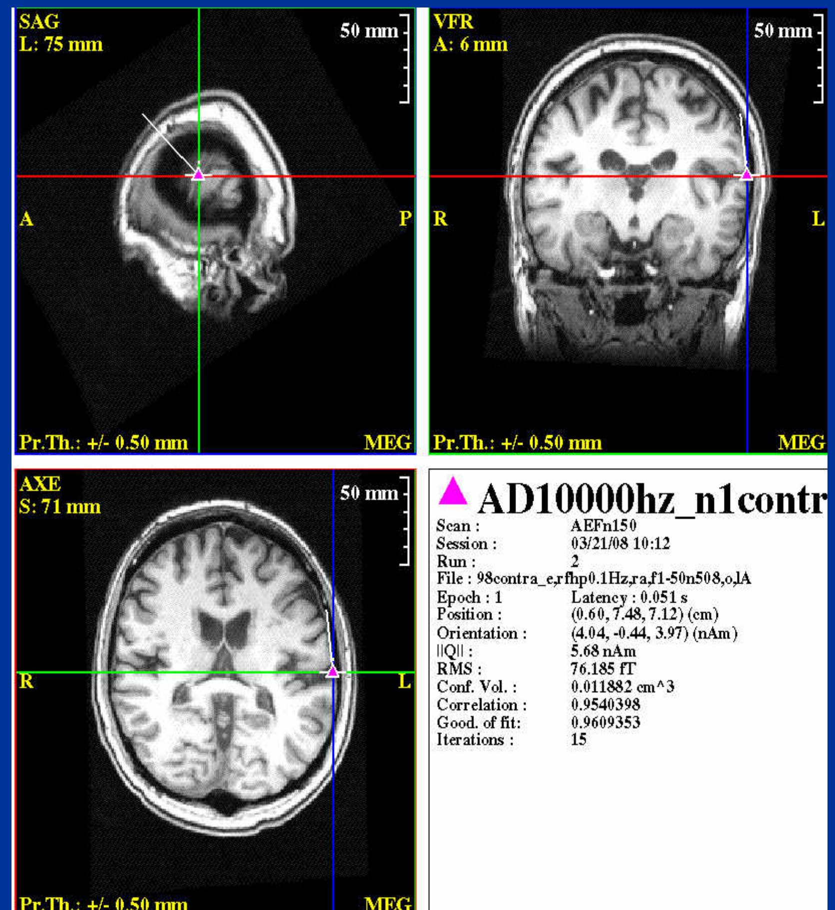


Tones presented to right ear

AEF 10k Hz tones presented monaurally to each ear in a patient with Unilateral tinnitus (ECD)



Tones presented to left ear



Tones presented to right ear

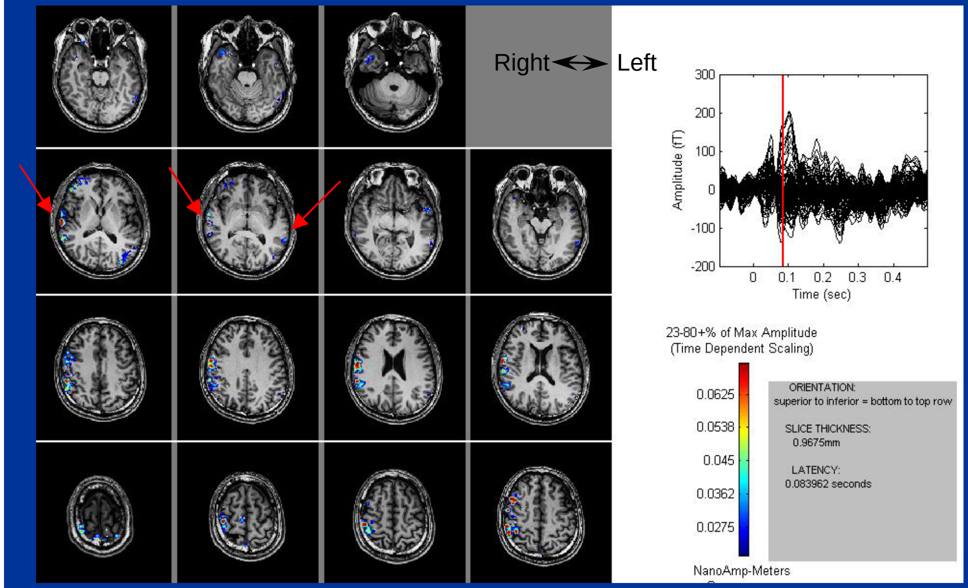
Note Cor. And GoF are poor for responses in Left hemisphere and location is lateral to 1kHz tone.

