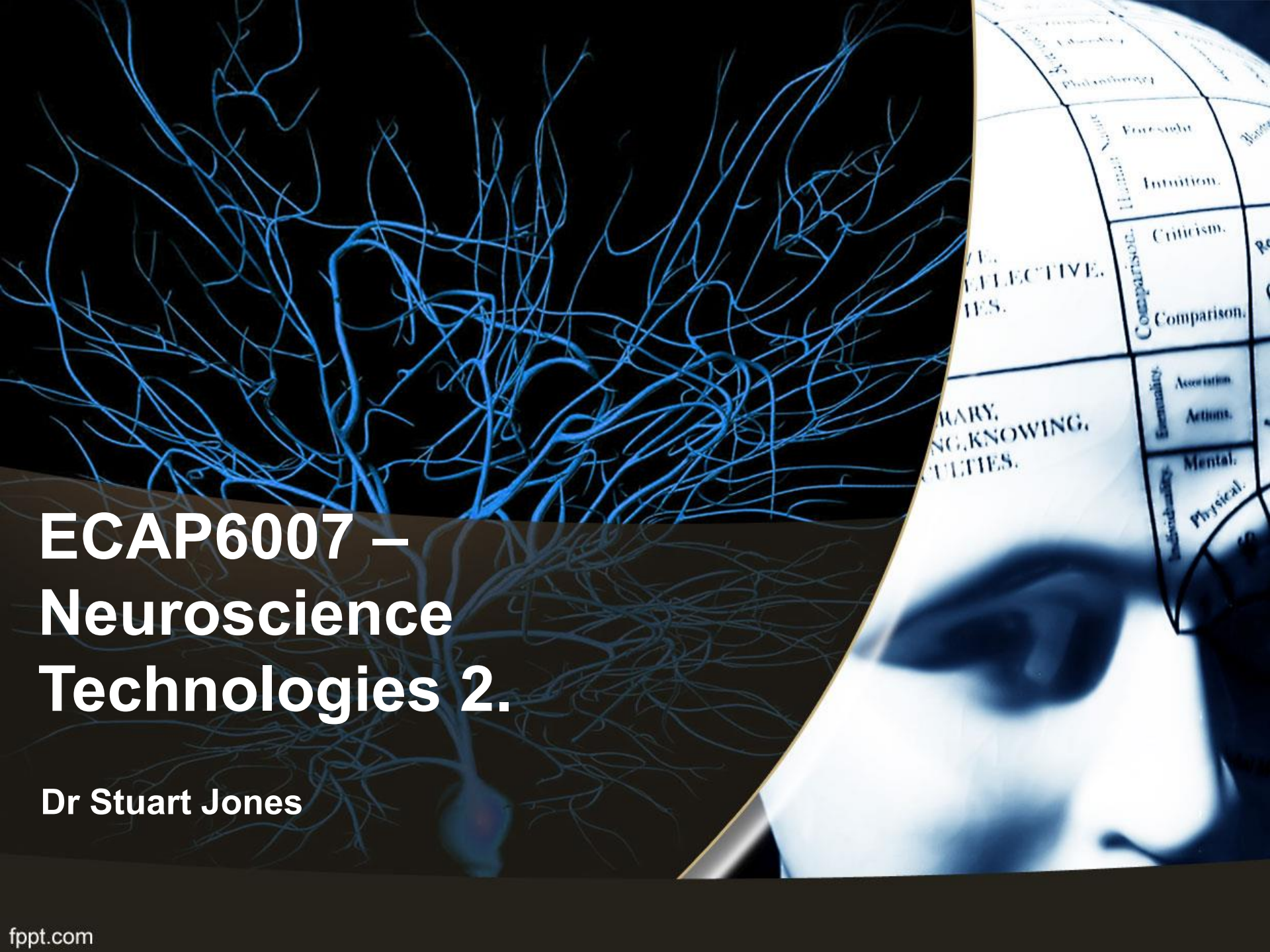




ECAP6007 – Neuroscience Technologies 2.

Dr Stuart Jones

Aim of the Lecture.

- To critically discuss neuroimaging techniques (continued from last weeks lecture).
- To provide scope into how researchers have used these tools.
- To discuss issues such as Spatial and Temporal Resolution.

Neuroimaging Techniques.

