Introduction to Cognitive Neuroscience

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  - Office: 1S25
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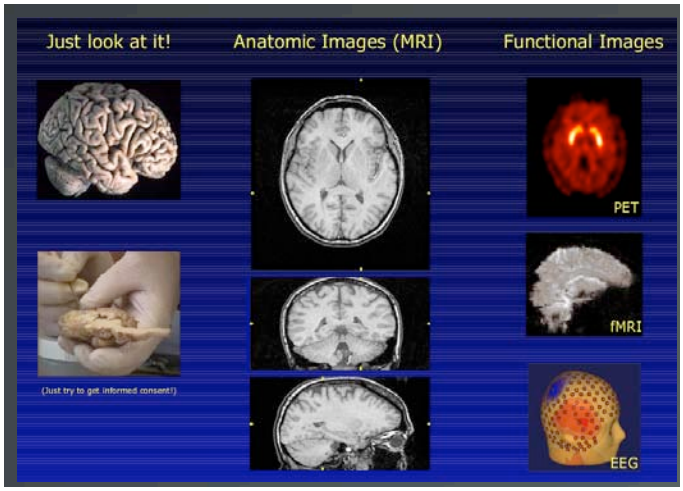
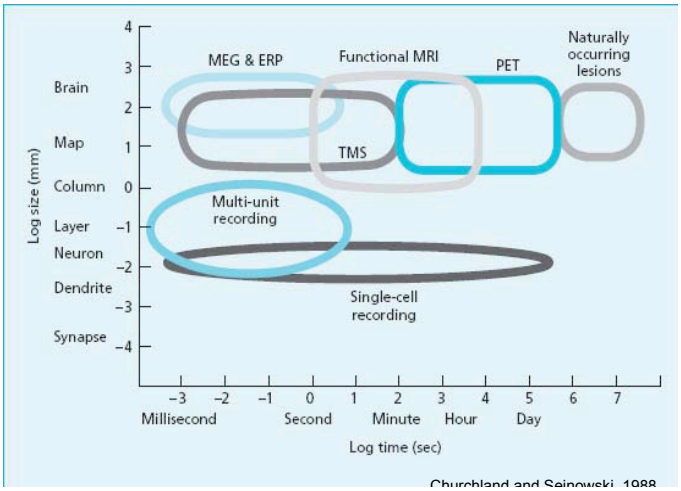
- Brain basics
- Imaging the brain
- Automatic threat detection
  - Please check blackboard AND:
  - http://www.beclab.org.uk
  - http://www.cognitiveneurosciencearena.com/whatiscognitiveneuroscience.asp

How can we discover what our brains are doing and how they are doing it?

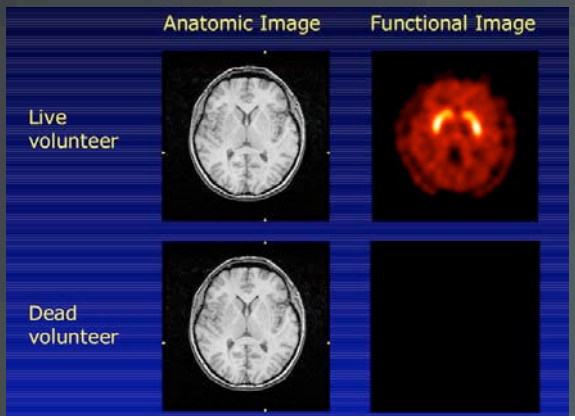
"That's amazing—I was just thinking the same thing."

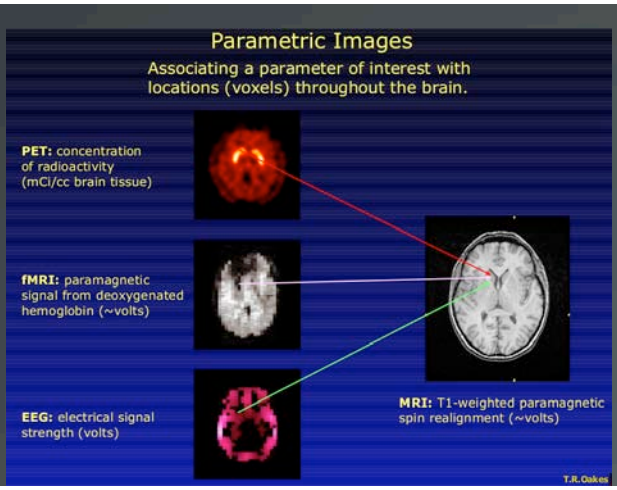




Churchland and Sejnowski, 1988

Functional imaging

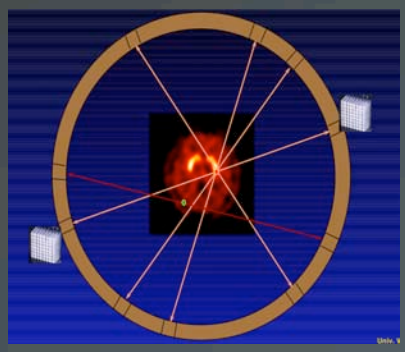




PET: Positron Emission Tomography

- Uses radioactive tracers introduced into the blood
- The tracers bind to some molecule of interest in the brain
- Amount and source of emitted radiation tells us about amount and location of molecule of interest
- Used to image blood, oxygen, neurotransmitters (e.g. Dopamine)
- Slow (minutes - hours)

