Eavesdropping on the Mind

COGS 17 - Spring 2019
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Announcements

- **Midterm 1 is Tuesday, 4/23/19**
  - Bring your ID
  - Exam is worth 25% of your grade
  - Homework 1 is due **before** exam (worth 2.5% of grade)
Technologies for Studying the Brain

Keep the following questions in mind:

● What does this technique tell us about the organization of the brain?
● What are the tradeoffs?
  ○ What can’t this technique tell us?
  ○ Why might we choose a different method?
● What is the resolution of the data?
Outline

Anatomical Exams
- Staining
- Lesions
- Electrical Stimulation

Charts physical structures invasive

Images Produced by Perturbation of System
- MRI
- CAT
- fMRI
- PET

Structure/non-invasive
Measure blood flow

Recordings of Endogenous EM Radiation
- Single Cell Recording
- Multi-Cell Recording
- Electro-Encephalogram & ERPs
- Magneto-Encephalogram

Measures electrical current
**Spatial vs. Temporal Resolution**

- **Heisenberg Uncertainty Principle**: States that the position and velocity of an object *cannot* both be measured exactly at the same time, even in theory.
  - **Temporal Resolution**: Precision of a measurement with respect to time.
  - **Spatial Resolution**: Precision of a measurement with respect to space.
Anatomical Exams
Staining

- Allows for visualization of cellular and molecular organization in the brain.
- Requires tissue slices from post-mortem brain.
  - **Cost**: Must sacrifice subject.
- **Great** spatial resolution.
- **No** temporal information.
Golgi Stain

- Stains the entirety of a neuron: Soma, dendrites, and axon.
- Only dyes some of the cells in sample.
- Mechanism is still largely unknown.
- Used by Santiago Ramon y Cajal.
  - Neuron Doctrine: “Nervous system is made up of discrete individual cells (neurons).”
- **Good** spatial resolution.
- **No** temporal resolution.
Nissl Stain

- **Nissl Body**: Large granular body found in neurons, body composed of rough ER and free ribosomes.
  - Site of *protein synthesis*.
- Aniline stain dye binds to negatively charged nucleic acids and stains *extranuclear* RNA in cells.
- Stains the *cell body*, or *soma*.
  - Does **not** stain the dendrite and axons.
Weigert Stain

- Used to stain elastic fibers, more specifically **white matter** or **myelinated** axons.
- Useful for visualizing fiber pathways.
Lesions

- Brain damaged naturally or experimentally.
- Observe behavior before/after damage to neural tissue.
- Later processing of post-mortem brain tissue allows for observation of damage.
- New techniques allow us to record in-vivo.
- **NO** temporal information.
- **GOOD** functional information.
- **GOOD** spatial resolution for damaged areas.
- Human Lesion Examples:
  - “Tan”
  - Phineas Gage
  - HM
“Tan”

- Patient of Paul Broca in 1861.
- Patient could only say “tan”.
- Brain analysis showed patient’s language comprehension was unaffected.
- Post-mortem exam found lesion in inferior frontal cortex.
- The area damaged was associated with language production.
  - Area known as Broca’s Area.
Phineas Gage

- Railroad construction foreman.
- In 1848, accident resulted in a rod being lodged through head.
- Destroyed much of his left prefrontal cortex.
- Changes in his mood and personality.
  - Foul-mouthed.
  - Flakey.
  - Irritable.
H.M

- Knocked down in bicycle accident at young age, resulting in seizures throughout life.
- Unresponsive to medication.
- Bilateral medial temporal lobectomy to correct epilepsy.
- Intact procedural memory, short-term memory, and priming effects.
- Unable to create new episodic memories.
Electrical Stimulation

- Electrical probe placed on surface or inserted into specific brain area.
- Stimulate particular parts of the brain and see how it affects the body.
- Live subjects, invasive.
- **NO** temporal resolution.
- **GOOD** spatial resolution for the stimulation site.
- Functional information comes from subject responses.
- Revealed parts of brain used for processing motor functions, or sensory functions, for different parts of the body.
Recordings of Endogenous EM Radiation
Single Cell Recording