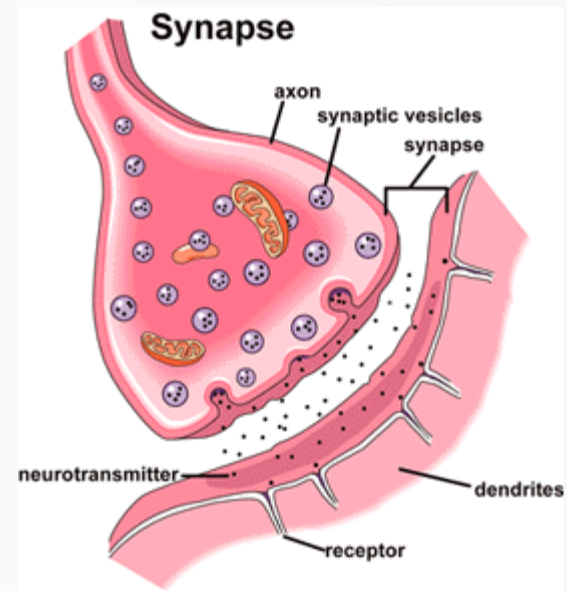
- Structural Imaging.
 - CT scan.
 - MRI scan.
- Functional Imaging.
 - EEG
 - MEG
 - FMRI
 - PET
 - Can also be structural
 - SPECT
 - Can also be structural.
 - TMS?
- Single Cell Recording.

Spatial Resolution

- Spatial resolution refers to the ability to sharply and clearly define the extent or shape of features within an image. It describes how close two features can be within an image and still be resolved as unique.

As an example.

- Synapse – site at which neural messages travel from one neuron to another.
- Some synapses are 10 times smaller than a Micron (1 millionth of a metre).



Temporal Resolution

- How the Brain changes over time.
- Issues at BOTH ends of the time frame.
 - E.g. How the brain develops from Child to Adult.
 - Slow process.
 - Electrical Signals pass through at very very quick speeds (thousandths of seconds).

Computed Tomography.

- Computed = Use of a computer.
- Tomography = imaging by sections or sectioning, through the use of wave of energy. A device used in tomography is called a tomograph, while the image produced is a tomogram



Computed Tomography (CT).

- Introduced in the early 80's.
- Also known as a CAT scan (Computed Axial Tomography).
- Very important medical tool for structural imaging and assessing neurological damage in living people.

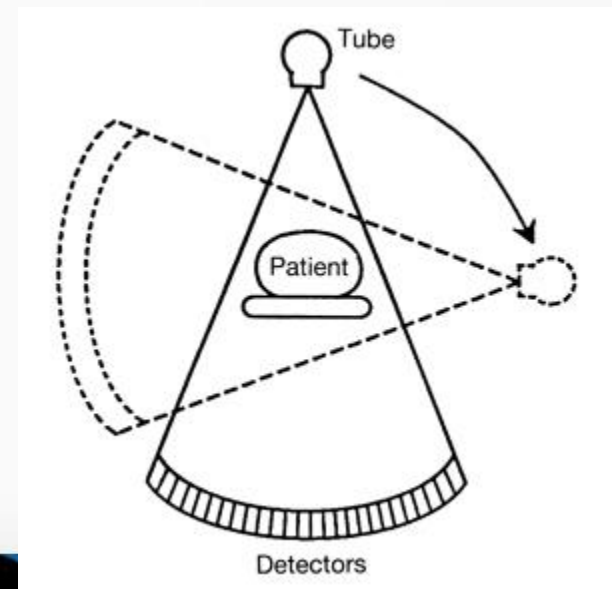
CT scan.

- Advanced version of a conventional x-ray.
- X-ray compresses 3D objects into 2D.
- CT allows for the reconstruction of three dimensional space from the compressed 2d images.



CT Scan

- Scan has two main parts.
 - X-ray source and a set of radiation detectors.
- Rotation.
- Process is repeated until x-rays have been projected over 180 degrees.
- Computer reconstruction.



How CT works.

- Absorption of x-ray radiation is correlated with tissue density.
 - Bone = High Density (lot of Absorption).
 - Air/Blood = Low Density (little, but some absorption).
- Neural tissue (between these extremes).
 - CT scans provide an image of the differential absorption of the tissue.
 - Issues with clarity.
- High density = Light
- Low density = Dark.



How CT works.