AEF Results

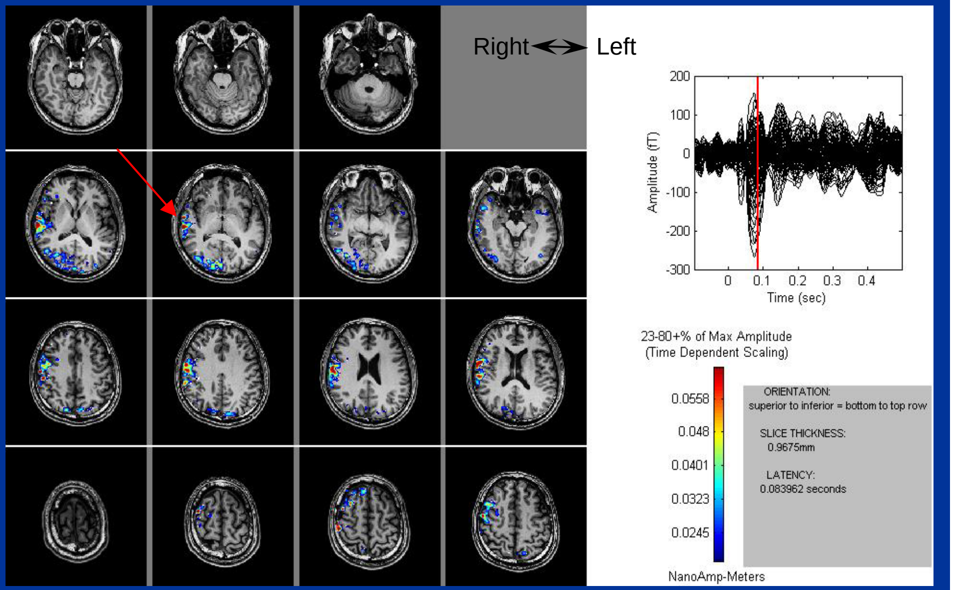
- AEF at 1 kHz localized to Auditory cortex using ECD analysis.
- AEF of 10 kHz localized medial to the 1 kHz tone when the tones were presented to the left ear.
- When the 10 kHz tones were presented to the Right ear the Correlation and goodness of fit were reduced and the localization is lateral to the 1 kHz tone.

AEF 8z Hz Tones (MR-FOCUSS)

Right ear stimulation



Left ear stimulation



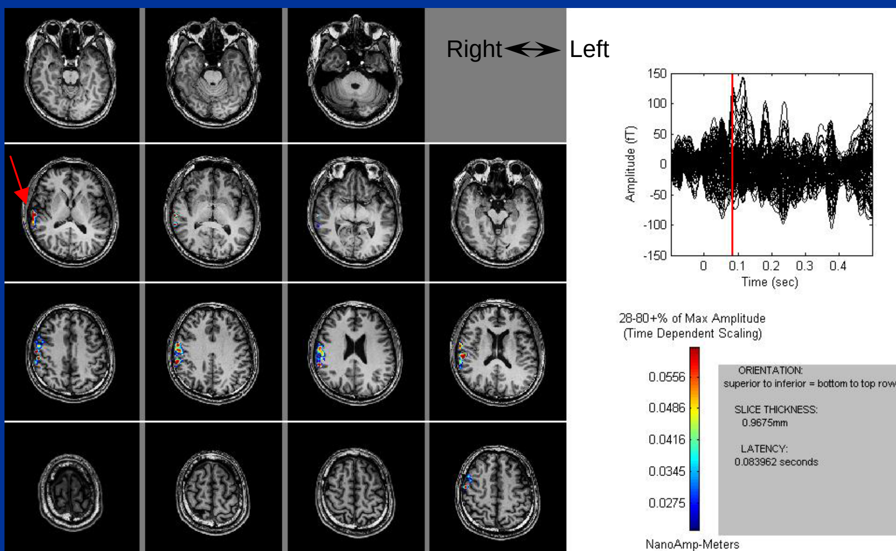
This patient tinnitus was frequency matched with 8, 10 and 12 Hz.

Left ear stimulation produced cortical activity in the right hemisphere, as expected.

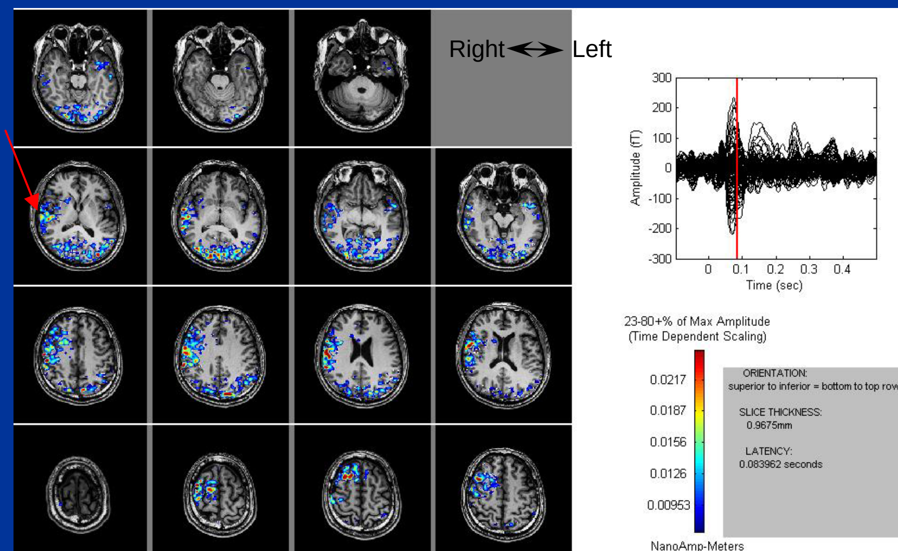
Right ear stimulation produced small cortical activity in the left hemisphere, but greater activity is seen in the right auditory cortex.

