Week 5

- Tuesday:
  - KW Chapter 7 : Neuroimaging
  - Review for Midterm
- Thursday:
  - Midterm Exam

Chapter 7 : Imaging The Brain

- *Note: in earlier editions of KW this is Chapter 6*

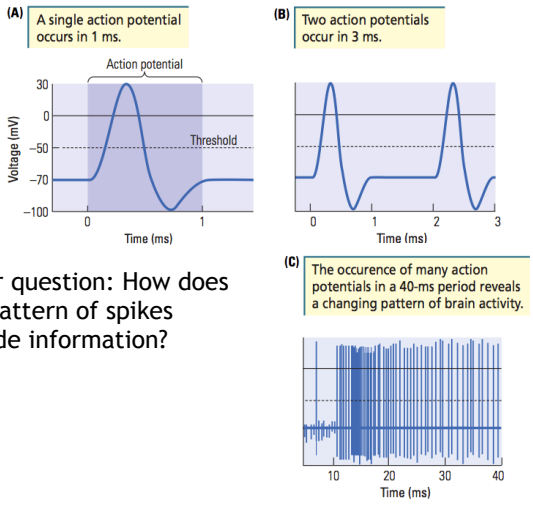
Brain Imaging Techniques : Overview

- Electrical
  - Recording
    - Single Cell, Multiple Cell
      - EEG, ERP
  - Stimulation
- Magnetic
  - Recording - MEG
  - Stimulation - TMS
- Structural
  - X-ray, MRI
- Dynamic / Functional electrical activity
  - metabolism / glucose
  - blood flow, other

Single-Cell recording

- Typically done in non-human animals
- Single electrode recording
- Arrays of electrodes
  - record from multiple cells

Action potential trains



- Major question: How does the pattern of spikes encode information?

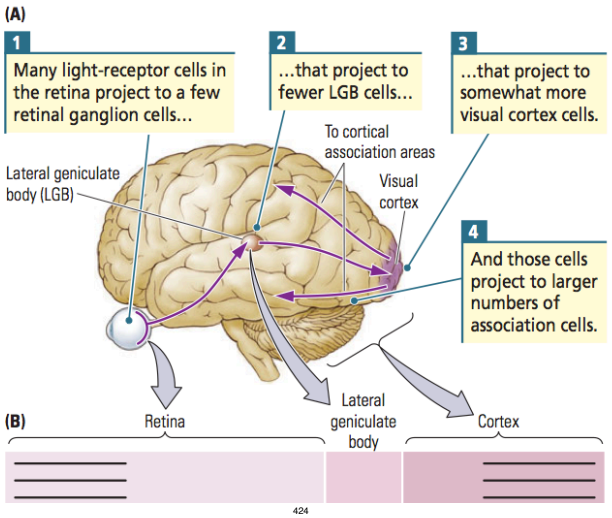
Neuronal Code

- Patterns of neuronal firing
  - steady rate (e.g. “heartbeat” or time counter)
  - bursts, associated with behavior
  - rarely fire at all
  - daily, monthly, or yearly patterns
- How does the pattern of action potentials encode information?
- Example: Pain fibers in the PNS use frequency encoding:
  - low frequency : mild pain
  - high frequency : severe pain
- Example: color sensitive neurons
  - medium frequency : no color
  - low frequency : green
  - high frequency : red

Findings re: Neuronal Code

- Cortical neurons
  - fire about 3x/minute, up to 10x/minute when excited
- Adjacent Neurons may have completely different function
  - e.g. Broca's area: neuron for word perception next to one for word production
- Learning :
  - Newly learned information/skills - requires lots of neurons
  - Old information : more sparsely encoded

Levels of Processing / # of neurons



Levels of Processing / # of neurons

- Sensory input - few to many to few neurons
  - Retina
    - photo-sensitive cells : many, capture low level features (Light & Dark)

      -->
    - ganglion cells : fewer

      -->
    - LGB cells : even fewer

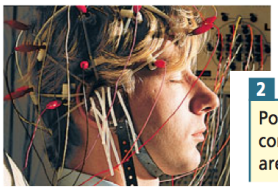
      -->
    - A17 (V1) Primary visual cortex : more cells, respond to visual features (line oreientation)

      -->
    - association cortex : many more cells

      "Grandmother!"

