Neuroimaging

How to see what’s really going on in there …

Structural vs. Functional imaging

Structural Imaging: Brain Anatomy

Functional Imaging: Brain Function

Structural Brain Imaging

CT

MRI

Localization of lesions

Structural Brain Imaging

Computerized Axial Tomography:

- X-ray technology
- Information on tissue densities (CSF, brain tissue, bone)
- Advantages:
  - Inexpensive
- Disadvantages:
  - Poor spatial resolution
  - Ionizing radiation

Magnetic Resonance Imaging:

- Static magnetic field: lines up hydrogen atoms
- Pulse sequence: disrupts hydrogen atoms
- Relaxation time: time it takes to return to original position; differs according to tissue type
- Advantages:
  - Good spatial resolution
- Disadvantages:
  - Can’t be used with people who have metal in their bodies or pacemakers
**Warning**: MRIs and Metal don’t mix!

**Structural Brain Imaging**

*The effect of a hair-band:*

With ... Without ...

**Structural Brain Imaging**

**3D Reconstructions of images:**
Can view brain in axial, sagittal, and coronal planes

movie clips ...

**Structural Brain Imaging**

**Functional Brain Imaging**

Structural MRI
Collects one image at each point in the brain

**Functional Brain Imaging**

Functional MRI
Collects many images at each point in the brain over time (e.g., every 2 sec for 5 mins)

**Functional Brain Imaging**

- Functional MRI (fMRI)
- Positron Emission Tomography (PET)
- Event-Related Potentials (ERP)
- Magnetoencephalography (MEG)
- Transcranial Magnetic Stimulation (TMS)
**Functional MRI**

- As neuronal activity ↑
  - blood flow ↑
  - blood oxygenation ↑
- fMRI relies on the **BOLD** effect
  - Blood Oxygen Level Dependent
    - Oxygenated blood – magnetic
    - De-oxygenated blood – paramagnetic

↑ neural activity → ↑ blood flow → ↑ oxyhemoglobin → ↑ MR signal

**Functional Brain Imaging: fMRI**

1. Functional images
2. Subtraction
   - Condition 1
   - Condition 2
   - Difference
3. Superimpose on structural MRI

**Functional Brain Imaging: fMRI**

- Compare MR signal in different conditions

**Functional Brain Imaging: fMRI**

- **Basal state**
  - arterioles
  - capillary bed
  - venules
- **Activated state**
  - arterioles
  - capillary bed
  - venules

↑ neural activity → ↑ blood flow → ↑ oxyhemoglobin → ↑ MR signal

**Functional Brain Imaging: fMRI**

- ROI Time Course
- fMRI Signal (% change)
- Condition

**Functional Brain Imaging: fMRI**

- Structural MRI
- Functional images
- Time
- Condition
Functional Brain Imaging: fMRI

Research Applications: Video clip ....

Clinical Applications: Pre-surgical scanning

Language mapping: Verb Generation

Advantages:
- Good spatial resolution

Disadvantages:
- Indirect measure of brain activity (i.e., doesn’t measure active neurons but increased blood flow)
- Regions of signal dropout: junctions between air and tissue

Functional Brain Imaging: PET

Positron Emission Tomography:
- As neuronal activity ↑
  • Supply of glucose and oxygen to region ↑
- PET uses radioactive forms of glucose and oxygen to trace regional cerebral blood flow (rCBF)
- How it works:
  • Inject / inhale tracer
  • Tracer reverts to its stable form by emitting a proton
  • This collides with electron – annihilation
  • Two gamma photons are emitted in opposite directions – detected by scanner

Positron emission
Functional Brain Imaging: PET

Condition 1  Condition 2  Difference

Recall – Recognition  Recognition – Recall

Cabeza et al. 2003

Functional Brain Imaging: PET

Clinical Applications: Changes in metabolism

Normal  Alzheimer’s

Functional Brain Imaging: PET

Advantages:
- Good spatial resolution
- Metabolic studies
- Receptor mapping
  - e.g., dopamine receptors

Disadvantages:
- Invasive
  - Injecting radioactive substances
- Poor temporal resolution
- Indirect measure

Functional Brain Imaging: ERP

Event-Related Potentials:
- Neurons generate electromagnetic fields when active
- If a large number of neurons are simultaneously active they can generate fields detectable on the scalp
- EEG: Recording the brain’s ongoing activity
- ERP: Recording the brain’s electrical activity in relation to an “event” (e.g., onset of a stimulus)
Functional Brain Imaging: ERP

128-Electrode Net:

Components of the waveform:

– Exogenous: early; related to physical characteristics of stimulus
– Endogenous: later; related to internal cognitive states

The N400: Semantically incongruent sentences

The pizza was too hot to cry vs. The pizza was too hot to eat

Difference waveforms: The P300

Inverse Problem: Where is the signal coming from?

• The skull and scalp distort electrical fields generated by neurons
• As we measure on the scalp, we have little information about the generators of the electrical fields inside the brain (i.e., the active brain regions)
• We don’t have information about the number, location, orientation, and strength of these generators
**Functional Brain Imaging: ERP**

*What is a dipole?*

- A dipole is the generator of the electrical field
- It is positive at one end, negative at the other

**Functional Brain Imaging: ERP**

*Inverse Problem: Dipole modeling*

- Dipole Modeling: Using mathematical models to determine the most likely generators of the electrical field
- Information about location used from fMRI and PET (where are the generators most likely to be?)

**Functional Brain Imaging: ERP**

*Cool ways to display ERP data*

**Functional Brain Imaging: ERP**

*Advantages:*
- Good temporal resolution: millisecond by millisecond
- Non-invasive
- Comparatively inexpensive

**Disadvantages:*
- Limited spatial resolution: The Inverse Problem
- Difficulty in “imaging” cells parallel to surface

**Functional Brain Imaging: MEG**

*Magnetoencephalography:*
- Neurons generate magnetic fields when they are active
- So if many neurons are simultaneously active, these magnetic fields are detectable on the scalp
- MEG:
  - SQUIDS are used to record these magnetic fields
  - Surrounded by super-cool liquid helium (dewer)
Advantages:
- Good temporal resolution: millisecond by millisecond
- Spatial resolution better than ERP (close to PET)
- Not as distorted by skull as EEG signal

Disadvantages:
- Very expensive
- Limited resolution for deep structures
- Difficulty in "imaging" cells radial to surface

Functional Brain Imaging

- Functional MRI (fMRI)
- Positron Emission Tomography (PET)
- Event-Related Potentials (ERP)
- Magnetoencephalography (MEG)
- Transcranial Magnetic Stimulation (TMS)

Transcranial Magnetic Stimulation:
- Doesn’t “image” neural activity
- Modulates or disrupts neural activity – creates a "reversible lesion" or "scrambles" neural activity
- How does it do this?
  • Coils placed on scalp create a magnetic field that induces an electrical field
  • This alters membrane potential of neurons, causing them to fire randomly
Functional Brain Imaging: TMS

TMS Coil

TMS of motor cortex: Causes muscle movement
Forearm
Jaw
TMS of Broca’s area: Disrupts speech production

Functional Brain Imaging: TMS

Advantages:
– Creates temporary lesion: can investigate if a region is necessary for a function

Disadvantages:
– Adverse effects (e.g., seizures)
– Only useful for brain regions close to the surface

Functional Brain Imaging: TMS

Take-home messages:
– Brain imaging is an exciting method we can use to figure out how the brain works
– If you want a picture of your brain, sign up for a brain imaging study near you!!

Donna’s brain