- Recording probe inserted in brain.
- Micro-electrode measures voltage differences between inside and outside of a single cell.
- Live subject is engaged in a task.
- **VERY GOOD** temporal, spatial and functional resolution, but only for the single cell (highly localized).
Examples: Mirror Cells and Face Cells
Electroencephalogram (EEG)

- Recording of brain’s **electrical activity**.
- Records *electric dipole*, or the separation of a positive and negative charges found in an electromagnetic system.
  - Dipole generated by changes in electrical potential of cells at the scalp.
- Non-invasive, inexpensive.
- **GOOD** temporal resolution, but **POOR** spatial resolution.
Electroencephalogram (EEG)

- *Electric field* created by neurons is detected on the **gyri** of the cortex.
- The electric fields measured in EEG are **perpendicular** to the cortex.

The gyri are the ridges and sulci are the grooves that appear on the wrinkled surface of the brain.
Electroencephalogram (EEG)

- Can be used to measure brain activity during a task or during a particular state, such as sleep.
**Event-Related Potential (ERP)**

- Measured brain response that is direct result of a specific sensory, cognitive, or motor event.
- Examines averaged EEG response.
- **Time-locked** to stimulus/task exposure to multiple trials.
- Detect fast changes in electrical activity elicited by a stimulus.
- **GOOD** Temporal Resolution.
- **POOR** Spatial Resolution.
- **STRONG** functional information related to a specific stimulus-response pairing.
Magnetoencephalogram (MEG)

- Records magnetic fields produced by electrical currents occurring naturally in brain.
- No magnet used.
- More expensive than EEG.
  - Uses Superconducting Quantum Interference Devices (SQuIDs)
- Measures activity parallel to the brain surface (from sulci).
- GOOD temporal resolution.
- GOOD spatial resolution.
- WEAK functional information.
Images Produced by Perturbation of the System
Magnetic Resonance Imaging (MRI)

- Utilizes strong magnets to generate images of organs in the body. *Structural info!*
- Machine applies a strong magnetic field.
- Hydrogen protons in tissues containing water react by aligning with the magnetic field.
- Once aligned, MRI is turned off.
- Energy released from protons in form of radio frequency signal can be recorded to create an image.
- **NO** temporal information.
- **BEST** spatial resolution.
- **NO** functional information.
Magnetic Resonance Imaging (MRI)

- MRI vs. MEG?
  - MRI collects \textit{structural information}.
  - MEG collects \textit{magnetic activity} from neurons, visualized as brain waves.
  - MRI uses magnets, MEG does not.
Functional MRI (fMRI)

- Indirect measurement of neural activity by detecting changes in blood flow.
- BOLD = “Blood Oxygen Level Dependent” signal
- Blood flow increases when a region is active. Noninvasive!
- Oxygenated and Deoxygenated blood differ magnetically
- GOOD Functional Info
- POOR Temporal Resolution
  - ~ seconds
- VERY GOOD Spatial Resolution
  - ~ Within millimeters
Positron Emission Tomography (PET)

- Technique used to observe metabolic processes in body.
- Introduction of radioactive tracers into body to detect areas of blood flow.
  - Example: Fludeoxyglucose.
- Gamma waves emitted are detected.
- PET can detect molecular changes even prior to structural changes, such as as in Alzheimer’s.
  - Ex: Brain metabolism is slower (and so less blood flow).
- **POOR** Temporal Resolution.
- **GOOD** Spatial Resolution.
- **GOOD** Functional Information.
Computed Axial Tomography (CAT)

- Utilizes x-rays to get a quick and rough image of brain structure.
- Detect abnormalities such as tumors or areas affected by a stroke.
- Construction of 3D image from multiple 2D x-ray images.
- **NO** Temporal Information.
- **OK** Spatial Resolution.
  - Not as good as MRI.
- **NO** Functional Information.