Multiple Neuron Recording : EEG

- Neurons fire in synchrony
- Tiny voltages + many many neurons = measurable voltage on the scalp



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Polygraph electrodes are connected to magnets, which are connected to pens...

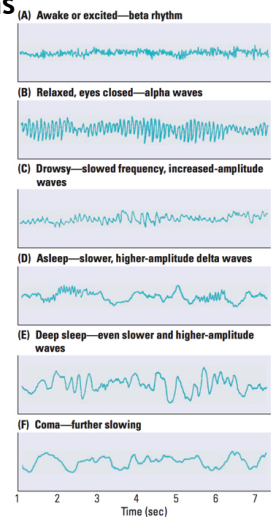
1
Electrodes are attached to the skull, corresponding to specific areas of the brain.

- EEG : Electroencepha logram

EEG Patterns

- Majority of EEG signal comes from neurons in Layers V and VI
- Pacemaker cells keep these cells synchronized

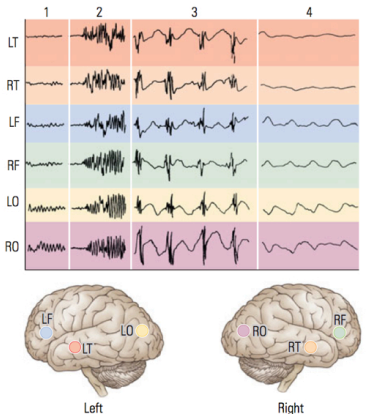
- Frequency & pattern :
- Faster, smaller, & more complicated with increasing arousal
- Slower & larger amplitude in sleep, coma



Epilepsy

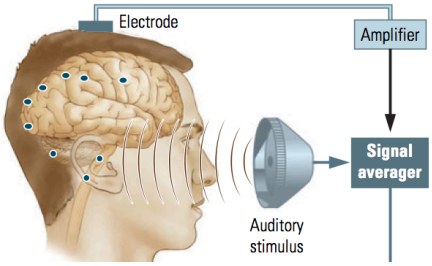
- Seizure
  - large groups of neurons firing all at once
  - out of control
  - pattern spreads
  - can involve entire brain
- Key
  - 1=pre
  - 2=onset
  - 3=clonic
  - 4=coma

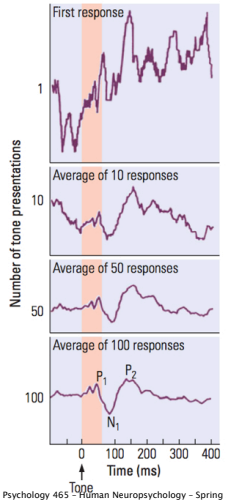
- Note largest spikes in RO area - source of seizure?



ERP - Event-Related-Potentials

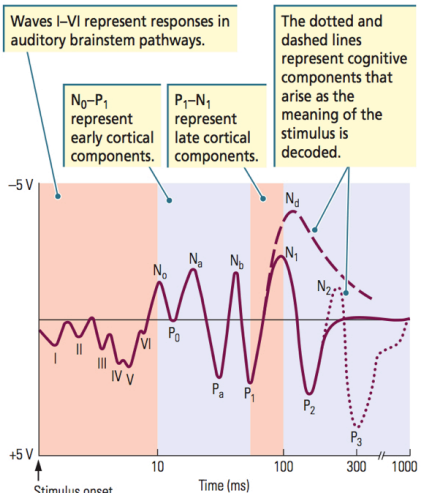
- Can you see "thinking" by watching EEG?
- In a single recording: No, it's too noisy
- By statistically averaging multiple events, a pattern emerges





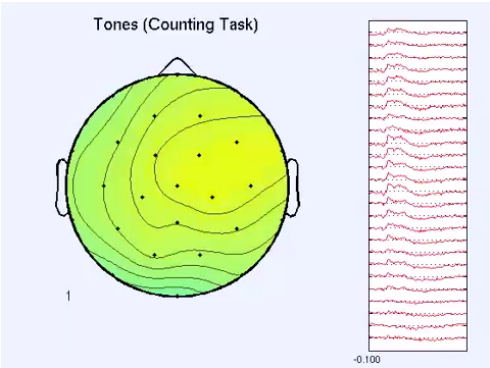
Common ERP patterns

- (P)ositive and (N)egative waves
- Early waves in brainstem (I, II, III, IV, V, VI)
- Later waves in cortex (N0, P0...N3, P3)
- Image: ERP in Parietal Cortex in response to spoken word



