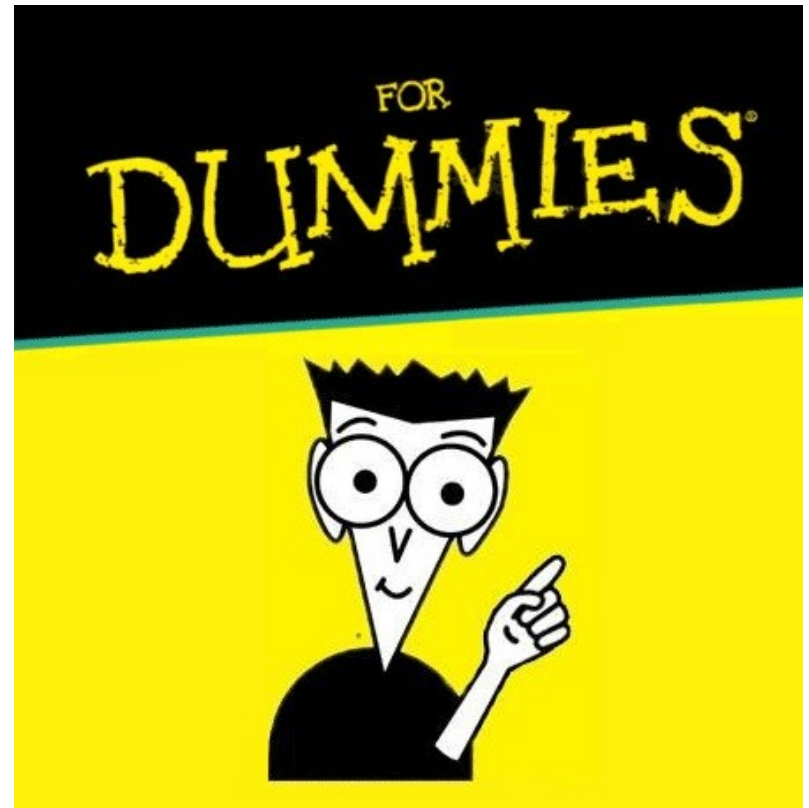


Basis of M/EEG Signal

David Sutton
Lucy Ferguson

Overview

- Introduction
- EEG vs. MEG
- Background
- Signal
- EEG
- MEG
- Disadvantages
- Advantages
- Summary



EEG



<http://opencc.co.uk/blog/out-of-touch-manual-keypads-and-controllers-face-competition-from-new-hands-free-computer-interfaces/>

Neuroscience - nervous system

- neural communication
- pyramidal neurons

Physics - “knowledge of nature”

- electromagnetism
- technology

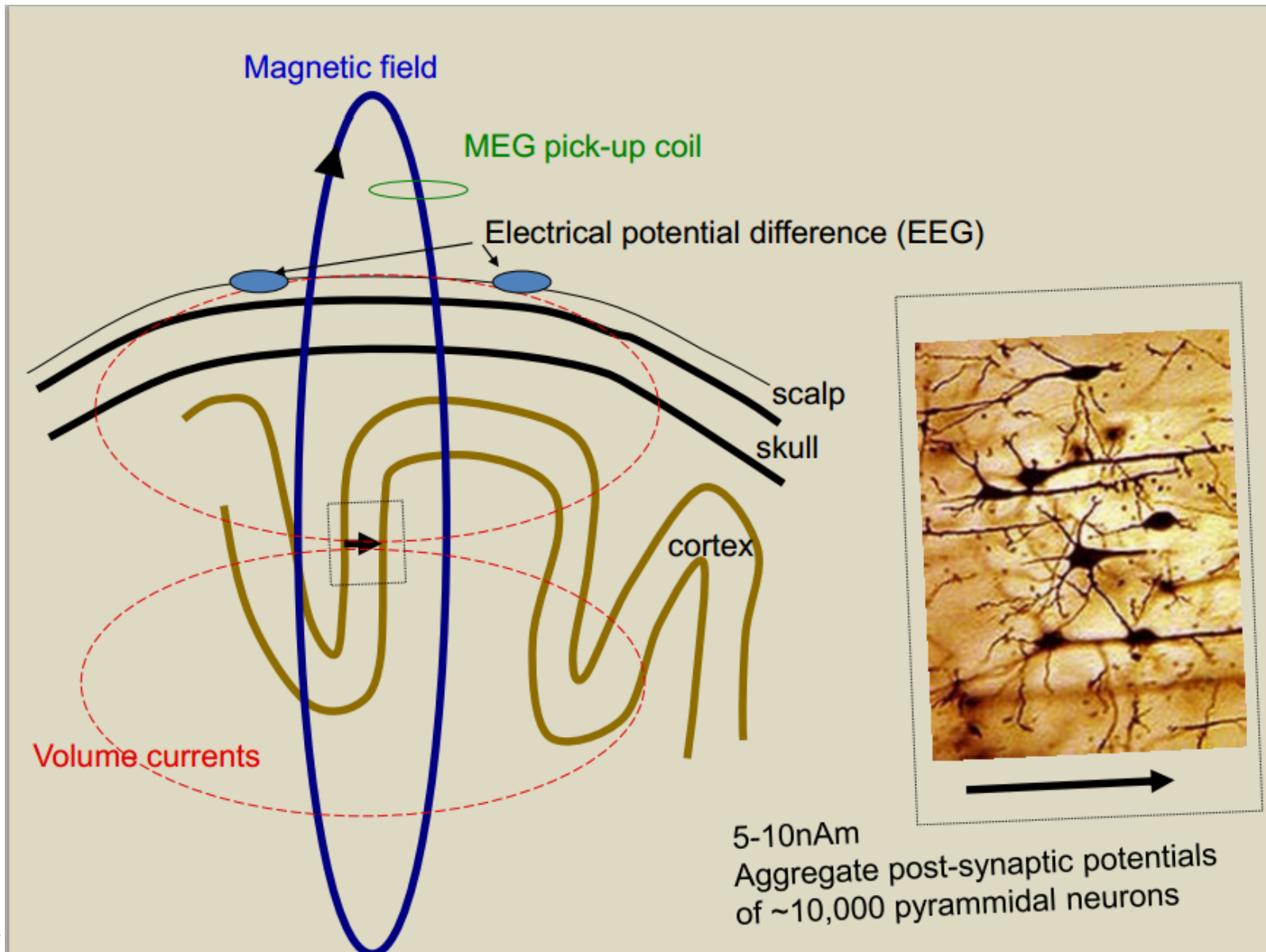
MEG



<http://www.admin.ox.ac.uk/estates/capitalprojects/previouscapitalprojects/megscanner/>

- Measures the magnetic fields generated by neuronal activity – generally the field generated by post-synaptic currents across pyramidal neurons (EEG measures the current itself)
- Measured outside the head

EEG vs. MEG



EEG - History

Anatomy & Physiology: invasive vs. non-invasive

1875 - Richard Caton first observes that an electrical current can be detected on skull and brain

1890 - Adolf Beck reports electrical activity in animals

1912 - Pravidich-Neminsky published first EEG study

1914 - Cybulski and Jelenska-Macieszyna record seizures

Role of EEG in neuroimaging: identify neural correlates

MEG - History

1962: Discovery of the Josephson effect

1968: David Cohen makes first MEG recordings of human α -rhythm

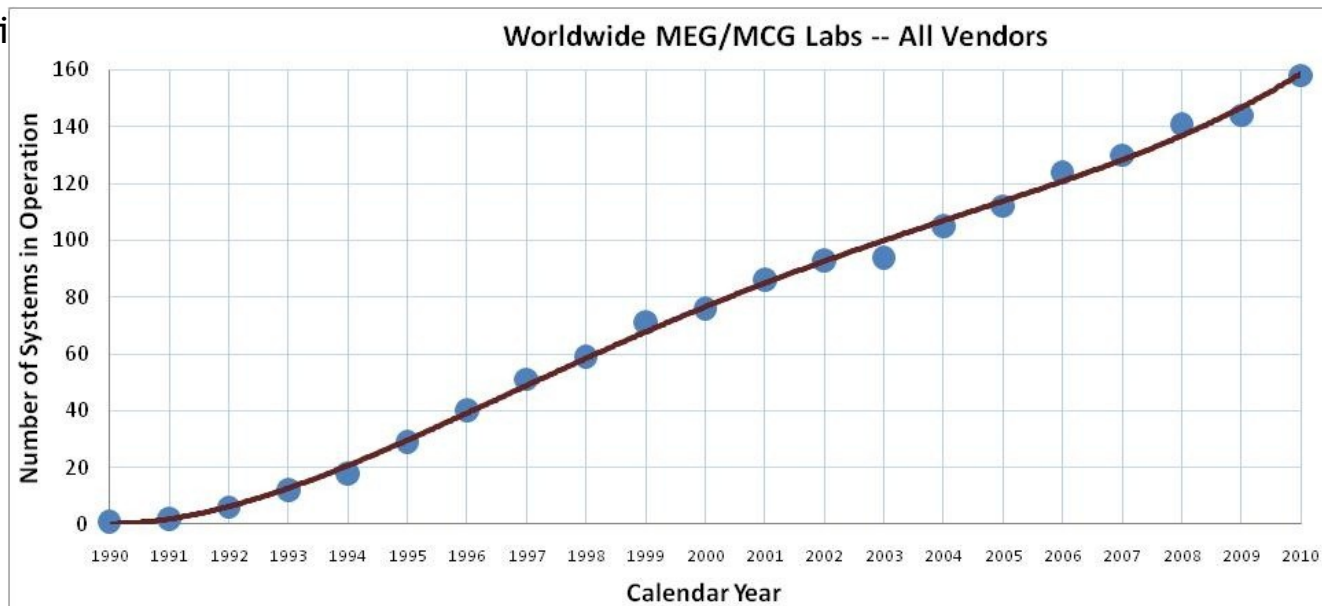
1970: Superconducting quantum interference device (SQUID) invented by James Zimmerman