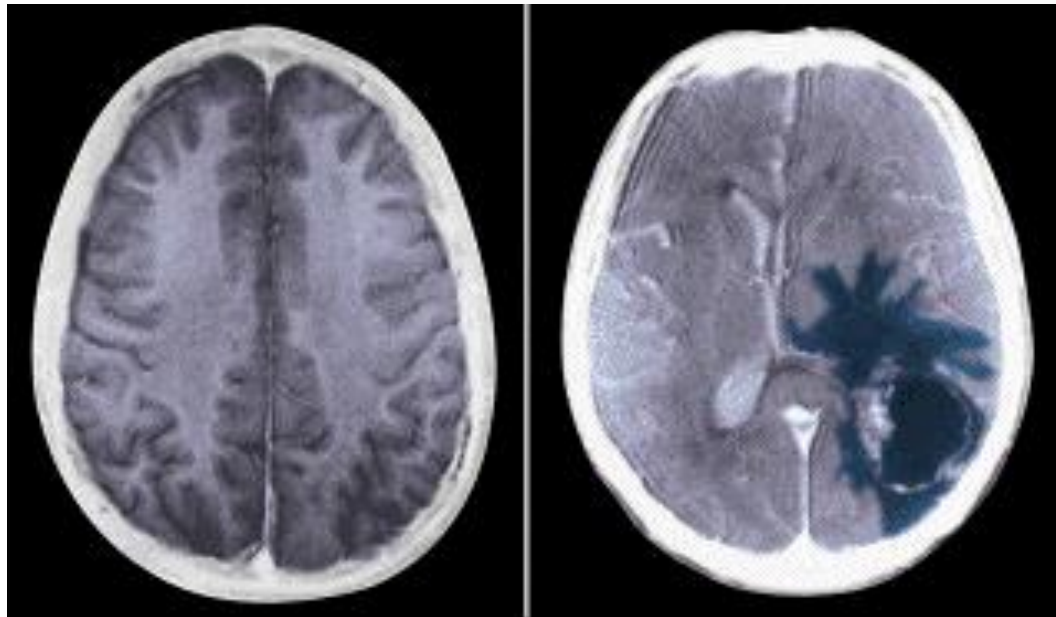
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About the CT scan.

- <http://www.youtube.com/watch?v=rN4E8Y5loAs&feature=related>
- <http://www.youtube.com/watch?v=Tx-0emi4m8s&feature=related>

CT scan.

- Still widely used.
- Clarity issue though.
- Radiation.
- Highly available.
- Fast
- Cheap.



Toxoplasmosis



Magnetic Resonance Imaging



MRI.

- Magnetic resonance imaging (MRI) is a type of scan that is often used to diagnose health conditions that affect organs, tissue and bone.
- Exploits the magnetic properties of organic tissue.

MRI.

- Most of the human body is made up of water molecules, which consist of hydrogen and oxygen atoms.
- Proton = Subatomic Particle found in the nucleus.
- Hydrogen atoms consist of a single proton.

MRI

- Protons are in constant motion which creates a tiny magnetic field.
- When the powerful magnets that are used in MRI are switched on, all the protons become oriented in the direction parallel to the magnetic force.

MRI

- The MRI scanner sends radio signals to certain areas of the body which 'snap' the protons out of position.
- When this happens, each proton transmits a radio signal that provides information about its exact location in the body.

MRI

- MRI measures the distribution of protons and other magnetic agents in the tissue.