AEF 10k Hz Tones (MR-FOCUSS)

Right ear stimulation



Left ear stimulation

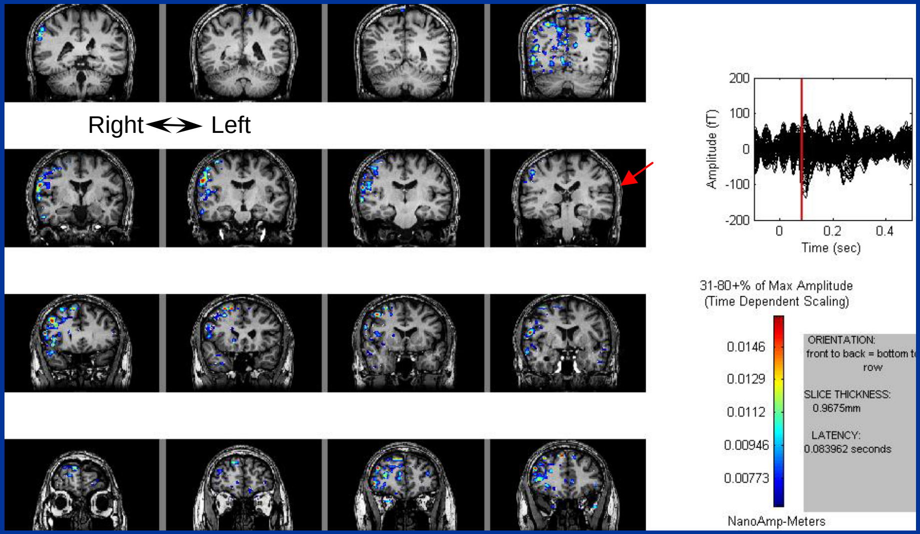


Activity only localized to Right hemisphere no matter which ear was stimulated. Note the poor evoked MEG waveform from Right ear stimulation.

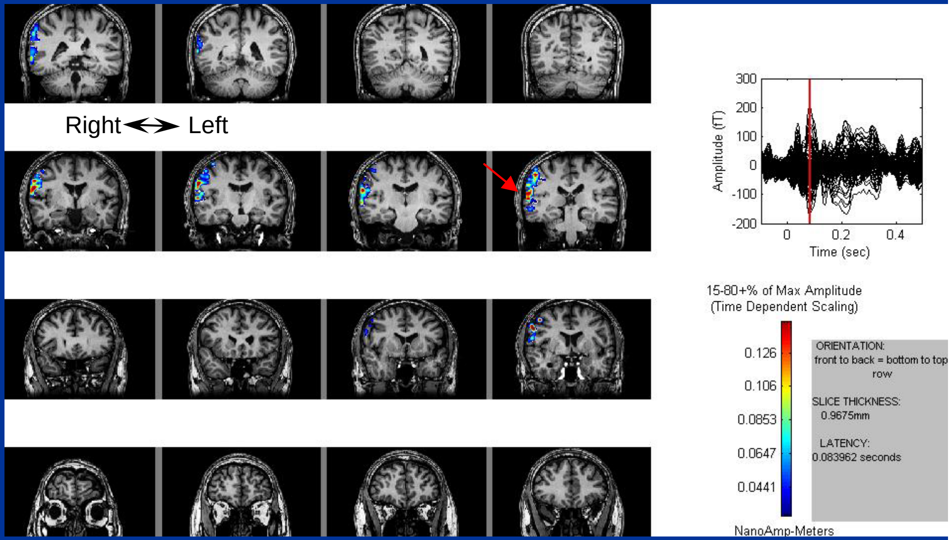
Left cortex is producing the tinnitus and therefore not able to detect the tone, so the ipsilateral cortex takes over the task of hearing the tone at the tinnitus frequency.

AEF 12k Hz tones (MR-FOCUSS)

Right ear stimulation



Left ear stimulation



Activity only localized for the Left ear stimulation.

At the same latency the Right ear stimulation produces no responses in the Left hemisphere.

Coherence

- The analysis of coherence between EEG electrode site and MEG sensors has been performed for many years. However, at best only regional inference of cortical connectivity can be estimated without first imaging brain activity.

- Transients and oscillations of brain electric activity are found in MEG, EEG and ICEEG recordings of spontaneous brain activity. These transient waveforms and oscillations can be quantified by applying a time-frequency decomposition technique such as the short-time Fourier transform (sFFT).

- After transformation to a time frequency representation, the strength of network interactions can be estimated by calculation of coherence, which is a measure of synchrony between signals from different brain regions for each FFT frequency component.

- Basis for advanced network evaluation techniques (Granger causality, narrow band filtering or Essential Mode Decomposition with Hilbert transforms, wavelets) these are applied to non-stationary data.
  - Determine the direction of network interactions
  - Quantify significance of network structures