1972: SQUID technology is applied to MEG recording

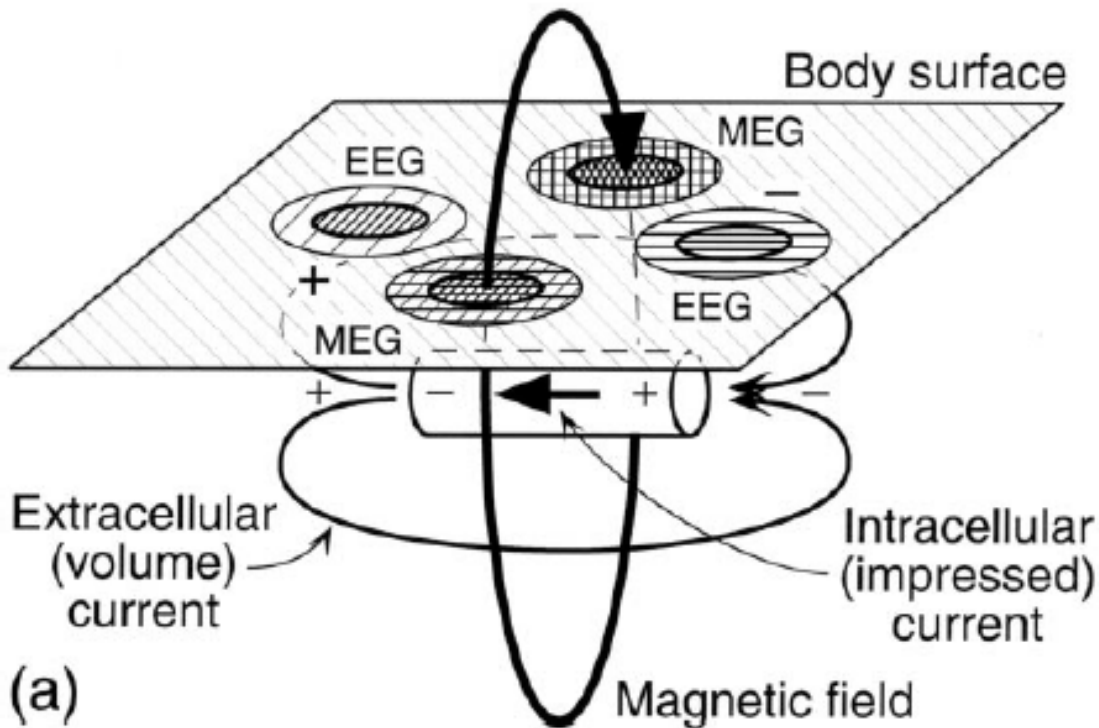
1979: 3-channel SQUID system is built

1992: First whole-cortex MEG system (64 channels) is built

2000: First i



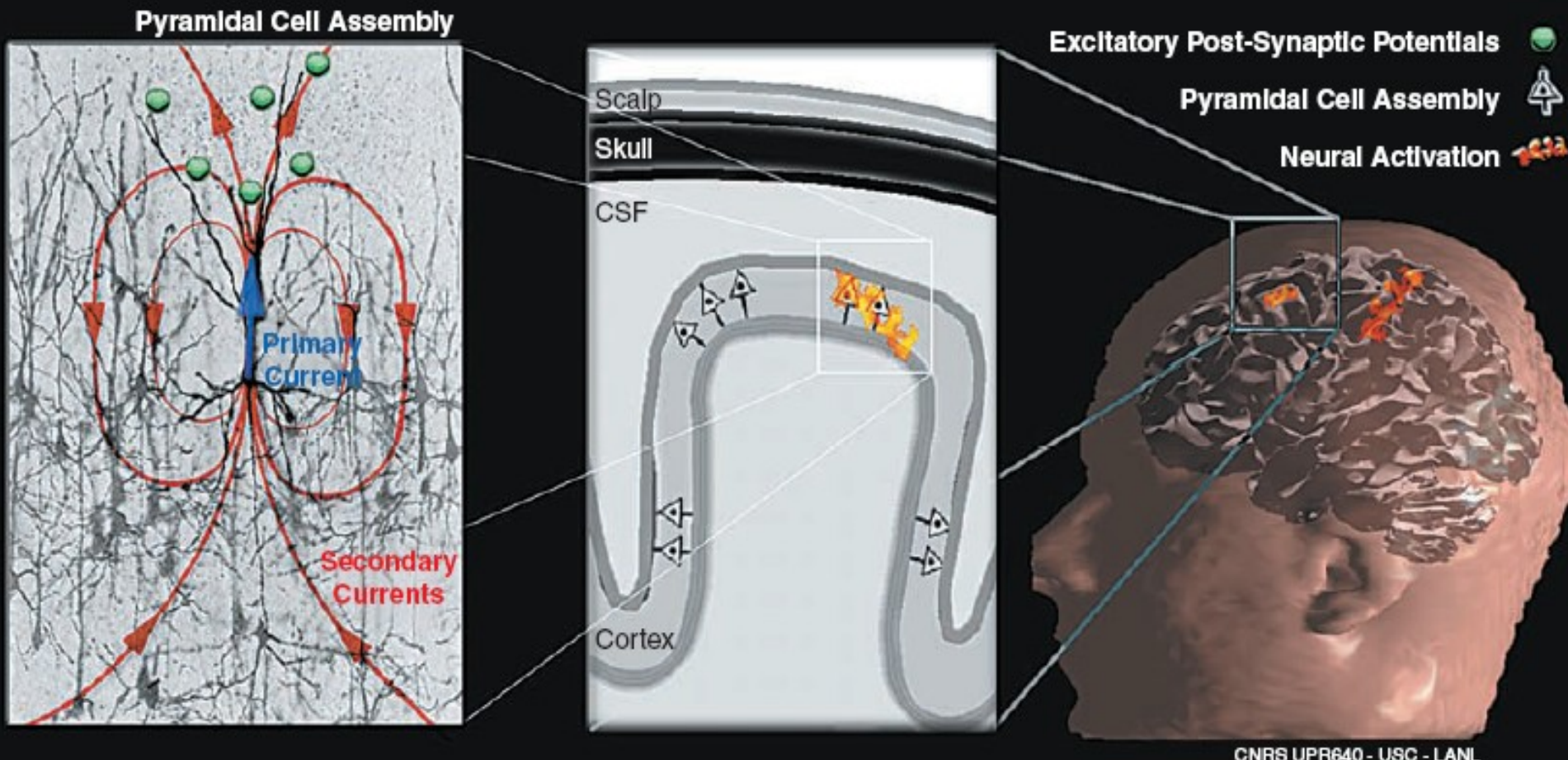
What Can EEG Measure?



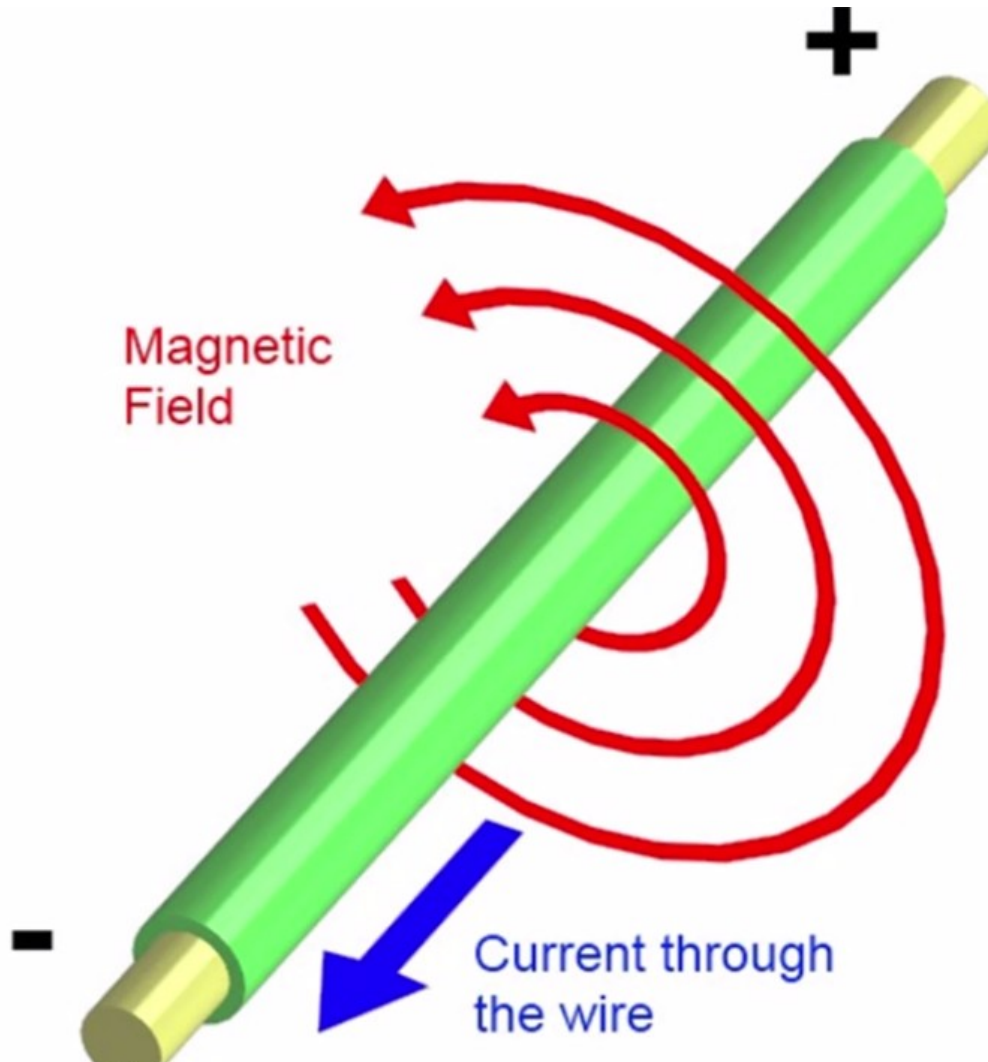
Tiege & Zlobinski, 2006

- Measures electrical potential differences between pairs of scalp electrodes
- Gyri (radial)
- EPSP apical dendritic trees
- Depolarisation of dendrites
- Current \rightarrow volume conductor
- Extracellular currents = issue

What Can EEG Measure? (Continued)

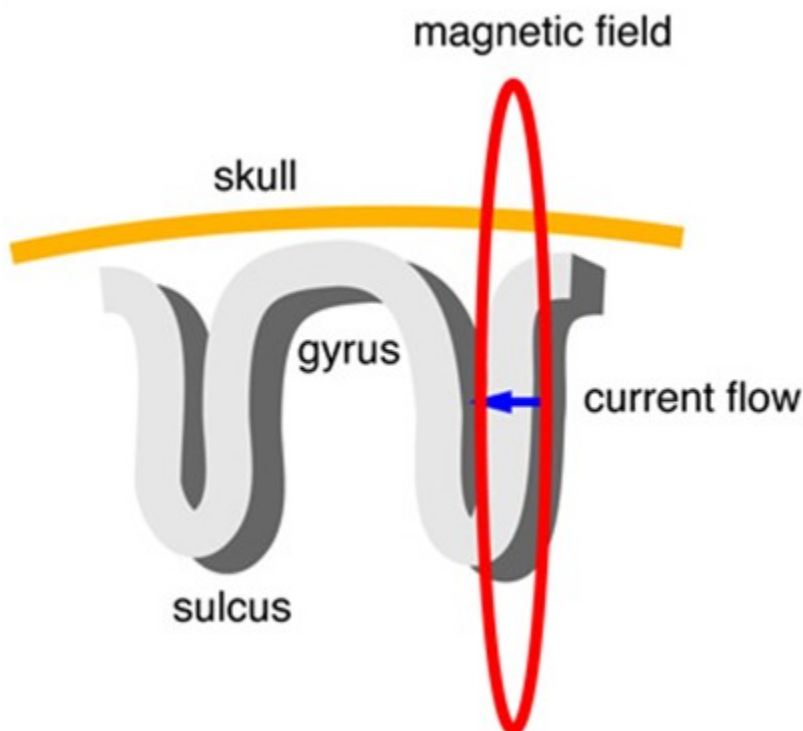


Electrical Current \rightarrow Magnetic Field



What Can MEG Measure?

The magnetic field generated by an electrical current exits the head, where it can be measured



<http://www.ctf.com/images/megbasics.jpg>

Unlike the EEG signal, the magnetic field measured by MEG is not distorted by the different conductive properties of the head and scalp

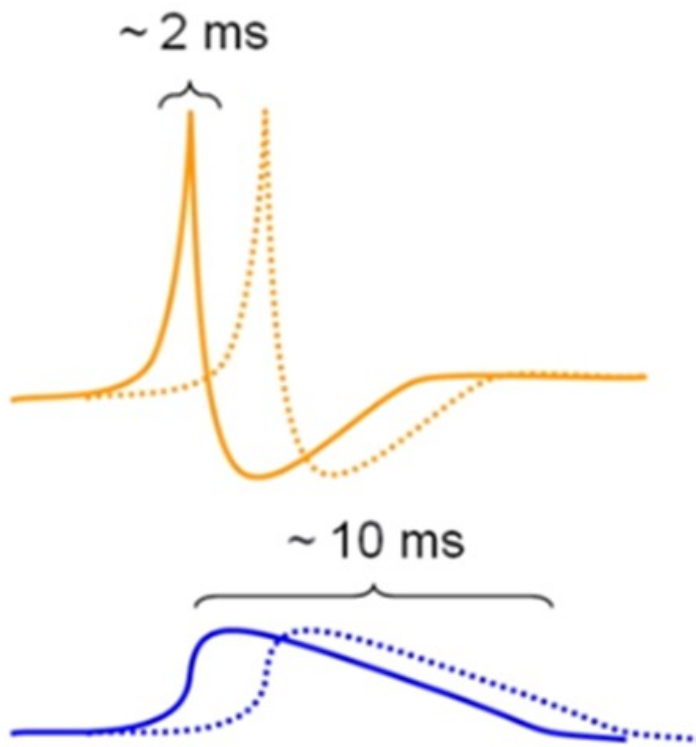
N.B. MEG is less sensitive to *radial* sources



Easier to detect fields generated in sulci rather than in gyri

What Can MEG Measure? (Continued)