PET: Positron Emission Tomography



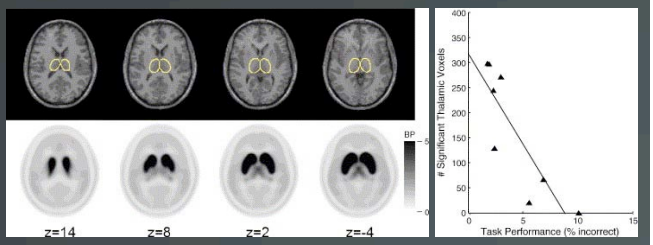
PET Tracers

Some PET Radiocompounds and Their Biomedical Applications:

15O-oxygen	Oxygen metabolism
15O-carbon monoxide	Blood volume
15O-carbon dioxide	Blood flow
13N-ammonia	Blood flow
18F-fluorodeoxyglucose	Glucose metabolism
18F-fluoromisonidazole	Hypoxic cell tracer
11C-SCH23390	Dopamine DI receptor
11C-flumazenil	Benzodiazepine receptor

(Adapted from www.austin.unimelb.edu.au/dept/nmpet/pet/detail/radionuc.html)

Measuring dopamine neuromodulation in the thalamus: Using [F-18]fallypride PET to study dopamine release during a spatial attention task



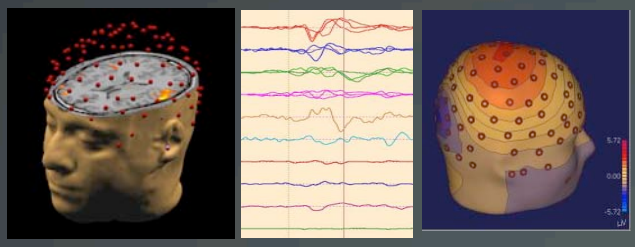
Christian et al., 2005; http://dx.doi.org/10.1016/j.neuroimage.2005.11.052

EEG: Electroencephalography

- Measures electrical field on scalp
- Electric field changes with neural activity in the brain
- EEG can detect fast changes to the electrical field (e.g. < 50 milliseconds)
- Cannot tell us exactly where the source(s) of the electrical field changes are

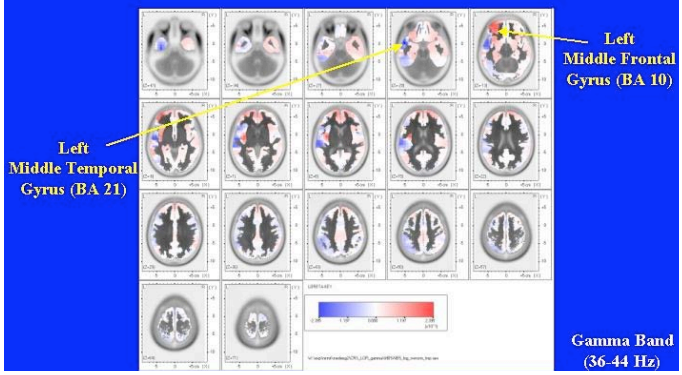
EEG

EEG: Electroencephalography



http://www.mrc-cbu.cam.ac.uk/research/eeg/eeg_intro.html

Compassion vs. Neutral: Low Resolution Electromagnetic Tomography



MRI: Magnetic Resonance Imaging

- Uses an extremely powerful electromagnet to detect brain structure and function
- Magnetic field: 3 Tesla: approx. 60,000 x Earth's magnetic field
- Functional MRI (fMRI): based on magnetic properties of haemoglobin with and without attached oxygen

