A Lesson from Pinky and the Brain

Cognitive Neuroscience

Topics to Cover

• Basics of Neuro Anatomy
  – Neurons, Brain Structures
• Transduction
• Representations in the Brain
• Hemispheric Lateralization
  – Corpus Callosum, Split Brain Patients
• Localization of Function vs. Mass Action
• Measuring Brain Activity
Cognitive Processes and Neuropsychology

- Review of topics covered
  - High and low-level processing
  - Sensation & Perception
  - Attention
  - Memory
  - Language
  - Problem Solving
  - All have biological correlates in brain

- The Amazing Brain
  - Knowledge Representation:
    - "most mysterious thing in the world" (William James, 1890)
  - It stands to the everlasting credit of science that by acting on the human mind it has overcome man's insecurity before himself and before nature

Neuroscience of I-P

How is information...

1. ...acquired (sensation)?
2. ...interpreted to confer meaning (perception and recognition)?
3. ...used to ruminate (thinking and consciousness)?
4. ...to predict the future state of the environment and the consequences of action (decision making)?
5. ...to communicate (language)?

Neural Anatomy

- Neurons
  - Cell body
  - Dendrites
  - Axon
  - Terminal Buttons
  - Myelin Sheath
  - Synapse
**Action Potential**

- All or None

**The Synapse and LTP**

- Brief video (~3 mins) on Synapses [Link]
- Briefer video on LTP [Link]

**Characteristics of Neurons**

- Action Potentials
- Propagation
- Communication
  - Synapses
  - Neurotransmitters
  - Excitation and inhibition
- Long Term Potentiation (LTP)
  - “cells that fire together, wire together” (Hebb)
Excitation, Inhibition, and the Praying Mantis

- What do you know about the praying mantis?
  - Females sometimes decapitate males during copulation... what?!
  - Why??

What do we know so far?

- So we know how one neuron sends a signal to another.
- Where does it all start?

Sensory Transduction
Sensory Transduction

An example with visual stimuli
Visual Phototransduction

Hemispheric Lateralization

How do the hemispheres communicate?
Corpus Callosum & Split-Brain

Gazzaniga's Split-Brain Studies

Localization of Function

• Homunculus

http://www.youtube.com/watch?v=ZMLj2TYcCAo
Cognitive Processes and the Brain

- Localization vs. Mass Action
  - Karl Lashley, rats, engrams, and % of your brain
  - Equipotentiality
  - What does it mean to be localized?

Localization Gone Wrong!

- Anton Mesmer
- Franz Joseph Gall
- Phrenology
  - S.I. Franz quote...

BRAIN ANATOMY
(MODELS OF LOCALIZATION)
Brodmann’s Areas (Brodmann, 1909)

Major Structures: Lobes

- Cerebral Cortex
  1. Temporal
  2. Occipital
  3. Parietal
  4. Frontal

Structures in Cerebral Cortex
The Brain & Memory

- Engram
- Specific representations vs distributed representations
- Hippocampus
- Amygdala
- Striatum

Localization of Memories?

- Specificity Coding (spareseness)
  vs.
- Distributed Coding

“Grandmother cells”...“Halle Berry cells”?

Subcortical: Hippocampus

- Damage / Removal
  - H.M.
  - Clive Wearing
- Contents
  - Episodic memory?
  - Semantic memory?
  - All LTM?
- Consolidation
  - Long Term Potentiation
  - Reconsolidation?
Amygdala

- Highly arousing or emotional memories
- Fear conditioning in rats
- Located adjacent to the hippocampus and can regulate hippocampus (memory) function.
  - Stress

Habit Learning and Implicit Memory

- Basal Ganglia / Dorsal Striatum
  - Caudate nucleus, putamen
  - Knowlton et al. (1994)
  - Weather Prediction Game
  - Control, Hippocampus, Striatum

The Brain & Language

- Broca’s Area
- Wernicke’s Area
- Superior Temporal Gyrus (STG)
  - Interaction of semantics and syntax
- Inferior Frontal Gyrus (IFG; BA: 44,45,47)
  - Syntax and working memory
- Middle Temporal Gyrus (MTG)
  - Semantic processing
(Paul) Broca’s Area

Broca’s Aphasia:
– Characterized by slow, laborious speech.
– Speech production problem.
– Comprehension is intact, can understand others.

Wernicke’s Area

Wernicke’s Aphasia:
– Speech comprehension problem.
– Not aware of speech errors.

[Image of brain with labels for Broca’s Area and Wernicke’s Area]

http://www.youtube.com/watch?v=67HMx-TiA8I

MEASURING BRAIN ACTIVITY
Historical Neuroscience

- Historical vs. Modern Approaches
  - Direct Observation
  - Case Studies (e.g., HM, NA, Clive Wearing)
  - Lesion/ablation
  - Single cell recording, microelectrodes

How do we measure the brain?

Case Studies

Henry Molaison (HM) 1926-2008
Hippocampus Damaged by Herpes Simplex Encephalitis

Clive Wearing (1938 - )

Slice it out and see what happens!

Lesion / Ablation

=?
Do we need to slice it out?

- Transcranial Magnetic Stimulation (TMS)

We can deactivate it with temperature or chemicals.

Visual short-term memory deficit from hypothermia of frontal cortex. (Ferry, Roozendaal, & McGaugh, 1999)

Role of norepinephrine in mediating stress hormone regulation of long-term memory storage: A critical involvement of the amygdala. (Ferry, Roozendaal, & McGaugh, 1999)

How about in autopsy?

Dr. Lucy Rorke-Adams (former caretaker of Einstein’s brain)

Dissection of H.M.’s Brain at UCSD (2008)
Measuring Brain Juice

Microelectrodes & Measuring Neurotransmitters

Stereotaxic Surgery

Computerized Axial Tomography

- Indirect Observation
  - CT or CAT (Computerized Axial Tomography)
  - Electroencephalography (EEG)
  - Magnetoencephalography (MEG)
  - Positron Emission Tomography
  - fMRI (functional Magnetic Resonance Imaging)

Computerized Axial Tomography
Electroencephalography

- Electroencephalography (EEG)
  - Procedure
  - What are we measuring?
  - Advantages and Drawbacks

Magnetoencephalography

- Magnetoencephalography (MEG)
  - Procedure
    - Magnetically Shielded Room
  - What are we measuring?
  - Advantages and Drawbacks
Magnetoencephalography

- EEG
  - Electrical signal (can be distorted)
  - Measures sulci & gyri (top)
    - Broader sensitivity
- MEG
  - Magnetic field (less prone to distortion)
    - Greater spatial mapping
    - Measures sulci only

Positron Emission Tomography

- Positron Emission Tomography (PET)
  - Procedure
  - What are we measuring?
  - Advantages and Drawbacks
Magnetic Resonance Imaging

- Magnetic Resonance Imaging
  - Procedure
  - What are we measuring?
  - Advantages and Drawbacks
  - What makes it fMRI?
    - (i.e., functional)

Magnetic Resonance Imaging

Magnetic Resonance Imager (MRI)

MR Images
Uses of fMRI

• Lie Detection (e.g., Langleben et al., 2005)

• Sleep and Memory Consolidation
  – Emotional Memory? (Payne & Kensinger, 2011)

• Seeing the future?
  – Episodic memory (Schacter, Addis, & Buckner, 2007)
The DANGER of Using Magnetic Resonance Imaging

Summary

• Biological correlates in brain

• Neurons and their interactions

• Brain areas and localization

• Different ways to measure activity in brain