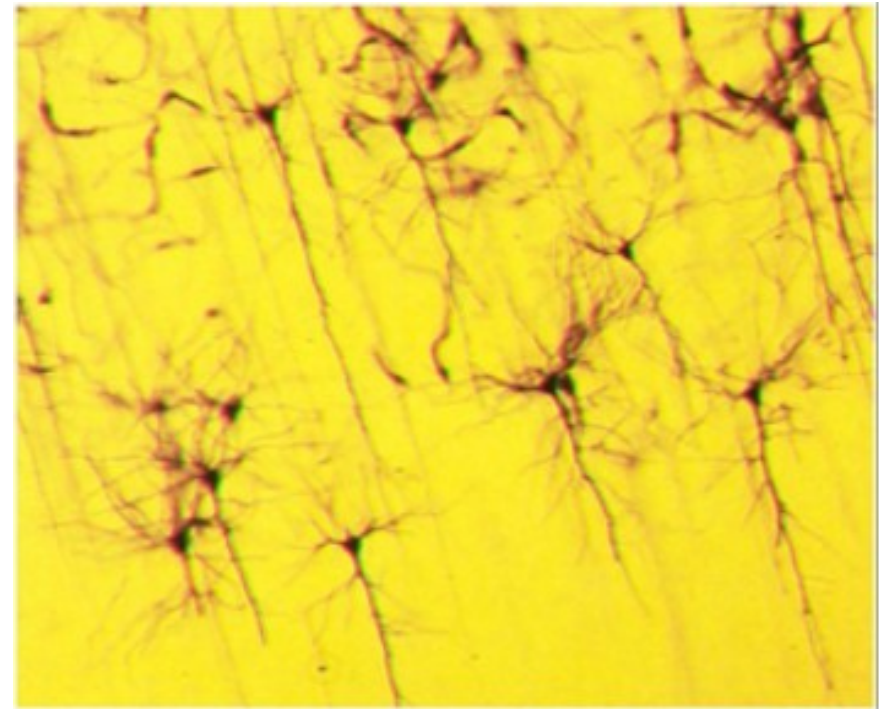
Monophasic signals



<http://www.youtube.com/watch?v=CPj4jJACels>

Post-synaptic potential

Cell alignment



<http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/brain/brain-slides/Slide12.jpg>

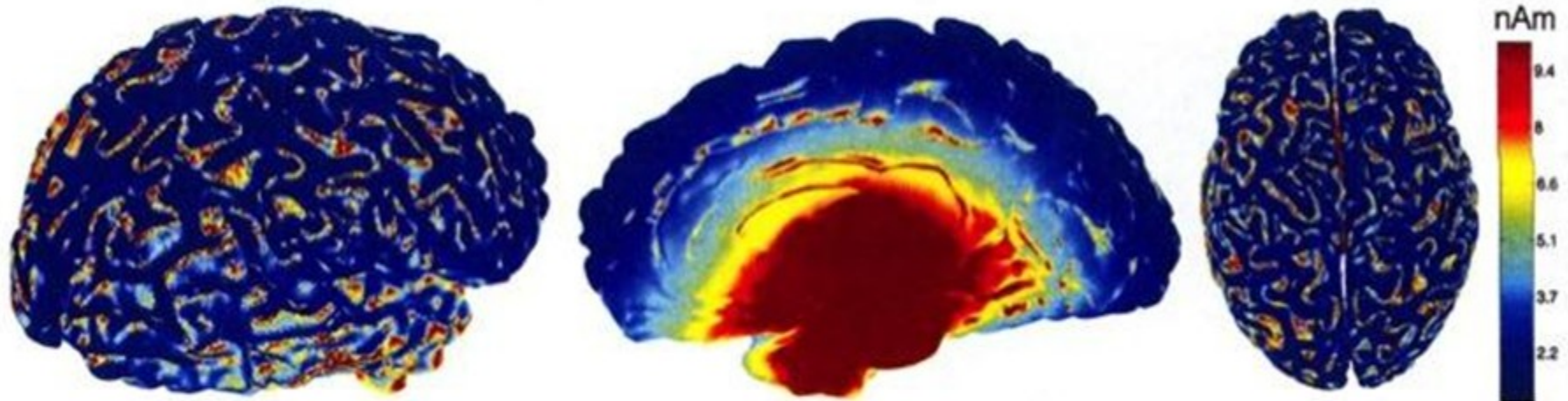
Pyramidal cells

Deeper Structures

MEG is less sensitive to magnetic fields generated by deeper sources

Sensitivity loss is proportional to squared distance between source & sensor

Source strength needed for Detection Probability of 70% (Subject IEH)



EEG - Instrumentation



(specialneedsdigest.com)



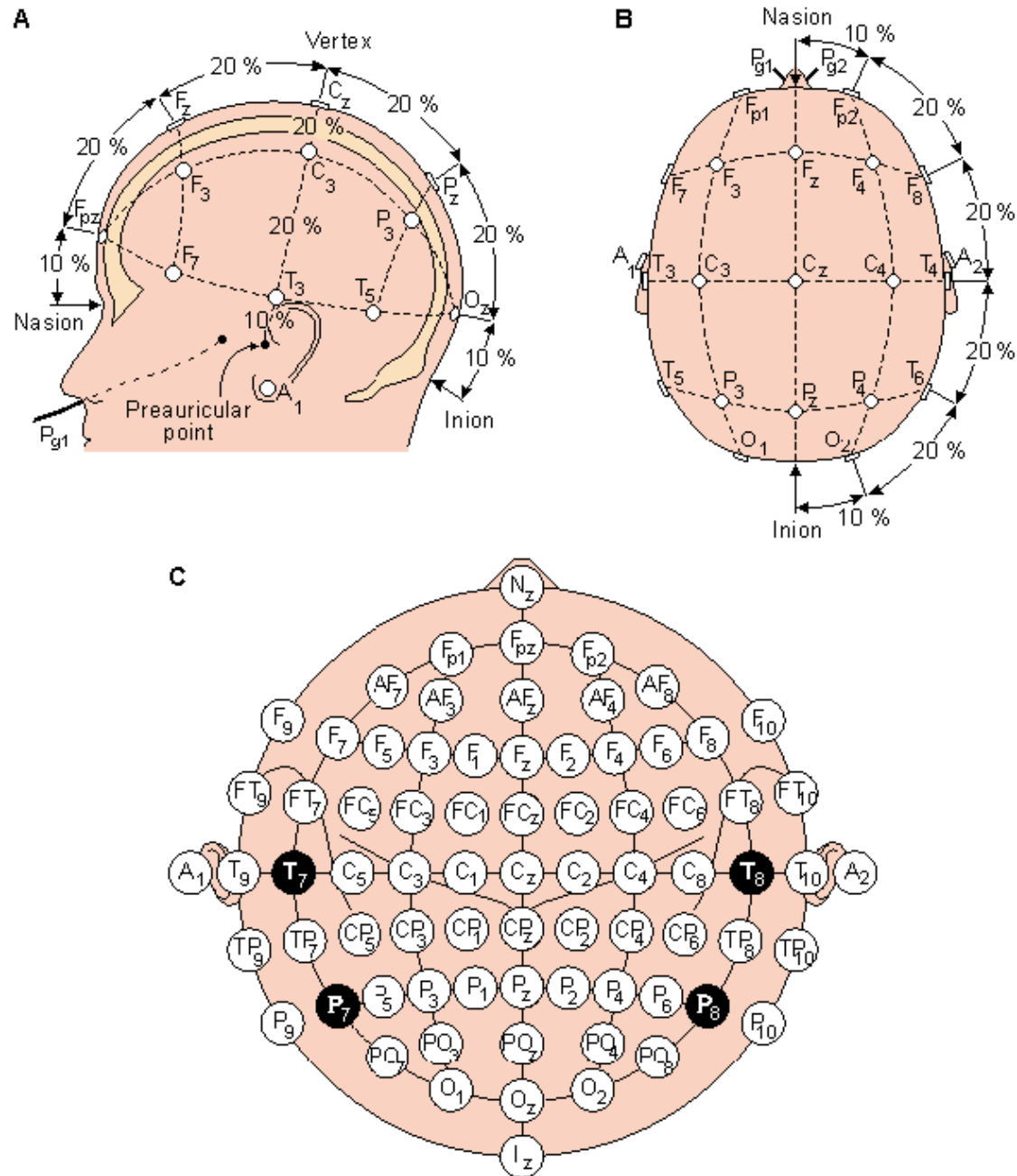
(biosemi.com)

- Cap (different numbers of electrodes)
- Gel
- Thin sticks
- Reference Montage

EEG - Instrumentation (Continued)

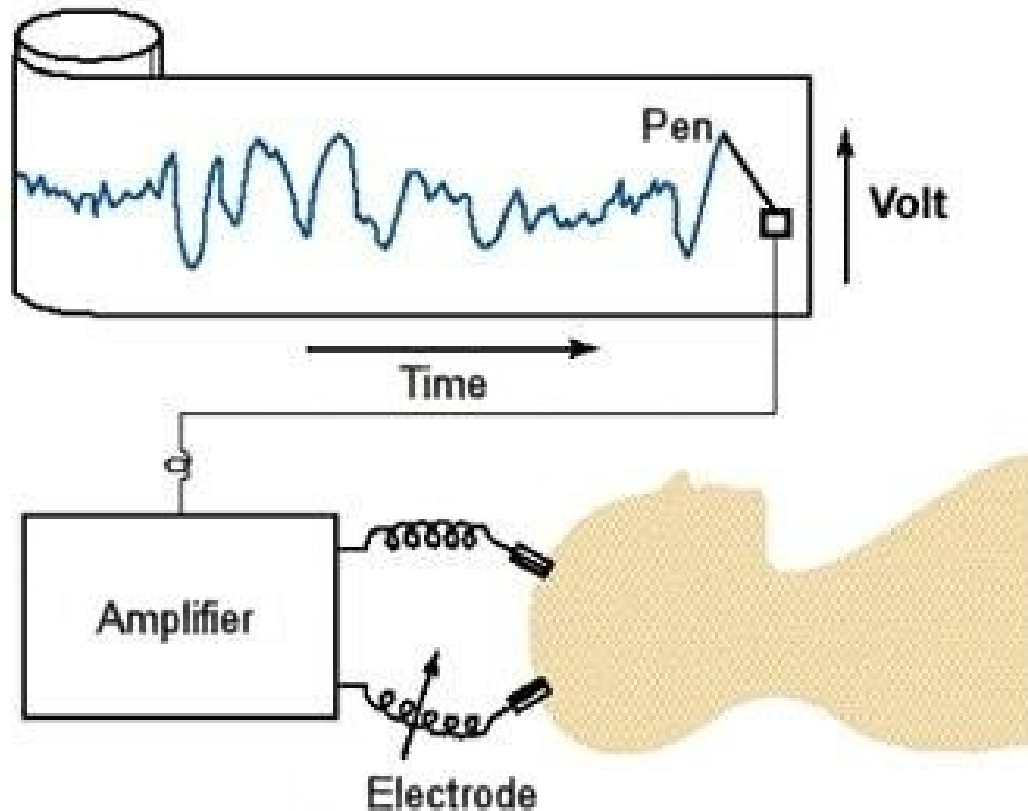
10-20 System

Electrode placement occurs over frontal, parietal, temporal, central, and occipital regions (see Friedrich & Friederici, 2005)



EEG - Machine

- 8 – 64 identical channels recording simultaneously from as many different pairs of electrodes
- Electrodes & electrode board
- Amplifiers
- Filters
- Pen & chartdrive (screen)