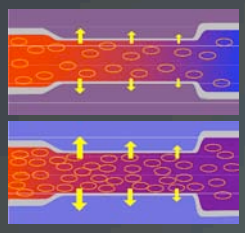
MRI: Magnetic Resonance Imaging

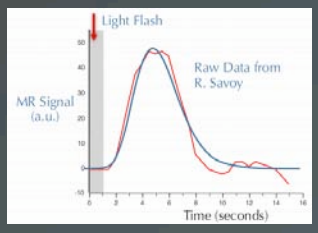
- 3T Siemens Trio MRI scanner

MRI: Magnetic Resonance Imaging

fMRI

- Detects changes in oxygenated blood concentration due to changes in blood flow





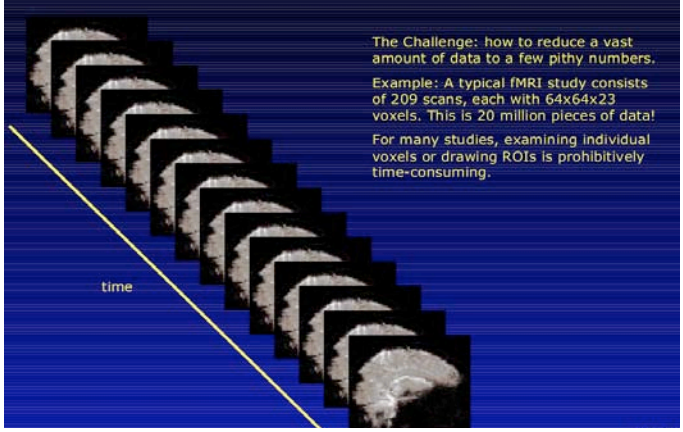
fMRI

- Reasonable time resolution (a few seconds), but not as fast as EEG (or many neural processes!)
- Good 3D spatial resolution: can identify source of MRI signal to within a few mm
- Non-invasive, but still certain restrictions (no metal or pacemakers!) and LOUD!!!
- Relative measure: must always have a within-subject control condition (no purely between-subjects designs)

FMRI: Typical experiment

- Repeatedly scan participants (one complete brain scan every 2-3 seconds) while they perform a task
- Two or more conditions (e.g. Angry versus Happy faces, easy versus difficult task, warm heat versus painful heat)
- Continue until enough repetitions of each task condition have been collected (approx. 20/condition)
- Typically acquire 30-60 minutes of data

Data Reduction



The Challenge: how to reduce a vast amount of data to a few pithy numbers.

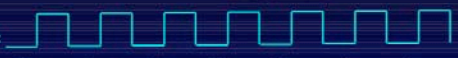
Example: A typical fMRI study consists of 209 scans, each with 64x64x23 voxels. This is 20 million pieces of data!

For many studies, examining individual voxels or drawing ROIs is prohibitively time-consuming.

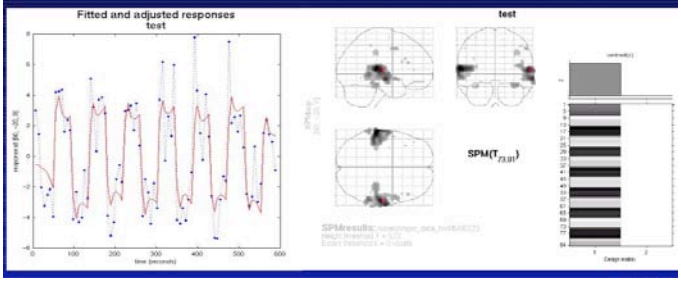
Data Reduction: Statistical Parametric Map (SPM)

Goal: Find brain regions that are activated by a tone.

Model for Listening task:

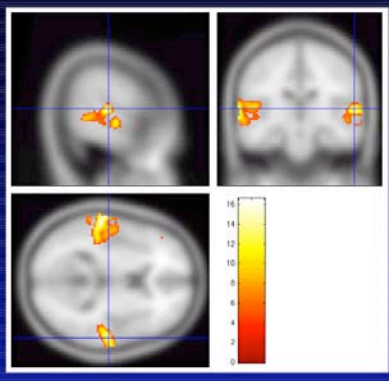


tone is: off on off on off on off on off on off on off on

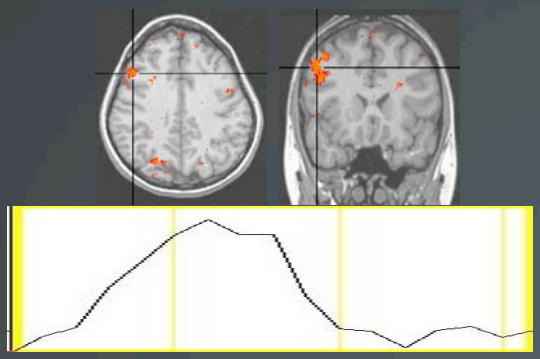


Data Reduction: Statistical Parametric Map (SPM)

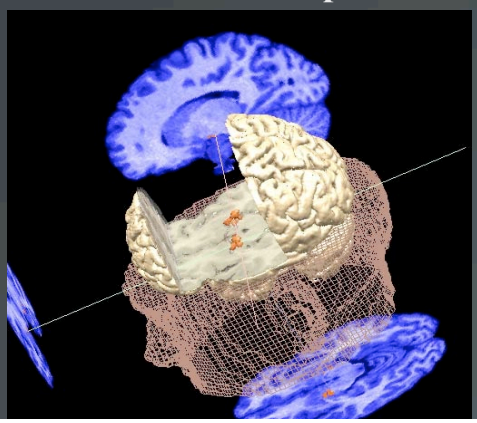
- Where is the activation?
- How strong is it?
- How significant is it?
- Is it repeatable?
- Can these results be generalized to a larger population?