MEG Coherence mapping:
Compared to Electrocortical Recordings

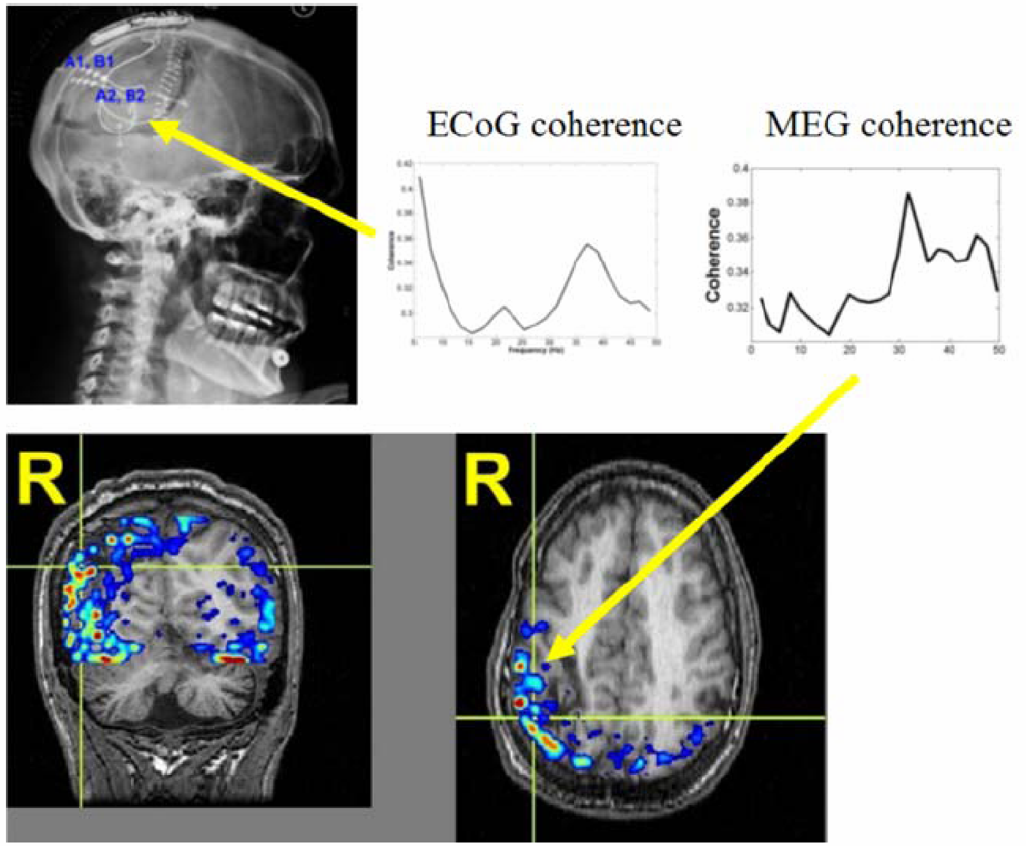
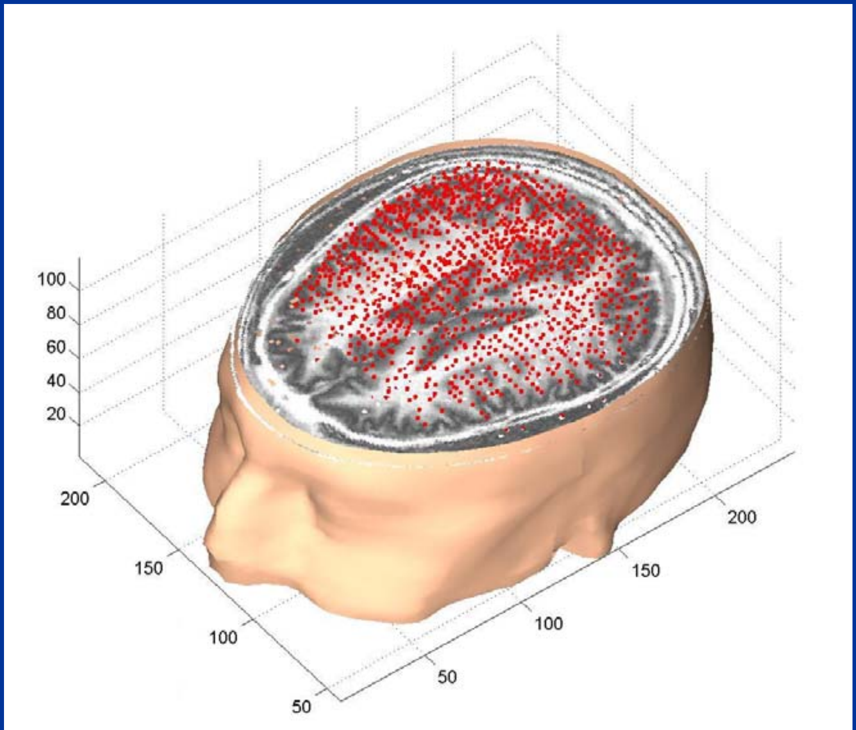


Fig 1. MEG imaged coherence and corresponding interictal ECOG coherence are similar, especially in the 30-40 Hz coherence band.

Moran J. et al. *2006, MEG Coherence Imaging Compared to Electrocortical Recordings from NeuroPace Implants to Determine the Location of Ictal Onset in Epilepsy Patients,* in *15th International Conference on Biomagnetism*.