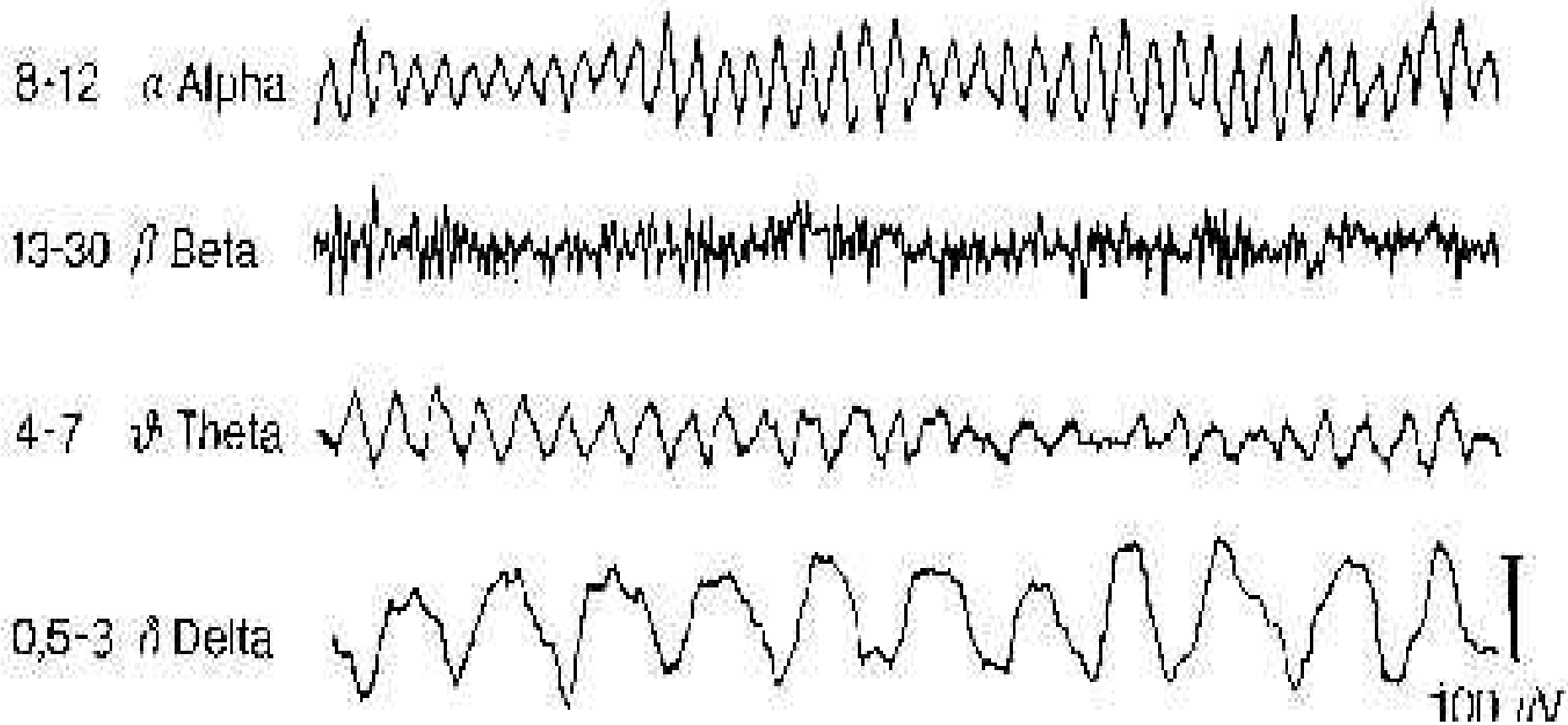


Tiege and Zlobinski, 2006

EEG Frequency Spectrum

Waves	Frequencies per second	Amplitude in μV	Characteristics
Beta-waves	14 - 30	5 - 50, mostly below 30	Sharp spike-waves over 35 Hz, Frontocentral, precentral & posterior Criteria of light sleep stages
Alpha-waves	8 - 13	5 - 120, mostly below 50	Posterior-dominant, awake, eyes closed, mental inactivity, physical relaxation
Theta-waves	4 - 7	20 - 100	Strictly rhythmic or highly irregular Awake & drowsiness or light sleep stages
Delta-waves	0,5 - 3	5 - 250	Abnormality in waking adults, Accompaniment of deep sleep
Gamma-waves	31 - 60	-10	Legality of appearance and site not well established

EEG Frequency Spectrum



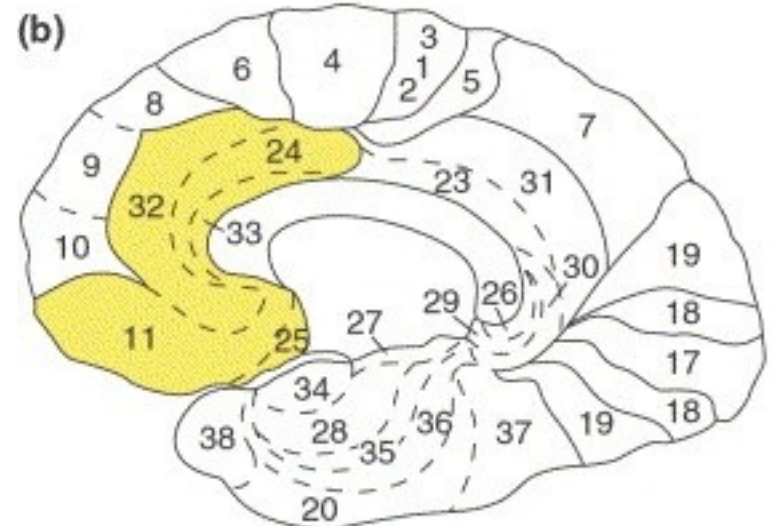
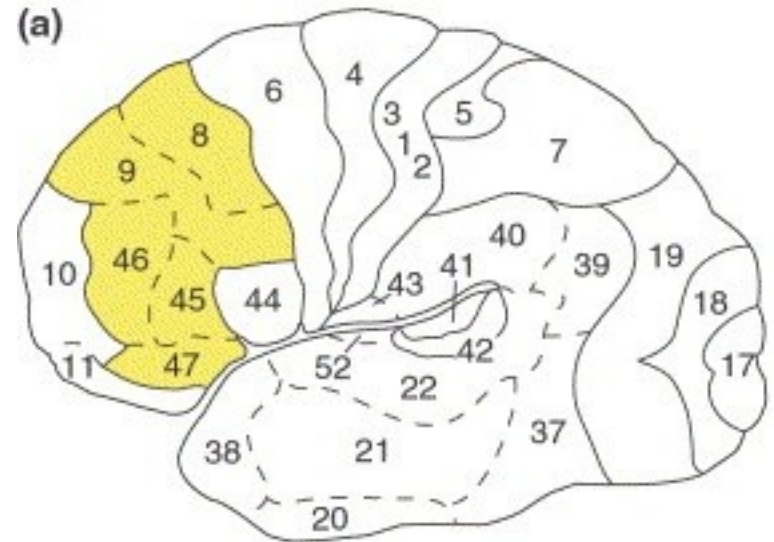
Tiege and Zlobinski, 2006

EEG Studies

**Muzur, Pace-Schott, and Hobson,
(2002)**

Role of Prefrontal Cortex in Sleep

- Mediates normal sleep physiology, dreaming, and sleep-deprivation phenomena

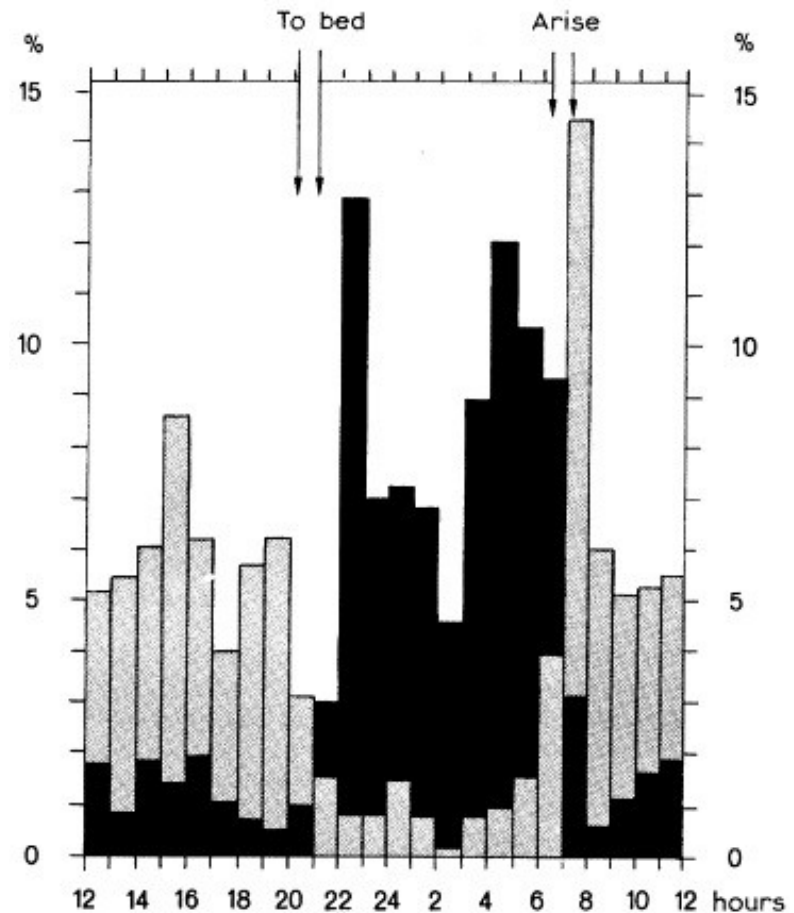


EEG Studies (Continued)

Janz, (2000)

Epilepsy with grand mal on awakening and sleep-waking cycle

- Strong association between sleep deprivation and seizures in idiopathic generalised epilepsy



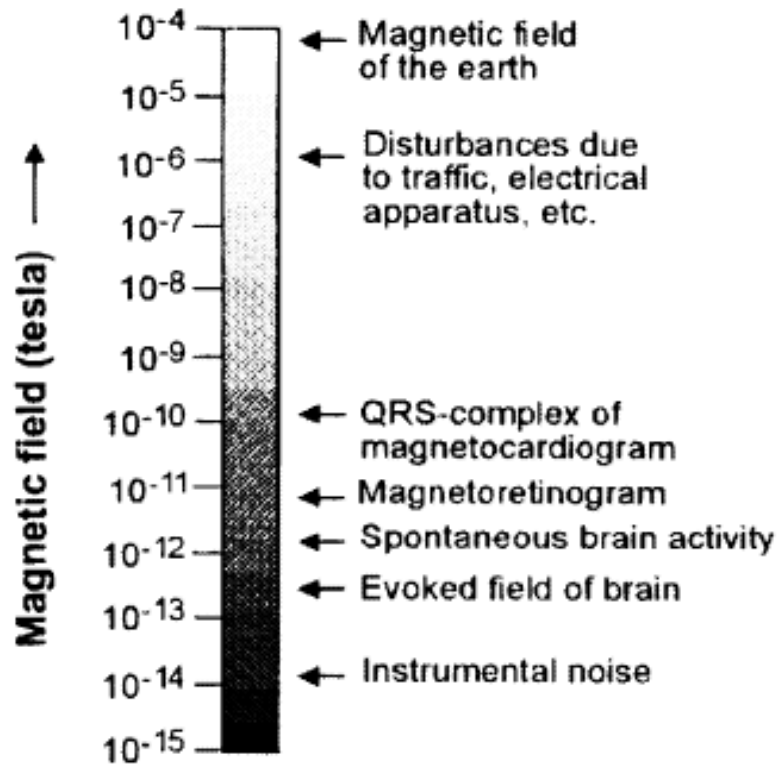


Figure 1.3: Comparison of field strengths

MEG - The Magnetic Field

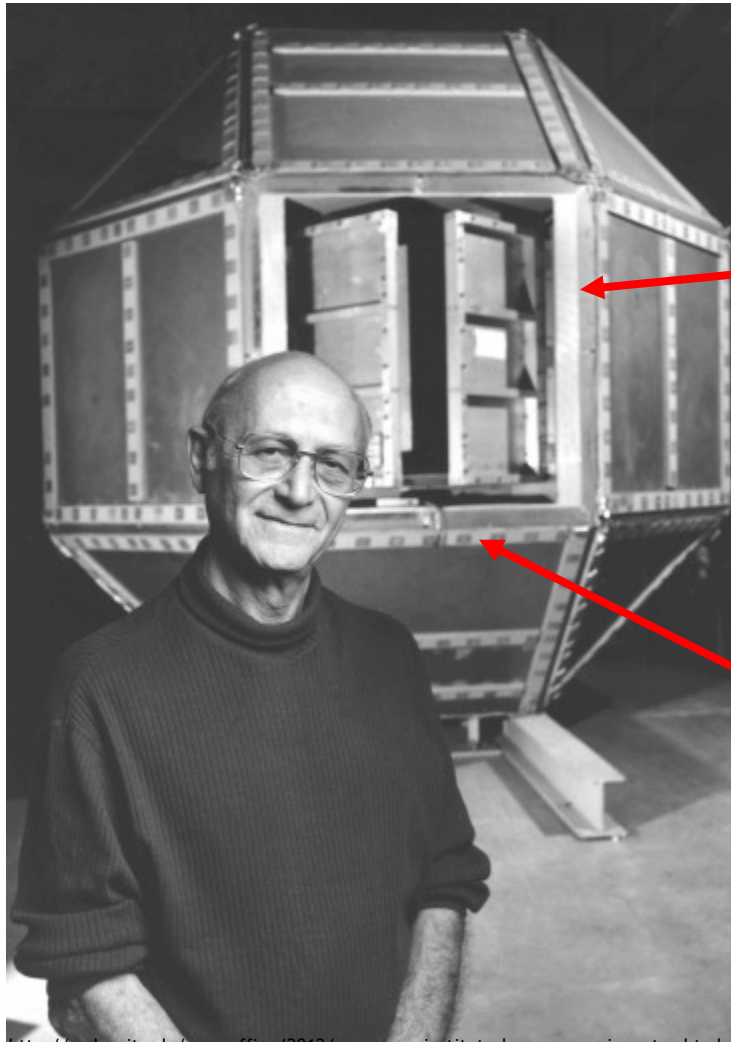
The magnetic fields generated by neural activity are significantly smaller than those created by other objects in the environment

Susceptible to interference from electrical equipment, cars, participant's heartbeat, etc.