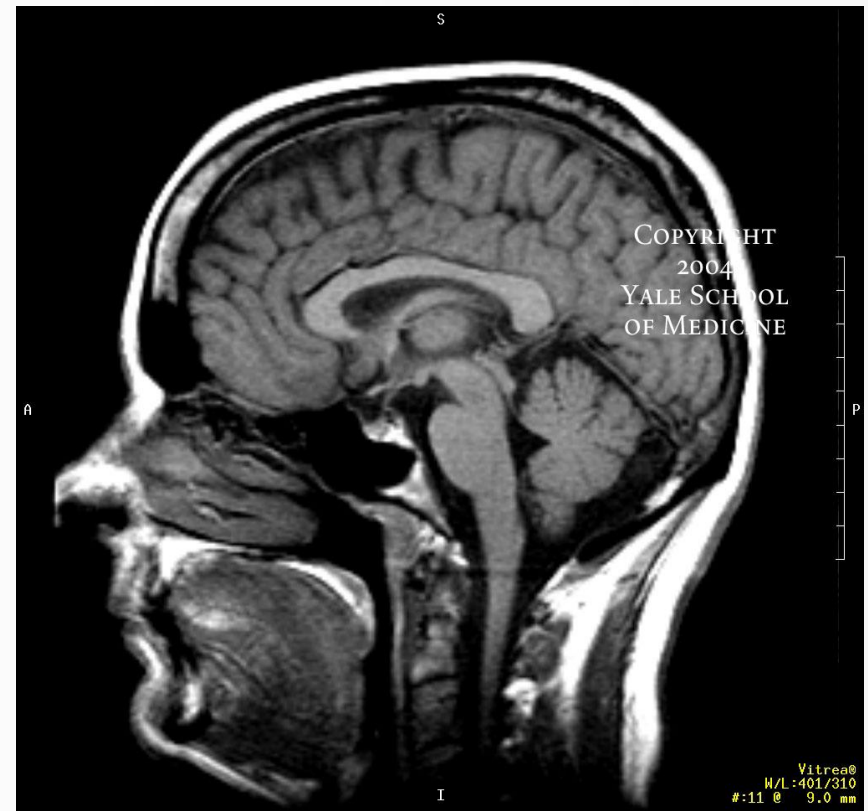
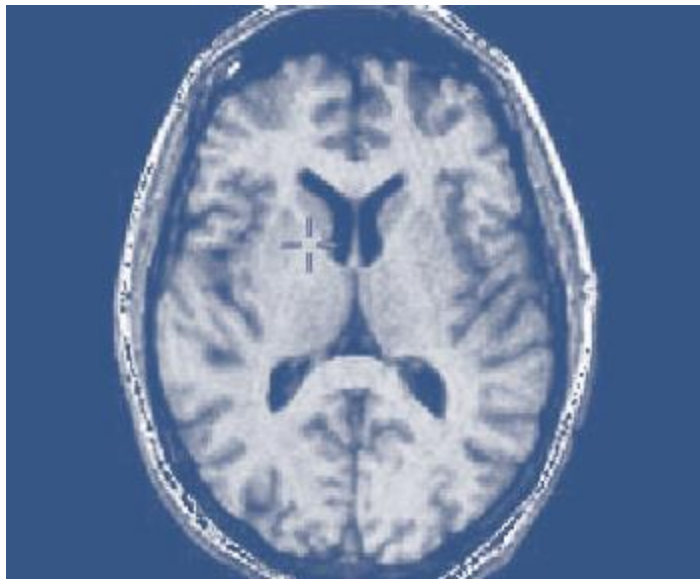
MRI – Clip.

- <http://www.youtube.com/watch?v=H5q79R9C-mk&feature=related>

Critique.

- Better Spatial resolution than CT scan.
- Not exposing Radiation.
- Some people cannot use it (e.g. Pacemakers).
- More expensive, slower.
- Sedated participants.

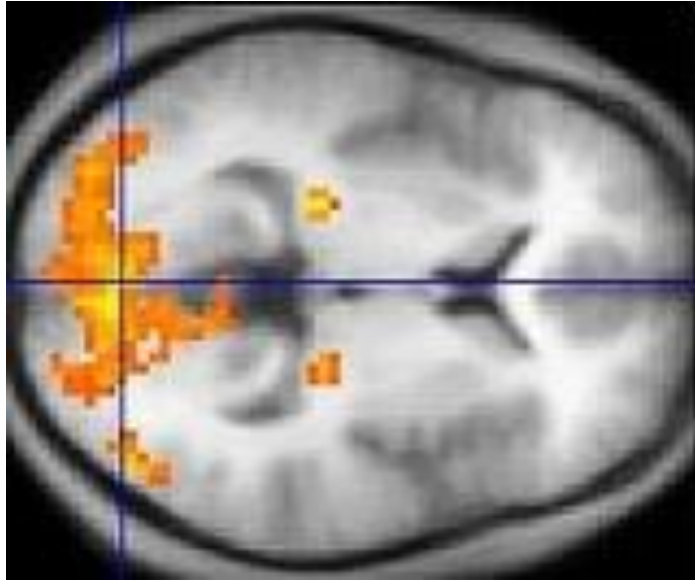
MRI



Functional Imaging.

- Single Cell Recording .
- PET
- TMS?
- FMRI.
- EEG.
- MEG.

Functional Magnetic Resonance Imaging (fMRI).



FMRI

- Works by detecting the changes in blood oxygenation and flow that occur in response to neural activity.
- Oxyhemoglobin has a different magnetic resonance than deoxyhemoglobin.
- When a brain area is more active it consumes more oxygen and to meet this increased demand blood flow increases to the active area.

FMRI.