Multi-electrode ERP

- An individual's event-related potentials (ERPs) to tones in a simple tone counting task. Right column plots ERPs at 26 scalp electrodes (negative is up). Voltage is represented in color on the cartoon head (cool=negative, warm=positive). Time (in seconds) is printed at the bottom of the column of ERPs. Most prominent ERP deflection is the auditory N1 that peaks around 100 ms post-stimulus.



MEG : magnetoencephalography

- Maxwell-Faraday equation - relates change in Electrical potential (voltage) "E-field" to change in magnetic field "B-field"

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

- Electrical voltages : can be measured with cheap equipment
- Magnetic fields : measured with fancy equipment
  - SQUIDs : Superconducting quantum interference device
  - Requires liquid helium
  - $$$
- Pro: higher resolution

Brain Stimulation

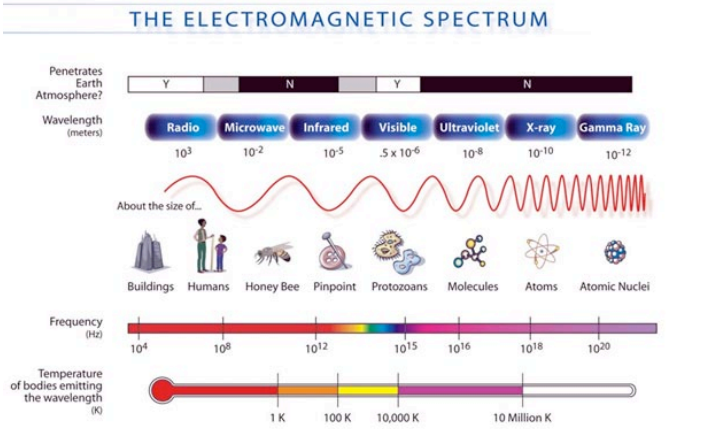
- Electrical
  - Surface
    - often used in brain surgery
  - Intracranial
    - DBS - Deep Brain Stimulation - mostly experimental, used for Parkinson's treatment
    - Very invasive - risks of infection, etc.
- Magnetic
  - TMS : transcranial magnetic stimulation

Transcranial Magnetic Stimulation

- TMS - new, still being researched
- very strong magnetic fields are created in the brain
- magnetic fields cause electrical currents in brain tissue
- mechanism - unknown

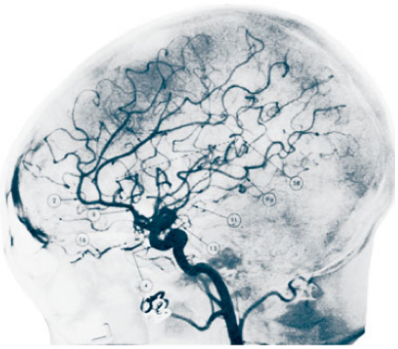
X-Ray techniques

- X-rays : very high frequency (small wavelength) waves
- Ionizing!



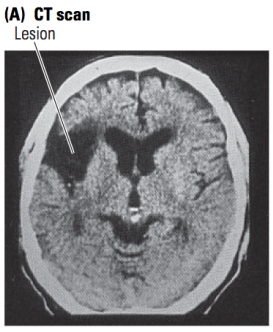
X-Ray Procedures

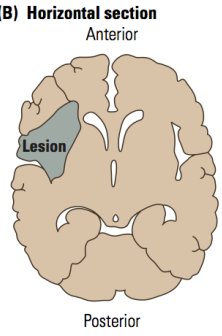
- Conventional - simple xray of the skull - shows gross features
- Contrast techniques
  - Pneumoencephalography - *air-brain-graph* - inject air into CSF for contrast
  - Angiography - inject material into blood which blocks xrays
- CT



CT : Computed Tomography

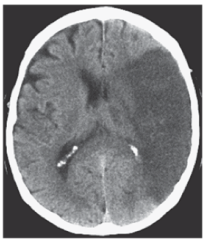
- Xrays are sent through head from all angles
- Computer reconstructs data into 3-D image
- Aka "Computed Axial Tomography" or CAT scan