Interference from heartbeat



Noise Reduction: Magnetically Shielded Room (MSR)

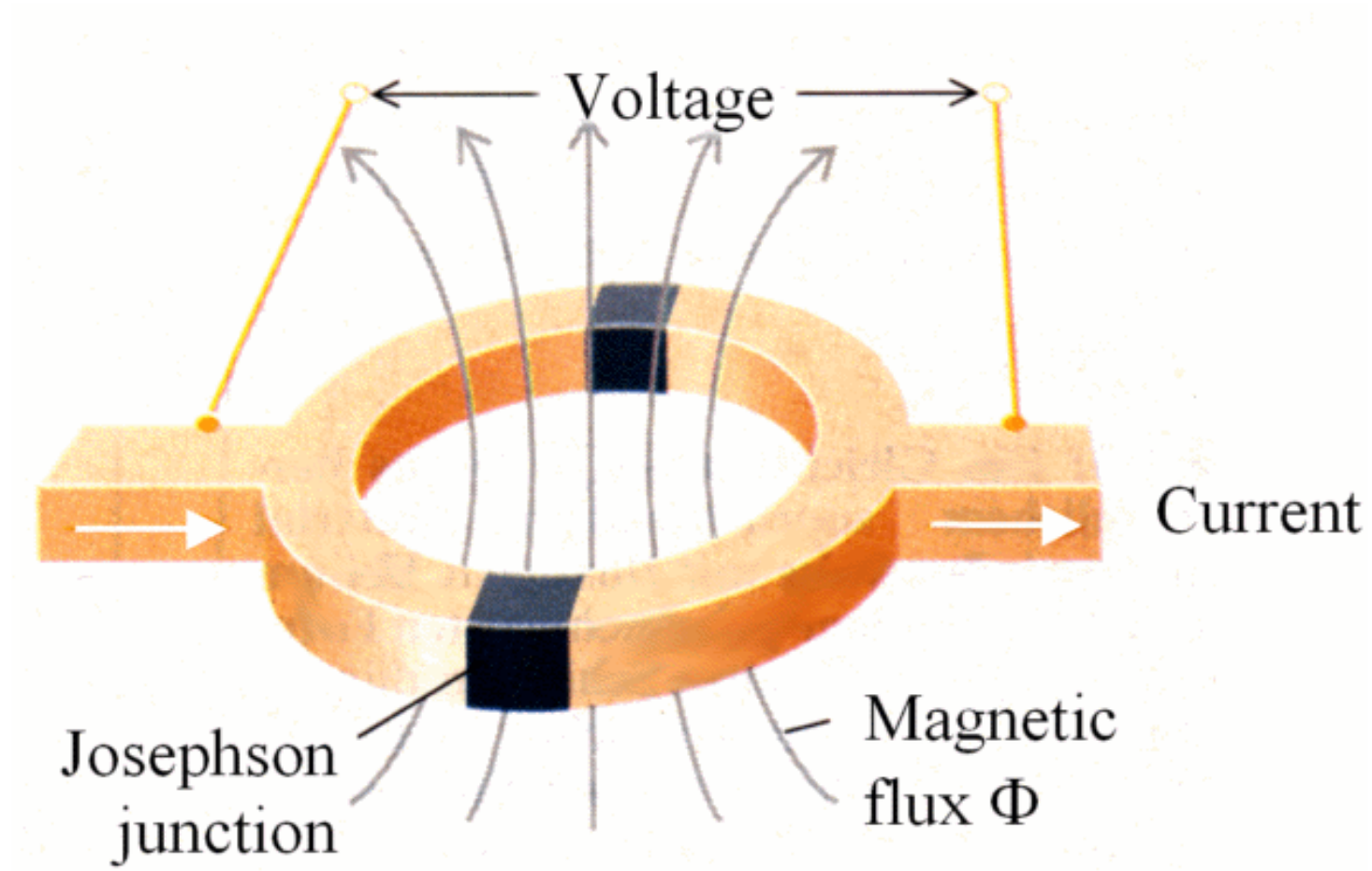


Spherical room = greater magnetic efficiency

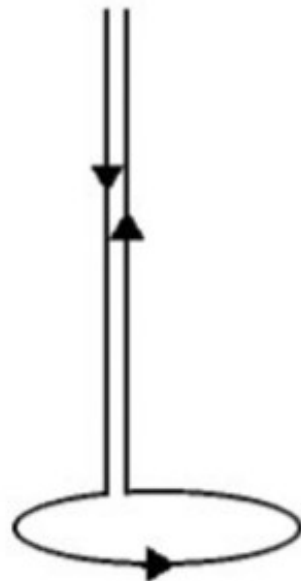
5 layers with different magnetic properties to protect from different frequencies of magnetic interference

Measuring The Magnetic Field: SQUIDS

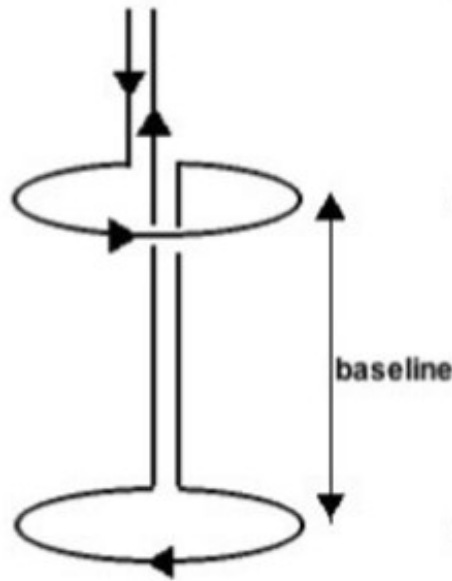
Superconducting Quantum Interference Device