Cortical Model

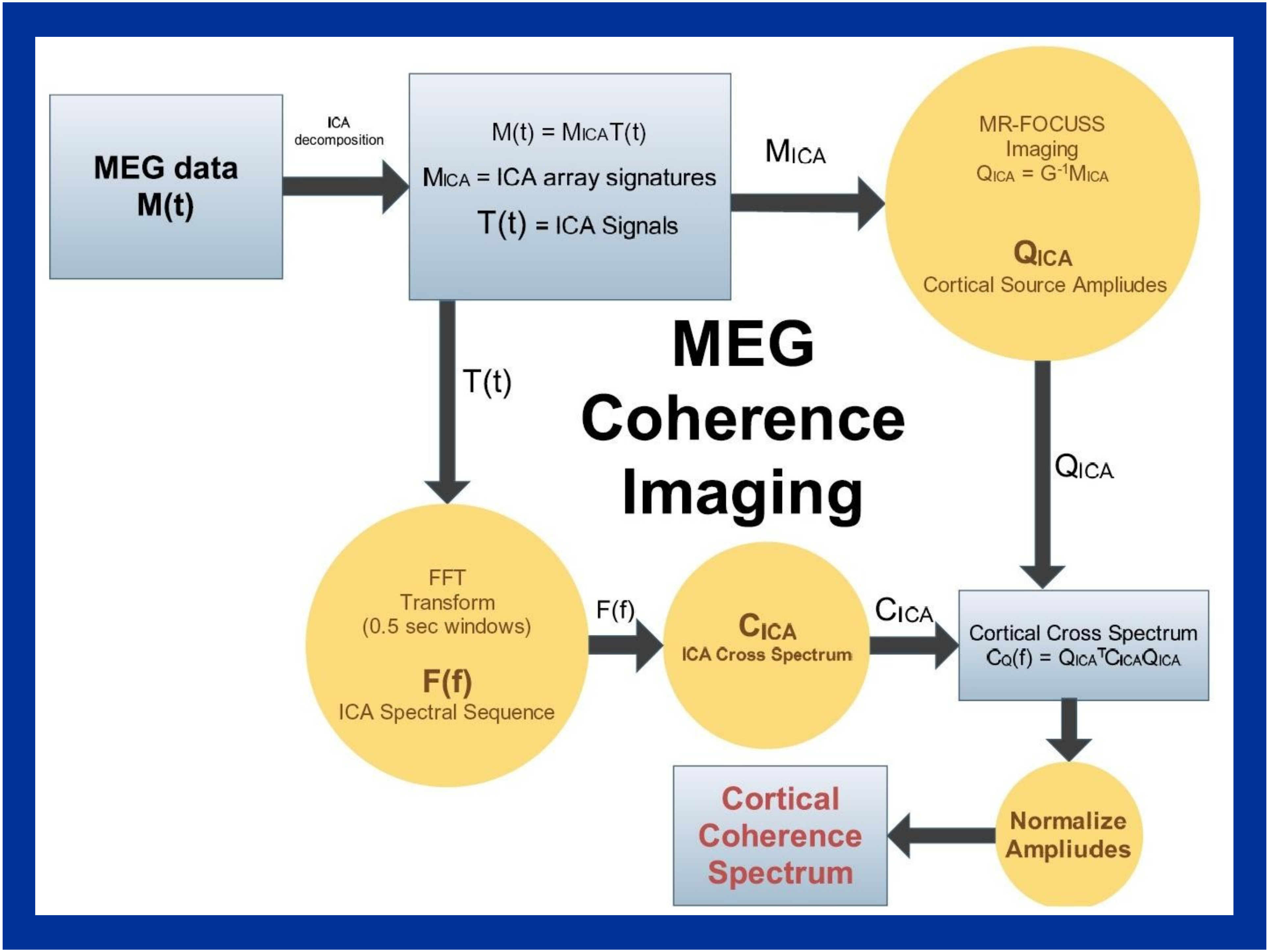


- Created from Volumetric MRI Data
- ~4,000 cortical locations
- Distribution matches cortical gray matter

Coherence Imaging: Calculation

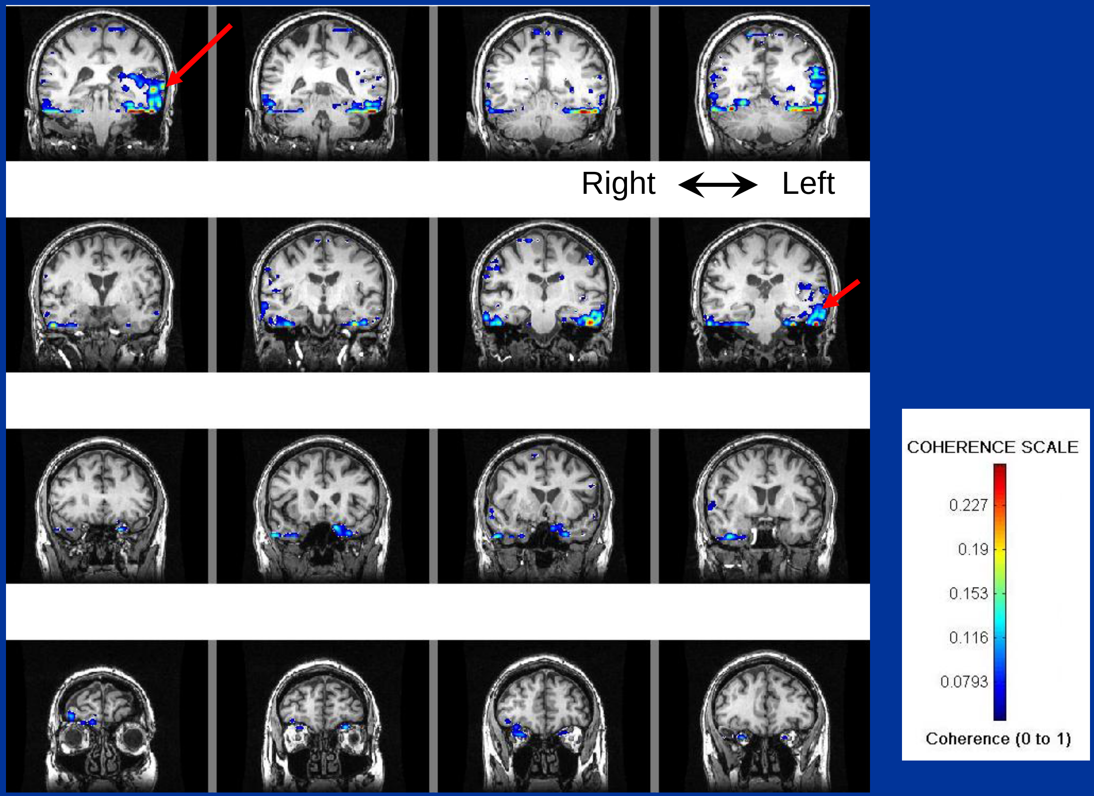
1. Calculate time sequence of brain activity (divide data into 7.5 sec window)
   a. ICA extraction of burst activity brain source signals
   b. MR-FOCUSS (current distribution) imaging of ICA components
2. Calculate FFT sequence (0.5 second windows)