- After an area of the brain is activated – there is an increase flow of arterial blood to the active area.
- The relative concentration of deoxyhemoglobin decreases.... leads to localised changing in MR.
- Blood Oxygenated Level Dependent (BOLD) MR.

FMRI

- <https://www.youtube.com/watch?v=8jc8URRxPIg>

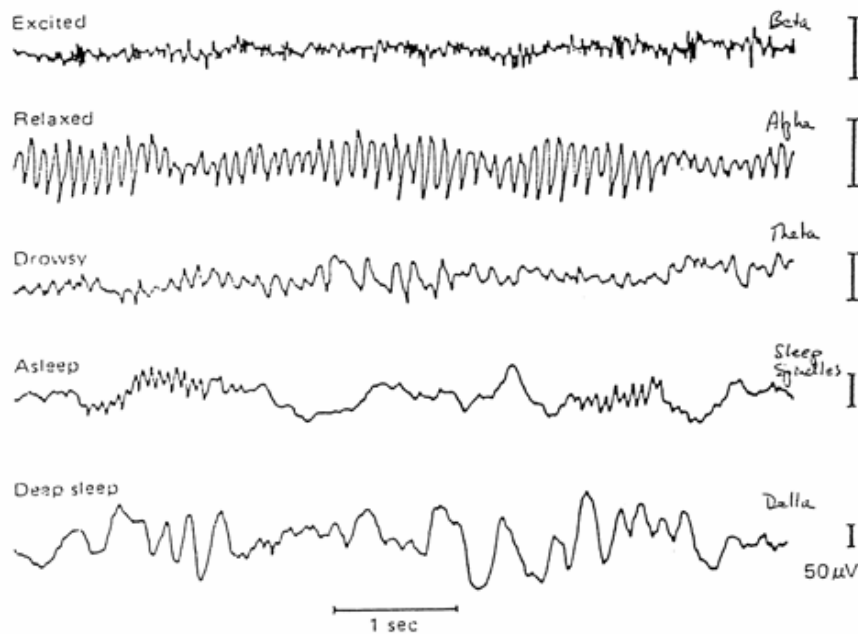
FMRI Critique.

- Very good spatial resolution. Has some limits.
- All regions of the Brain.
- Temporal Resolution better than PET but still low.
- Widely Available.

fMRI Critique.

- Non-invasive
- No radiation.
- Identifies a network of regions.
- Indirect measure of Neural Activity.
 - Correlation doesn't necessarily imply causality.

Electroencephalography (EEG).



Electroencephalography (EEG).

- Pioneering technique to measure brain activity.
- Measures brain electrical brain activity, non-invasively.
- When large populations of neurons are active together, they produce large electric potential.

EEG

- Same principle as single cell recording but with larger electrodes that can be placed on the scalp (non invasive).
- Measuring the change in voltage corresponding to the difference in potential.
- Tissues of the brain, skull and scalp passively conduct electrical currents.

EEG.

- Electroencephalogram = Record of the signals... “Lets look at the Electroencephalogram of Joe Bloggs”.
- EEG – Continuous recording.
- Important for Clinical Application – Predictable EEG signatures.
- ECG – Electrocardiogram – Heart.

EEG and Epilepsy.

- Valuable information in the assessment and treatment of Epilepsy.
- Focal seizures – begin in a restricted area – spreading throughout the brain.
- First hint of a neurological abnormality.
 - E.g. Tumors.

EEG and Cognitive Processes.

- Fairly limited - because it is very global.
- However, by extracting an evoked response from the EEG signal it is possible to explore how brain activity responds to a particular task.
- EEG traces from a series of trials are averaged out aligning the records according to an external event.
 - Evoked Response = Event-related Potential (ERP).

EEG

- Event related Potential (ERP) is the change in electrical activity that is time locked to specific events.
- When the events are repeated many many many times – small neural changes can be observed (CONSISTENT changes).
 - Background fluctuations removed – leaving an Event related signal....great temporal resolution.