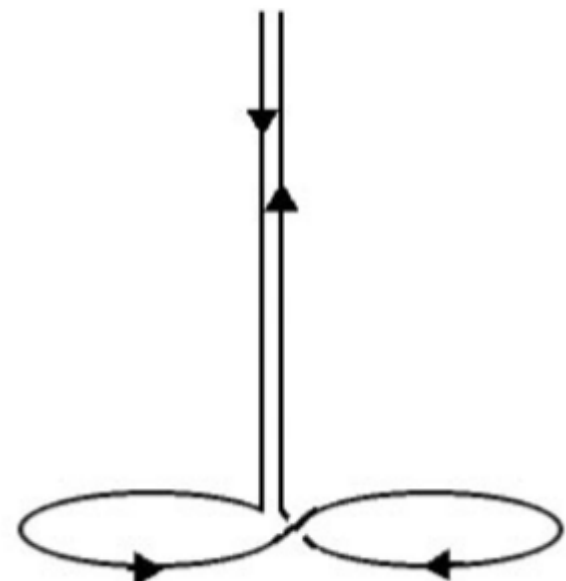
Flux Transformers



**axial
Magnetometer**



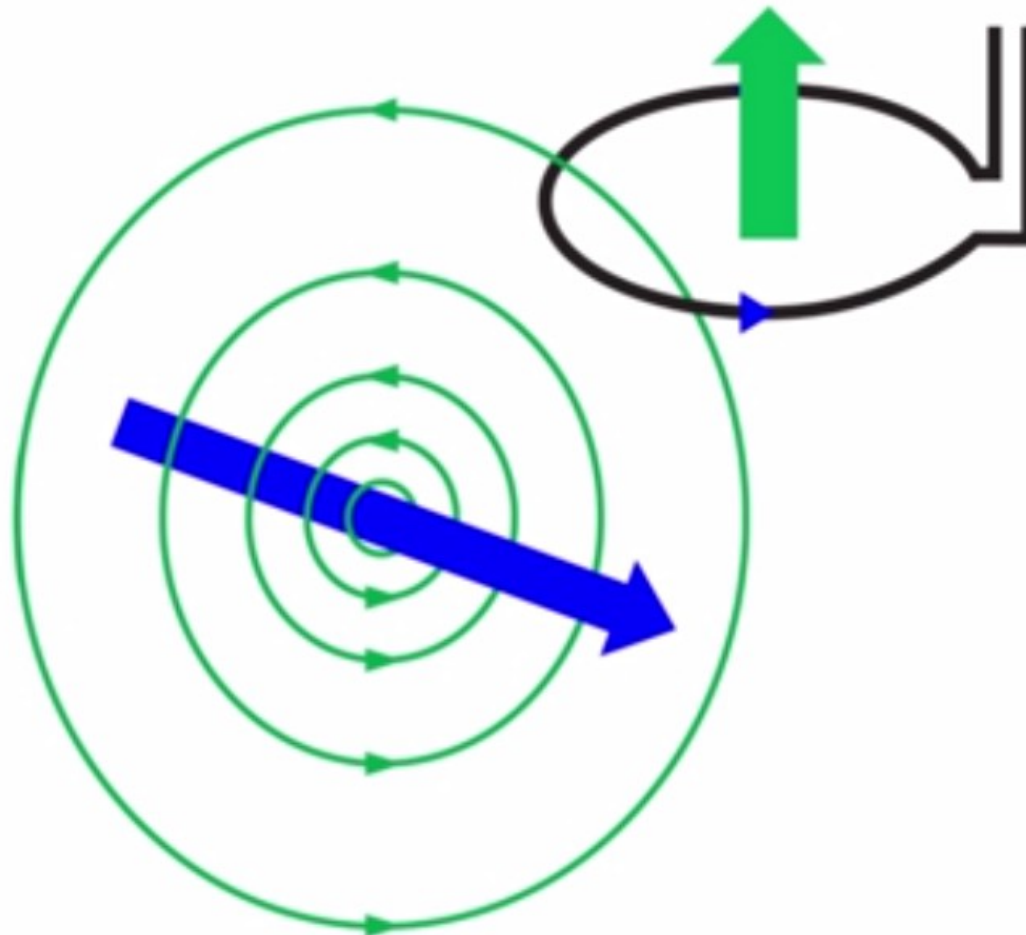
**1st-Order axial
Gradiometer**



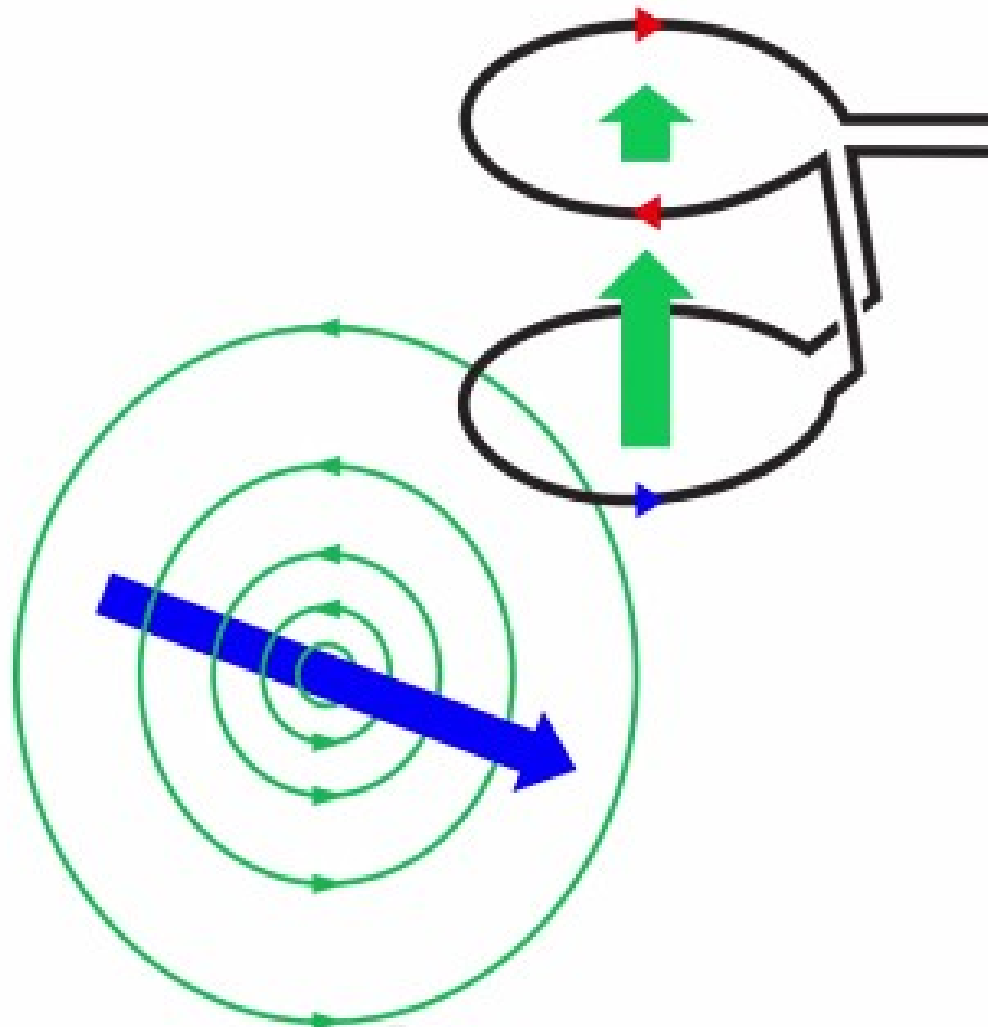
**1st-Order planar
Gradiometer**



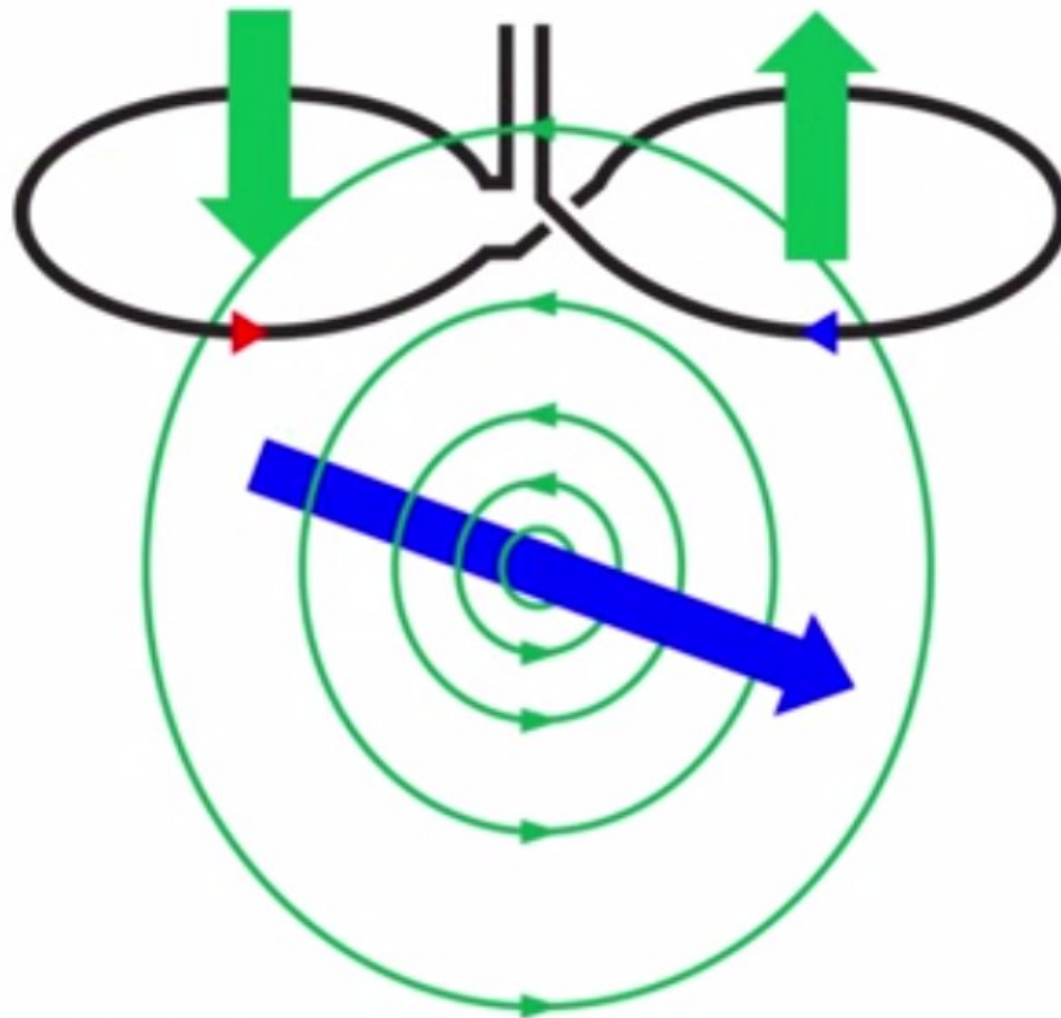
Magnetometer



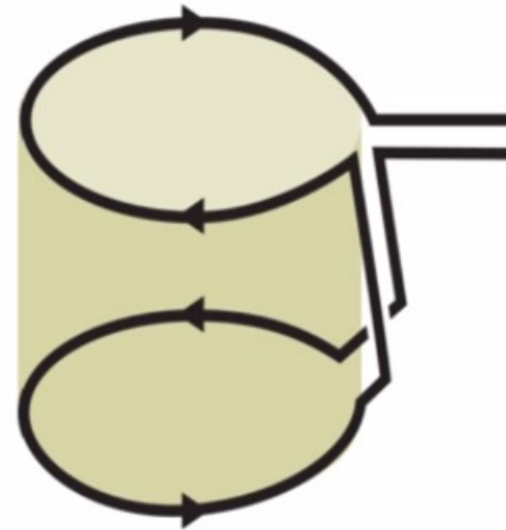
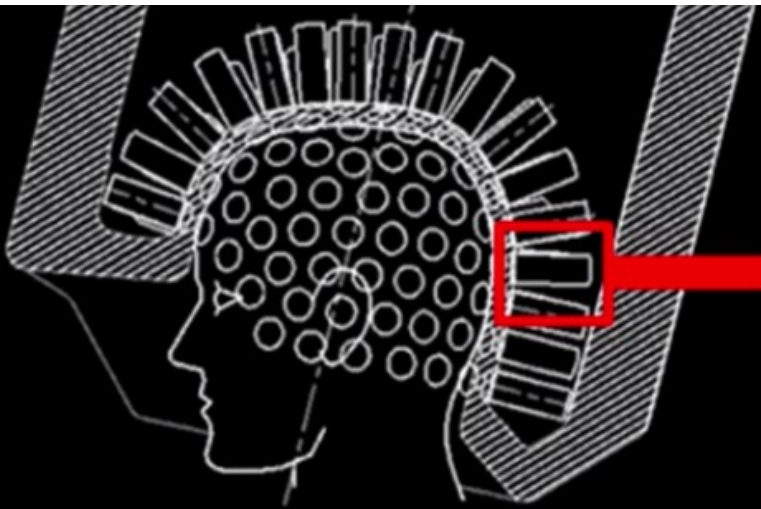
Axial Gradiometer