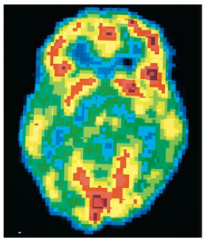


Neuroimaging

- Visualizing the brain *in vivo*
- CT : Computed Tomography
  - xray
  - cheap(er), quick
  - low resolution

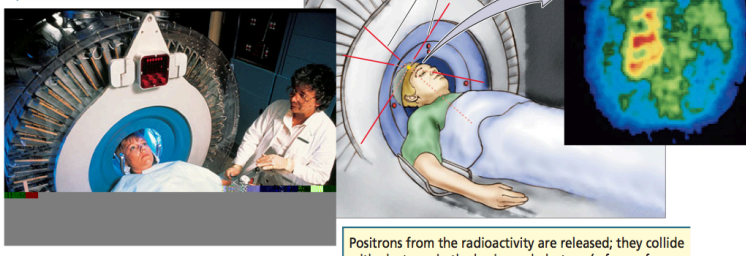


- PET : Positron Emission Tomography
  - radioactive injection
  - tag chemicals to image



PET Scanner

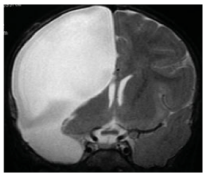
A small amount of radioactively labeled water is injected into a subject. Active areas of the brain use more blood and thus have more radioactive labels.



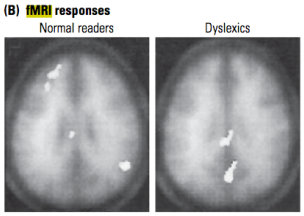
Positrons from the radioactivity are released; they collide with electrons in the brain, and photons (a form of energy) are produced, exit the head, and are detected.

MRI

- MRI : Magnetic Resonance Imaging
  - magnetic fields
  - detailed
  - expensive



- fMRI : Functional MRI
  - metabolism in real time



MR - Spectroscopy

- MRI normally images hydrogen molecules in water (80% of the brain) - Can't see other 20%
- MR Spectroscopy - uses different RF frequency to image non-water chemicals
- Experimental
  - e.g. can detect choline (precursor to Acetylcholine)

MR - DTI - Diffusion Tensor Imaging

- measures directional movements of H_2O molecules
- in ventricles & cell bodies: water molecules are random
- in nerve fibers, water moves along axis of fiber

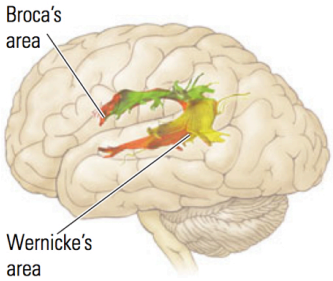
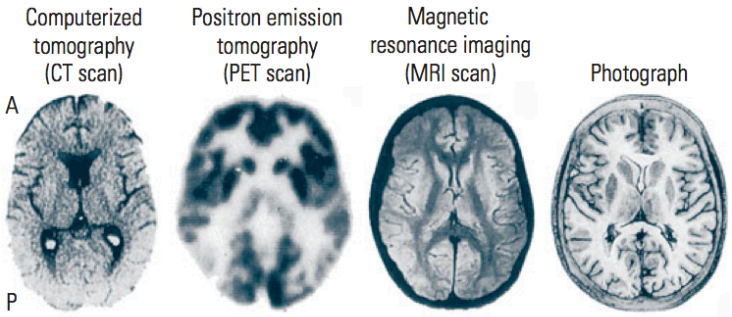


Figure 6.24

Diffusion Tensor Images of the Language Pathways Connecting Broca's and Wernicke's Regions

Comparison of Neuroimaging images



Imaging Comparison

Kind	Time	Resolution	Cost	Risk	Detect Function?
Xray - Conventional	fast	very low	$	☠	✘
Xray angiography	slow	high	$$	☠ ☠	✘
Xray - CAT	medium	medium	$$	☠ ☠	✘
PET	slow	low	$$$	☠ ☠	✔
MRI	slow	high	$$		✘
fMRI	slow	high	$$$		✔