   temporal sequences of sources are converted to temporal source FFT spectra
3. Calculate cross-spectral matrix between sources (ICA components) for each frequency
4. Calculate coherence between all network structures
5. For each active cortical site the average coherence with all other sources is calculated for each frequency.
6. Both the Imaginary and Real components are incorporated in the coherence imaging results.



MEG data M(t)
ICA decomposition
M(t) = MICA T(t)
MICA = ICA array signatures
T(t) = ICA Signals
MICA
MR-FOCUSS Imaging
QICA = G-1MICA
QICA
Cortical Source Ampliudes
MEG Coherence Imaging
T(t)
QICA
FFT Transform (0.5 sec windows)
F(f)
ICA Spectral Sequence
F(f)
CICA
ICA Cross Spectrum
CICA
Cortical Cross Spectrum
CQ(f) = QICATCICAQICA
Normalize Ampliudes
Cortical Coherence Spectrum

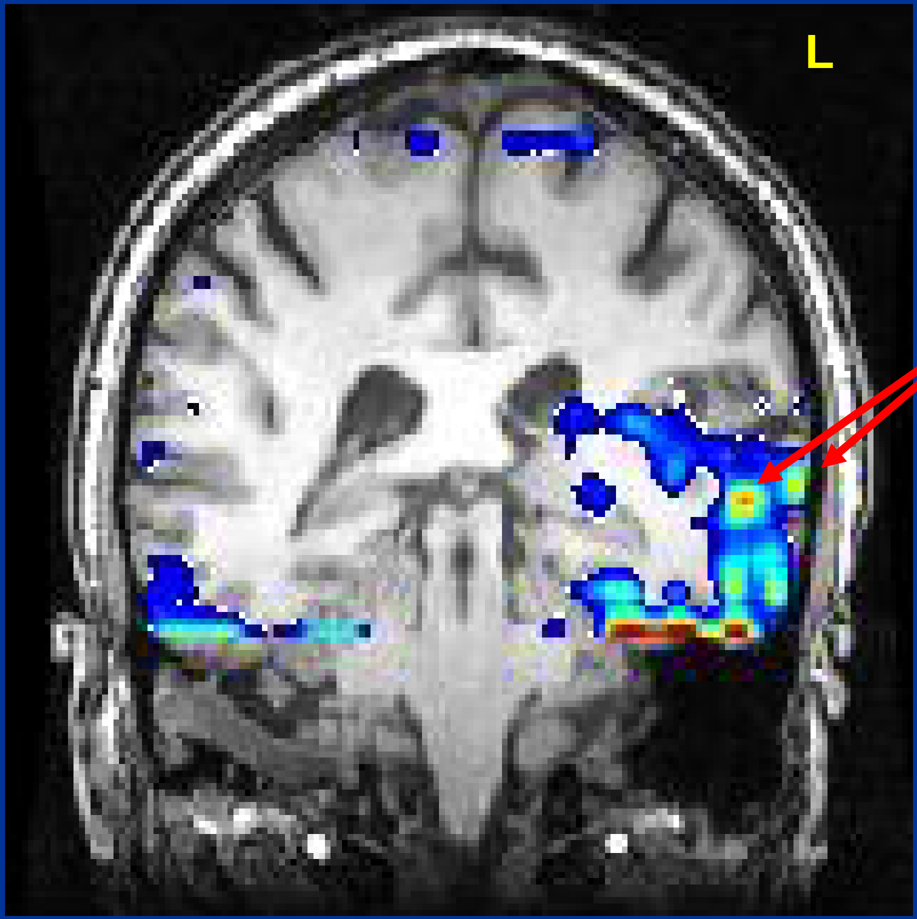
Coherence mapping



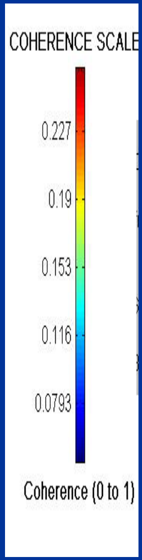
Same subject as ECD slides. MEG Coherence analysis of spontaneous activity while the patient perceived his/her tinnitus. MRI shows localization of activated cortex in the Left Auditory Cortex. Red indicates cortical areas that are highly coherent with all other brain regions.