Planar Gradiometer

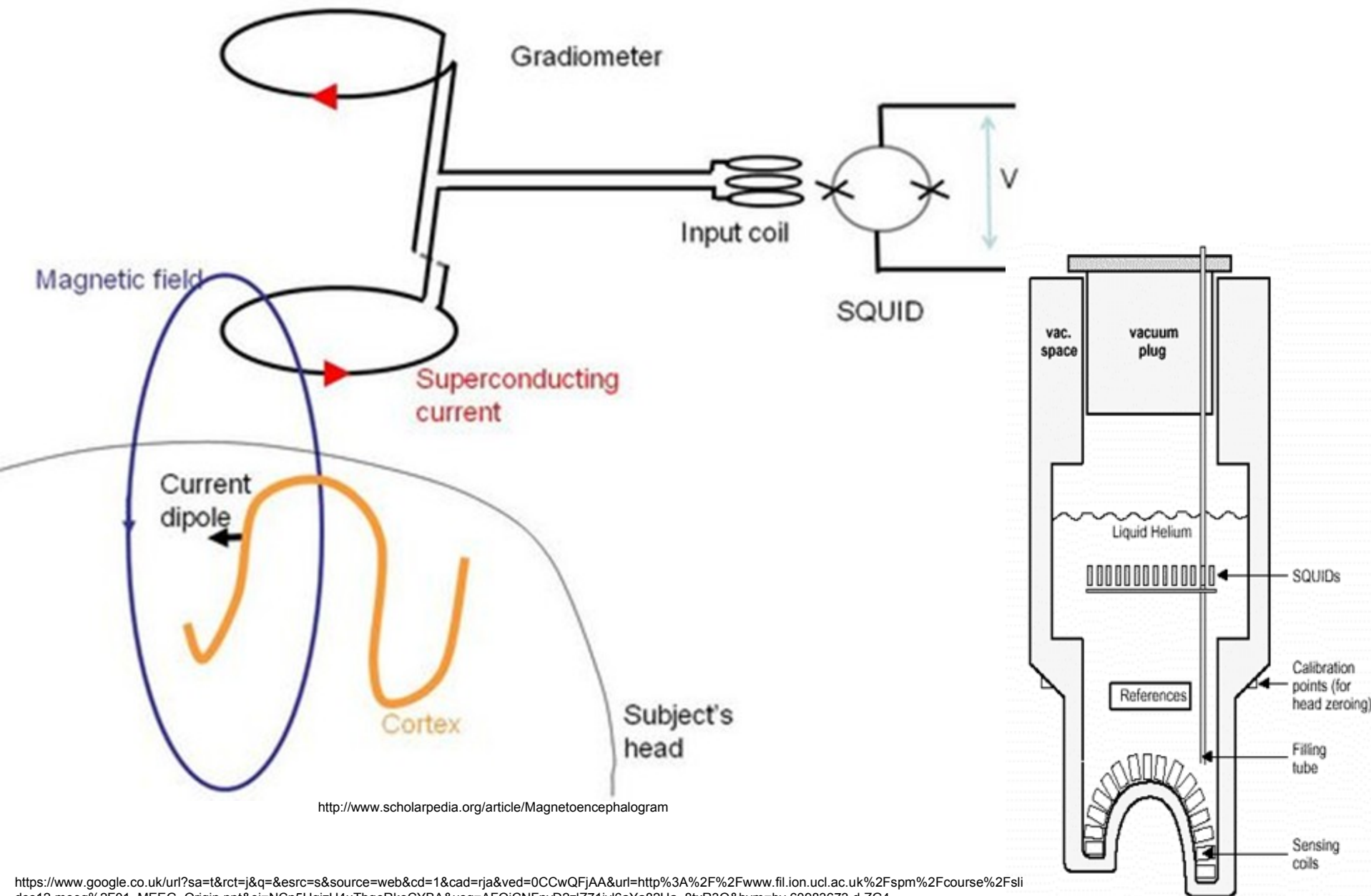


CTF 275 Channel Omega System



275 axial gradiometers

Reference sensors for noise
cancellation



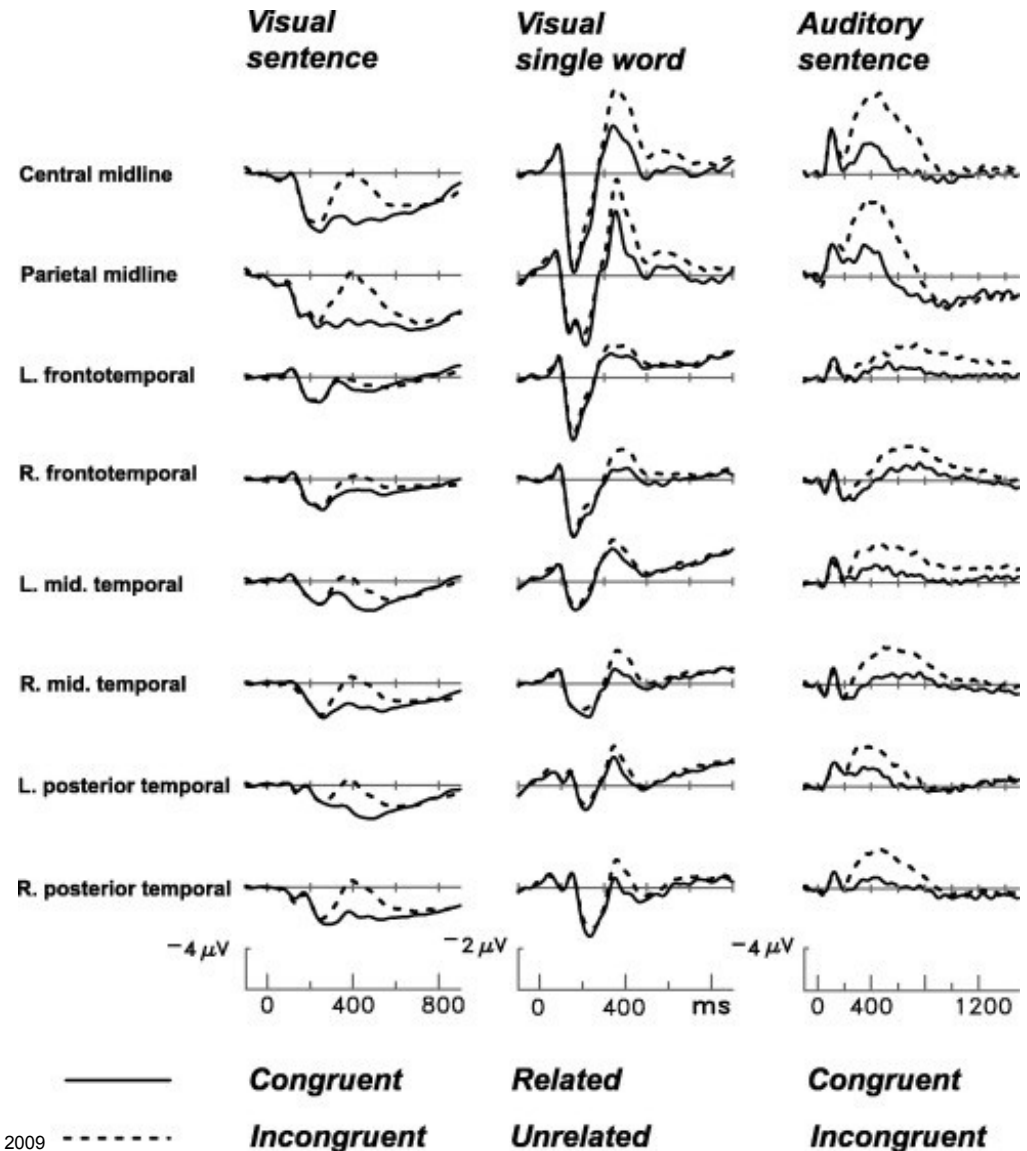
MEG Output



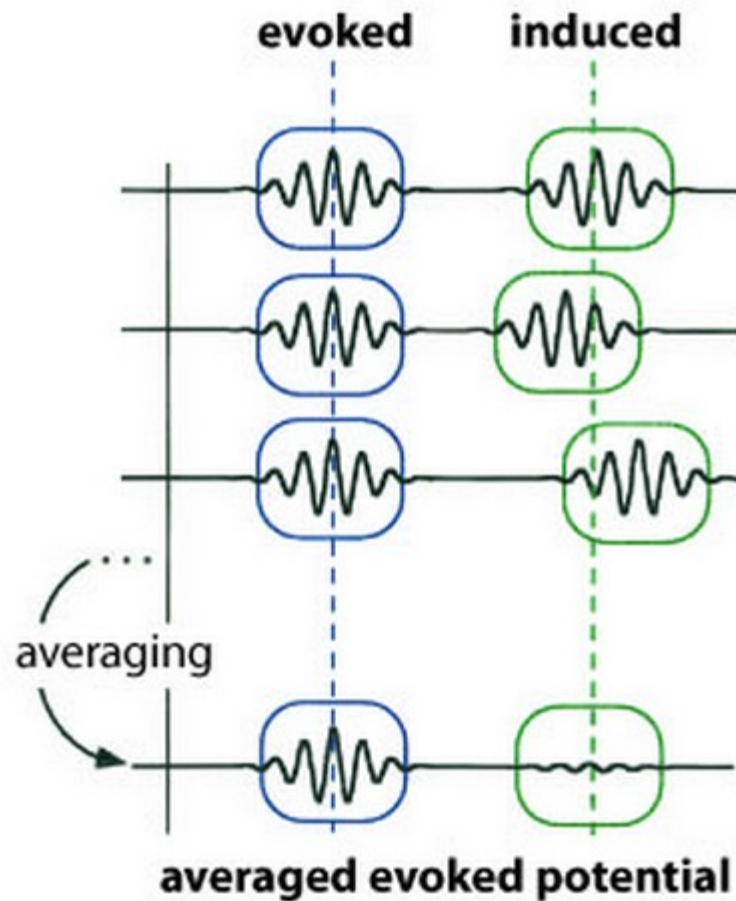
Event-Related Potentials (ERP)

- Many trials over the same time averaged together
- Waves described after polarity and latency (e.g. N400), method of release (mismatch negativity) and psychophysiological correlatives

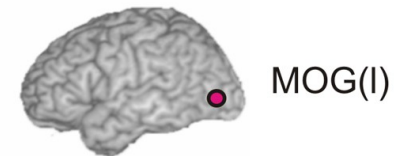
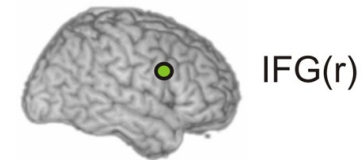
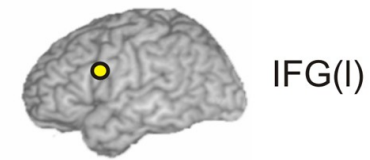
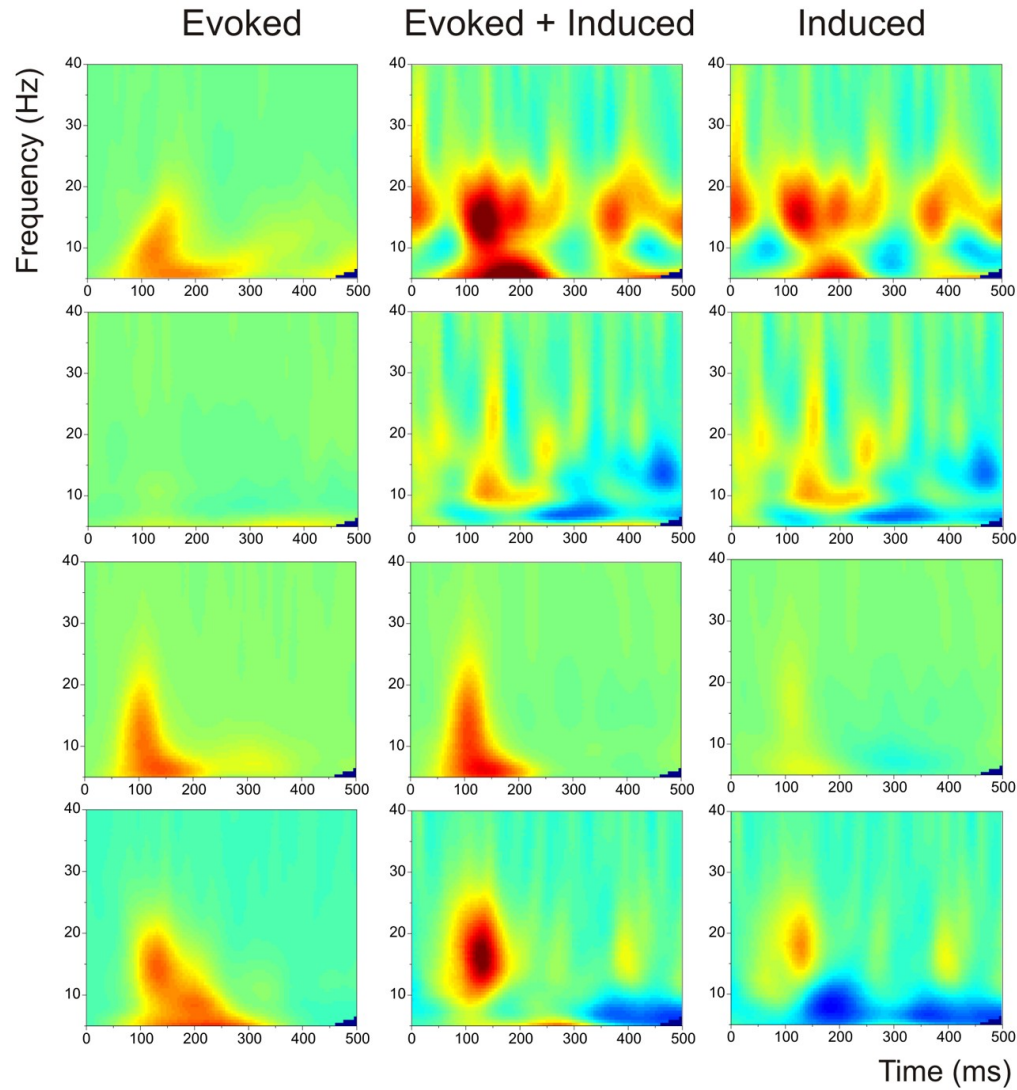
Tiege and Zlobinski, 2006