FMRI: Emotional pictures



FMRI: Emotional pictures



Questions to ask yourself whenever reading a Cognitive Neuroscience research paper:

- What can it really tell us about function? Does it tell us more than a behavioural experiment? (and is it worth the cost of $3 million per scanner, then $700 per hour)?
- Would it be as convincing without the pretty pictures of brains?
- Are the identified regions of the brain meaningful functional units? More generally, is the brain modular?
- Is it good science?

What can it really tell us about function?

- Coltheart (2004) poses the question:
  - "Has cognitive neuroscience, or if not might it ever (in principle, or even in practice) successfully use(d) data from cognitive neuroimaging ... to adjudicate between competing information-processing models of some cognitive system)?" (p. 21).

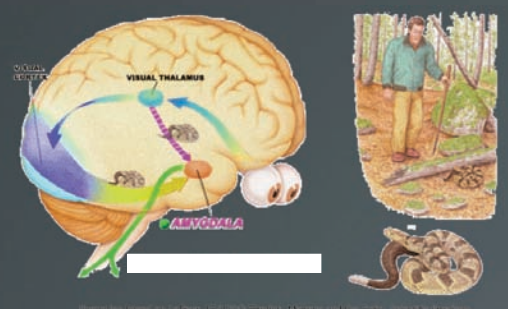
Coltheart, M. (2004) Brain imaging, connectionism and cognitive neuropsychology. Cognitive Neuropsychology, 2, 21-25.

Coltheart, M. (2006). What has functional neuroimaging told us about the mind (so far)? Cortex, 42(3), 323-31.

Are the identified regions of the brain meaningful functional units?

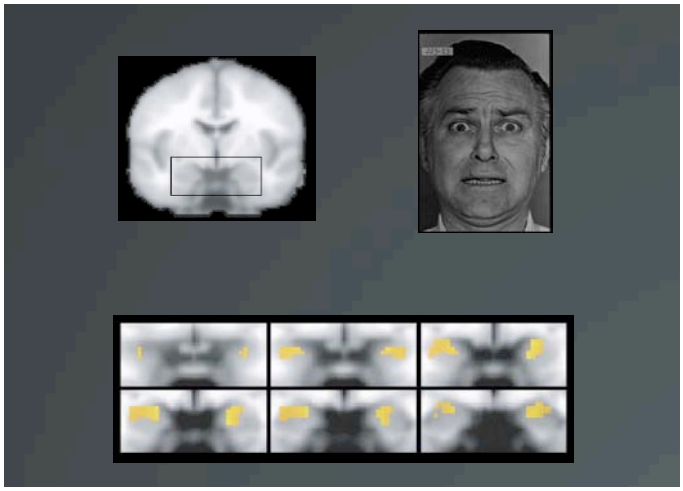
- Most cognitive neuroscience techniques have a spatial resolution of half a centimetre or more. This is a large region in comparison to the size of neurons or networks and nucleii of neurons.
- Do the "blobs" of activation (neuroimaging), lesions (neuropsychology) or virtual lesions (TMS) encompass more than one possible functional unit?

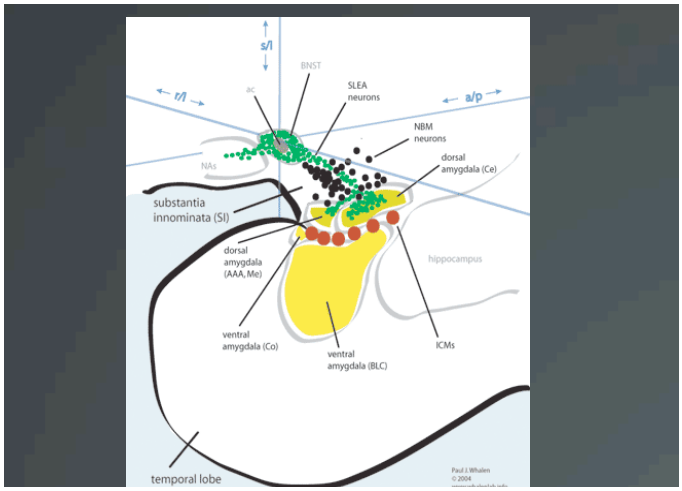
Example: LeDoux's model of fear



Example: Patient SM: bilateral amygdala damage

- Adolphs et al. ('94)
  - SM 30 years, normal intelligence
  - She had trouble:
    - recognizing facial expressions of fear
    - generating the facial expression of fear
    - drawing an expression of fear





OMG!!! My Brain Hurts!!