Expanded view

Coherence Imaging

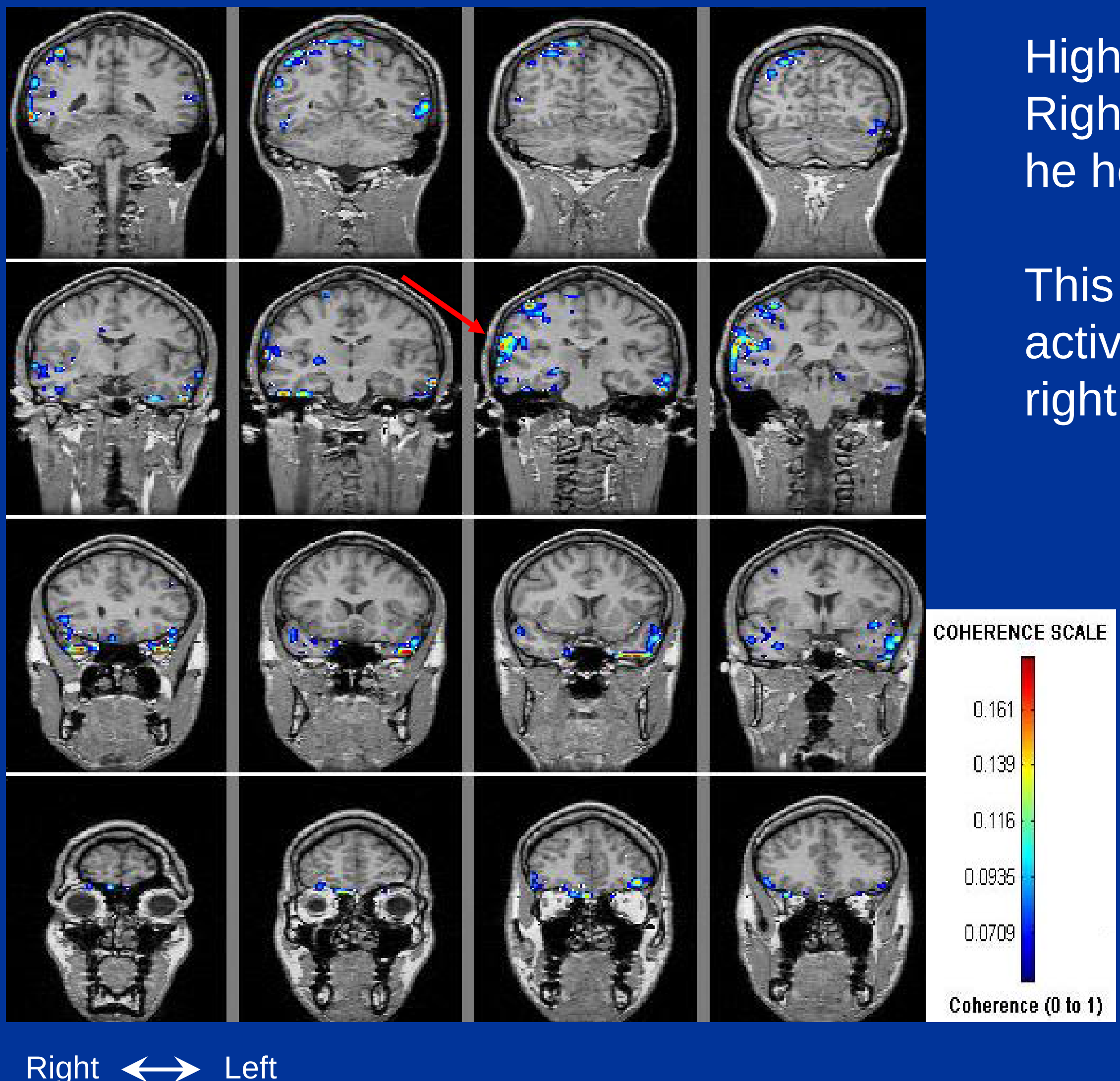


Auditory Cortex



Left Auditory cortex is significantly more active in this passive condition.

Coherence in Bilateral Tinnitus



Highest coherence is seen in the Right Auditory cortex even though he hears ringing in both ears.

This implies a network that is more active in the auditory cortex of the right hemisphere than in the left.

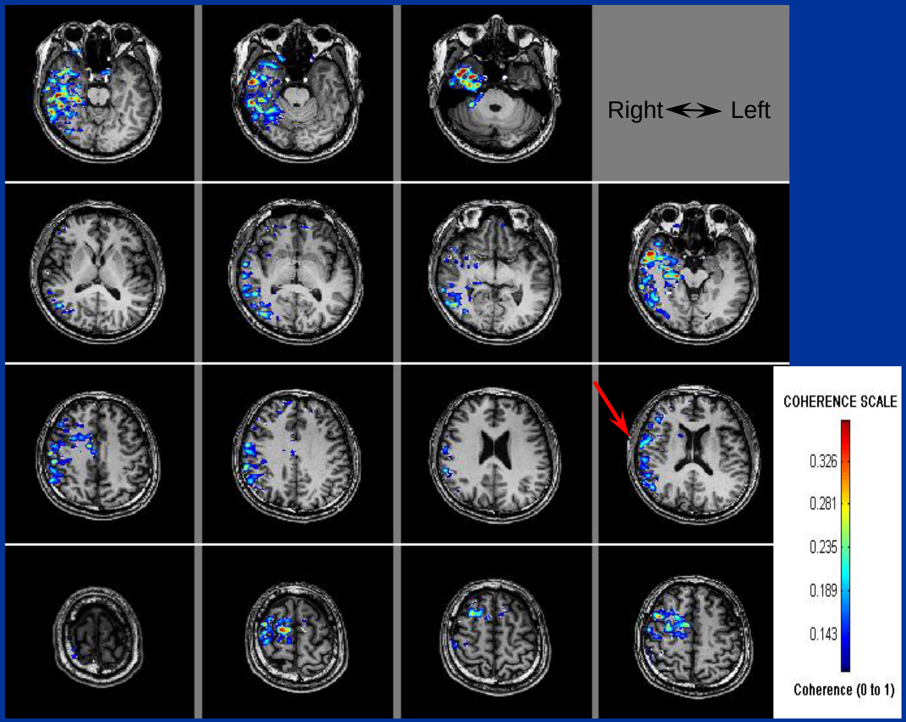
Coherence results

- Patient lay down with eyes open (no alpha activity) and ear plugs in (no sound stimuli).