Evoked vs. Induced Effects



WORDS



MEG - PTSD Study

B. Rockstroh, T. Elbert / *International Journal of Psychophysiology* 78 (2010) 14–19

17

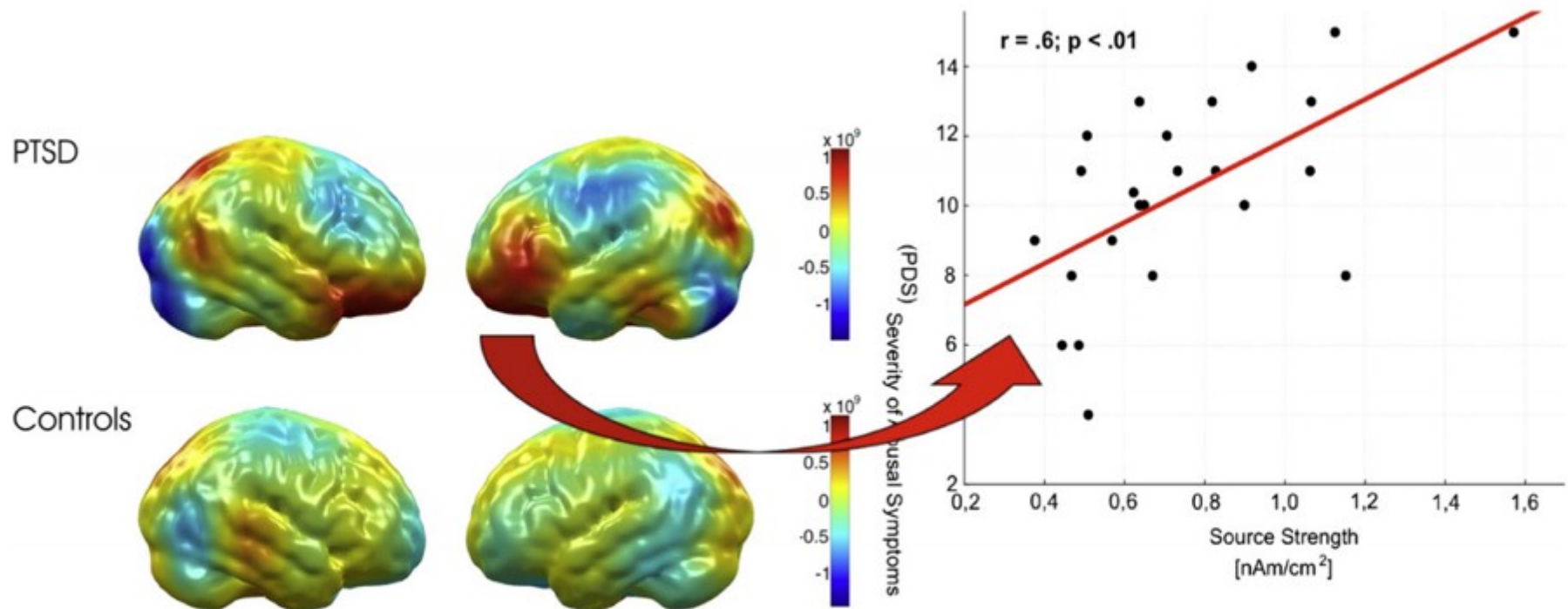
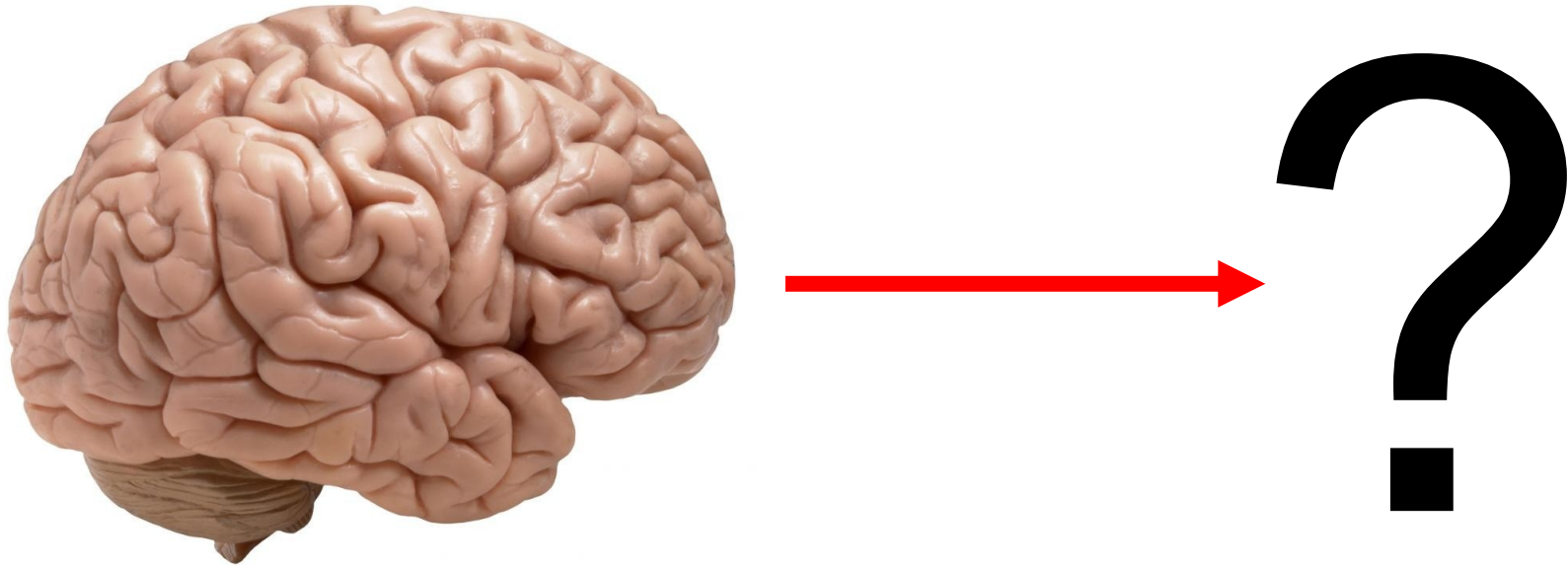


Fig. 2. Left: dipole activity projected on a standard cortical sheet in response to aversive pictures in individuals with diagnosis of Posttraumatic Stress Disorder (PTSD, top) and non-PTSD controls (bottom); color shading represents intensity of source activity with red and yellow colors indicating more pronounced activation. Graphs show an enhanced early (70–100 ms) activation in prefrontal, notably orbitofrontal regions that appears in PTSD clients but not controls in response to aversively arousing pictorial stimuli. Right: the intensity of this activation correlates with the severity of hyperarousal symptoms as measured by the CAPS-scale (each dot in the scatterplot denotes a patient).

Disadvantages

- Forward Problem
- Inverse Problem
- Spatial Resolution
- Artifacts
- EEG
 - Preparation
 - Current distortion
- MEG
 - Money
 - Deep sources

Forward Problem



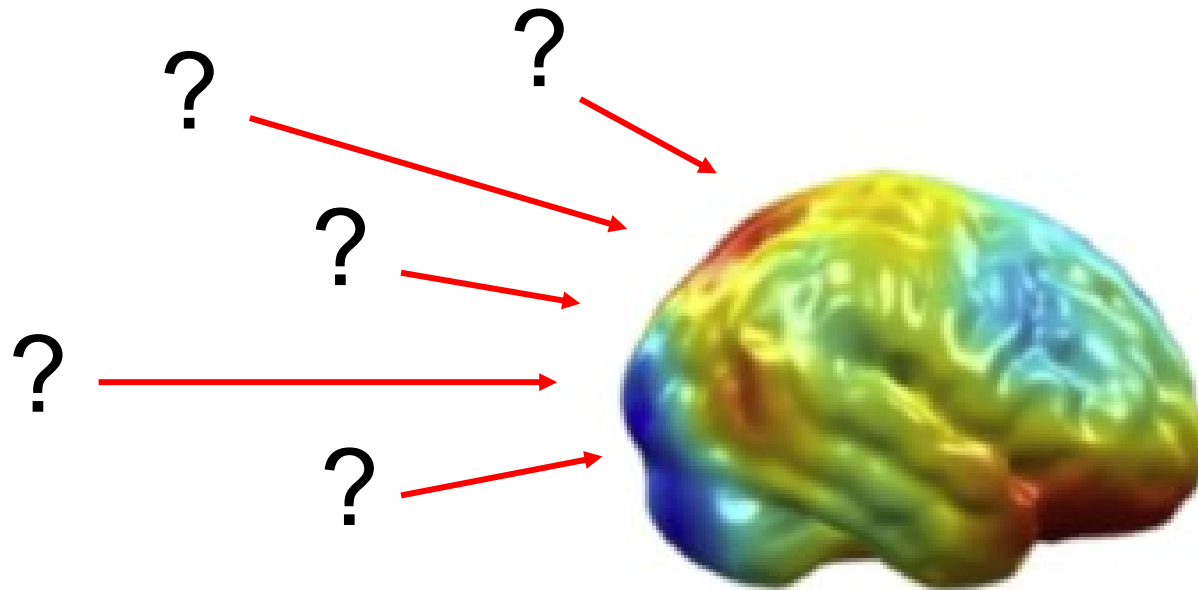
<http://buybrainfuelplustoday.com/wp-content/uploads/2013/11/brain.jpg>

Determining output which will be generated by a particular primary current source

MEG is relatively straightforward compared to EEG

UNIQUENESS – there is only one possible solution

Inverse Problem



Determining the *source* of the observed magnetic field

NONUNIQUENESS – there are an infinite number of solutions for this problem

An “ill-posed” problem

Inverse Problem (Continued)

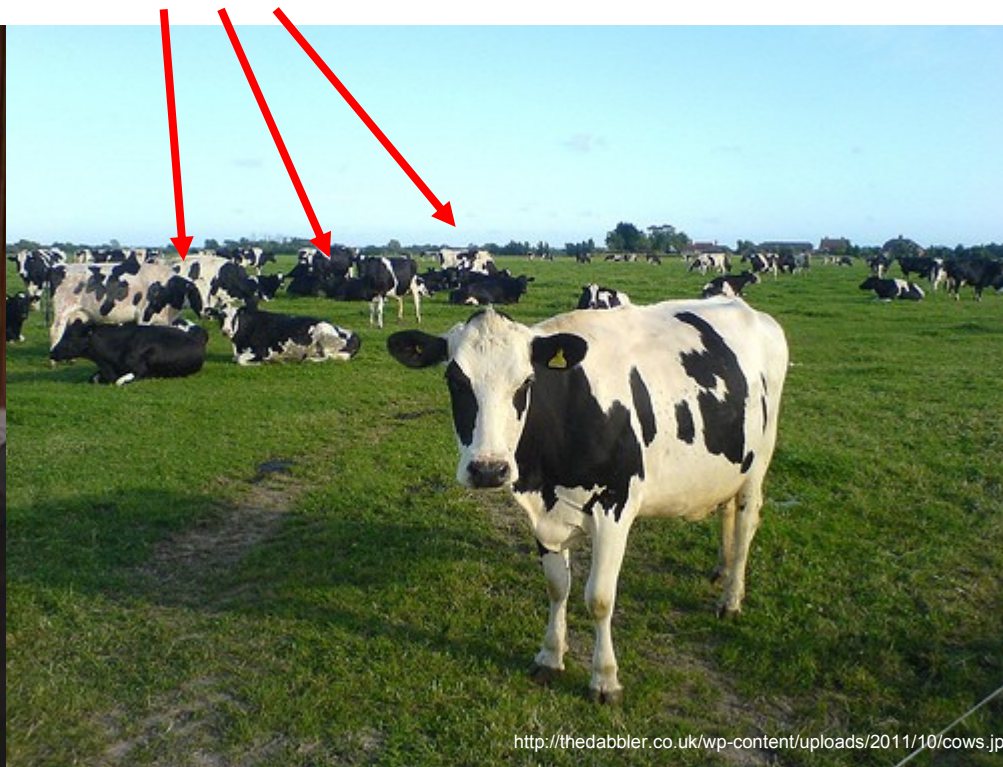
E.G. VISION

We can use a priori knowledge of object properties to determine whether something is small vs. far away...

SMALL



FAR AWAY



Overcoming Spatial Resolution

Lewine et al., 2007

- Traumatic brain injury
- MRI, SPECT, and MEG

Salek-Haddadi et al., 2006

- EEG-correlated fMRI
- Focal epilepsy



Advantages

- Temporal resolution
- Non-invasive
- Quiet
- EEG
 - Cheap
 - Clinical implications
- MEG
 - Preparation
 - Head distortion

Summary: EEG vs. MEG

Both EEG and MEG use the same underlying signal, but generate different outputs



<http://www.fastcompany.com/3008499/tech-forecast/these-brain-scanning-neuro-toys-are-about-change-everything#1>



<http://www.theredmenmovie.com/2009/11/magnetoencephalography-meg-scanner.html>

Thank You Gareth!

Resources

MEG brain waves

<http://youtu.be/eq8wHT8qYJs>

MEG and epilepsy

<http://youtu.be/YqO-Z7kDeoA>

Preparing for an EEG

<http://youtu.be/vniog26Qp94>

EEG Demonstration Video

http://youtu.be/bO-_Ztlxcr0

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<http://openc.c.co.uk/blog/out-of-touch-manual-keypads-and-controllers-face-competition-from-new-hands-free-computer-interf>

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specialneedsdigest.com

<https://www.ucl.ac.uk/stream/media/swatch?v=8af2e6e28e4d>

<http://www.youtube.com/watch?v=CPj4jJACels>