EEG

- <http://www.youtube.com/watch?v=HX7L11rhRTw&feature=fvw>

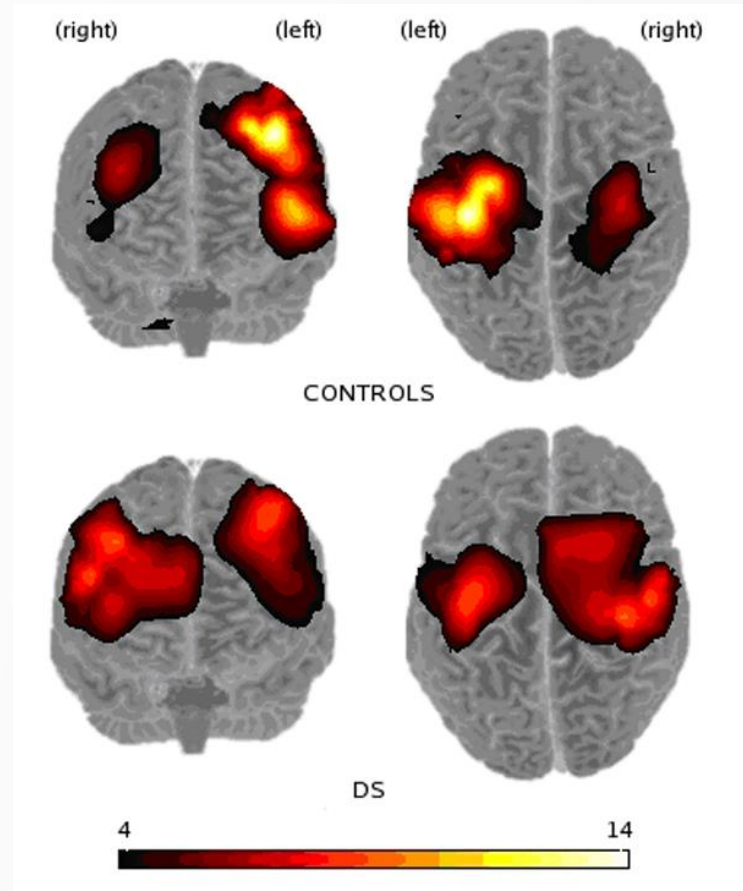
EEG – Critique.

- Poor Spatial Resolution.
- Not specific for Cognitive Function.
- Superficial Layers of the Cortex
- Side effects (Seizures).

EEG – Critique.

- Excellent temporal resolution.
- Measure state effects (sleep).
- Non-invasive.
- Inexpensive.
- Speed.

Magnetoencephalography (MEG).



Magnetoencephalography (MEG).

- Active Neurons produce small magnetic fields.
- MEG records the magnetic fields being naturally generated by the neural sources in the brain.

MEG

- Detected by sophisticated technology based on super-conducting detectors and analysers known as SQUID.
 - Superconducting quantum interference devices
- Magnetic Fields are analysed to find the location of the active neural sources.

MEG

- <https://www.youtube.com/watch?v=S4FaTp05LDI>
- <https://www.youtube.com/watch?v=cUbRbpWheRo>
- <https://www.youtube.com/watch?v=L3PJPbblWyg>

MEG critique.

- Non Invasive.
- Very high temporal resolution (as with EEG).
- Better spatial localisation than EEG.

MEG critique.

- Expensive.
- Interference.
- Activity may be associated with but not essential for the task.
- Limited spatial resolution compared to PET.

Task 1

- In small groups – consider the following...
- You are a top Neuroscientist at the world's leading Neuroscience research unit in which all of the Neuroscience equipment discussed in the last two lectures are at your disposal.
- Your role is to write a proposal, outlining a design and method for the following research questions.
 - Particular emphasis on justifying why you would use one method over the other.
 - Think practical implications as part of your justification (but you do not have to worry about costings).

Research topics

- 1) Exploring optimal attentional levels and brain activity required in successful golf putting.
- 2) Measuring the location of brain activity at rest (but not sleep) in children with ADHD.
- 3) Measuring Brain activation following distraction from a language task.

- 
- 4) Measuring the impact of drug treatments on a brain tumour.
 - 5) Measuring the impact of Alzheimer's disease.
 - 6) Does all language acquisition use the same parts of the brain?

- 
- 7) Can the biological basis of language and language organisation provide insights into people DEVELOPING Schizophrenia.
 - 8) Is Musical Ability linked to Brain function?

Task 2

- You are a top Neuroscientist at the world's leading Neuroscience research unit in which all of the Neuroscience equipment discussed in the last two lectures are at your disposal.
- You have the following equipment at your disposal (currently not in use).
 - TMS
 - FMRI
 - EEG
 - MRI.

- 
- Design 5 studies in the topic of memory in which you will need to use the equipment on previous slide.
 - One technology per study (4 technologies on the previous slide) and then one study which uses a combination of the technologies.