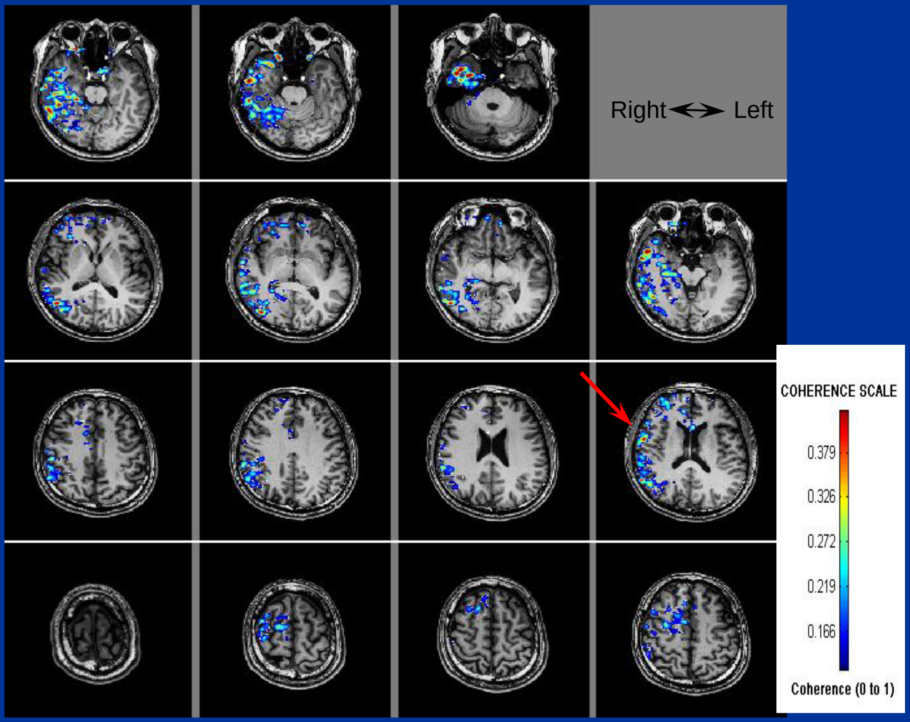
- He has high coherence seen in the left Auditory cortex. This implies a network that is active during rest in the auditory cortex of the left Hemisphere.

Coherence Results

Eyes Open



Eyes Closed

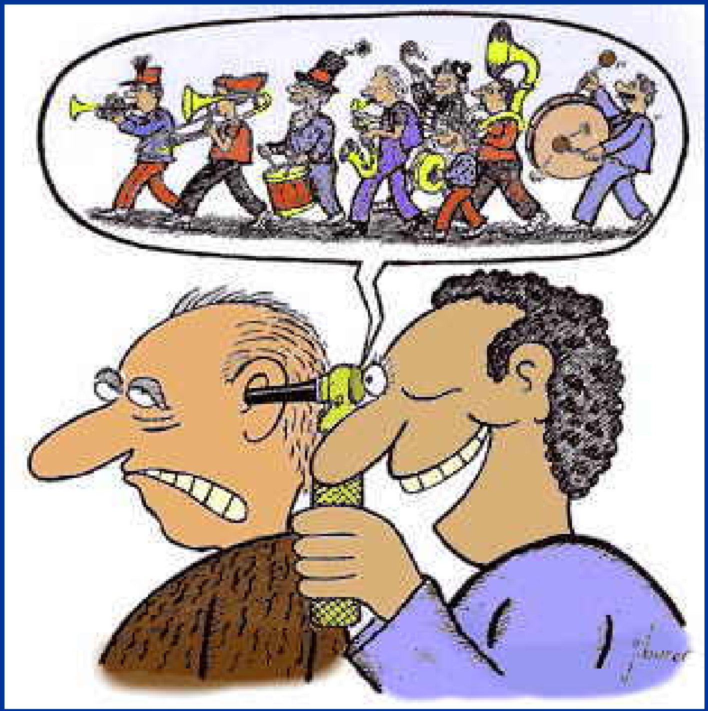


Patient #3, Highly coherent activity in the 1-50 Hz range is clearly seen within the right Auditory cortex in both conditions (eyes open, closed). This patient had unilateral tinnitus heard in the left ear.

Conclusion

- We have demonstrated that specific cortical areas in the auditory cortex, which may be responsible for tinnitus, are detectable using MEG.
- In subjects with tinnitus, highly coherent brain activity in the auditory cortex, contralateral to their perceived tinnitus dominated the coherence displays. i.e. the hemisphere of activity matched the auditory cortex that generates the perceived tinnitus.
- In the case of the patient who had bilateral tinnitus, the MEG scan found higher cortical coherence in one hemisphere.
- Auditory Evoked Fields produced poor responses in the cortex with tinnitus.
- Elucidating the underlying cortical networks of tinnitus are crucial for the understanding how disruption of these networks may improve this debilitating condition.
- These studies may further the basic science of validating neuronal network models of auditory functioning. Accurate models of these networks may prove useful for the development of future tinnitus treatments.

Thank you for your attention!
Arigatoo!



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