Four Main Approaches

- Experimental cognitive psychology
- Cognitive neuropsychology
- Computational cognitive science
- Cognitive neuroscience

COGNITIVE NEUROPSYCHOLOGY

Cognitive Neuropsychology

- Concerned with the patterns of cognitive performance (intact and impaired) shown by brain-damaged patients
- Informs us about normal human cognition
- Key assumptions:
  - Functional modularity
  - Anatomical modularity
  - Uniformity of functional architecture across people
  - Subtractivity
Cognitive Neuropsychological Evidence

- Dissociations
- Double dissociations

Example of Double Dissociation

- Case 1 – H.M.
  - Medial temporal lobe resection
  - Can remember what happened in past few minutes (short-term memory is okay)
  - Can’t transfer this information to long term memory

- Case 2
  - Frontal lobe stroke
  - Can’t remember what just happened…can’t keep a series of numbers in his head
  - Can make new long-term memories

Limitations

- Compensatory strategies used by patients
- Damage tends to be across modules
- Functions may not be so localized
- There can be large differences among individuals having broadly similar brain damage
Cognitive Neuroscience

- the study of the relation between cognitive processes and brain activities

- Potential to measure some "hidden" processes that are part of cognitive theories (e.g., memory activation, attention, "insight")

- Measuring when and where activity is happening. Different techniques have different strengths: tradeoff between spatial and temporal resolution

The four lobes, or divisions, of the cerebral cortex in the left hemisphere.
The four lobes within the left hemisphere including some of the main gyri or ridges.

The main areas of the brain identified by Brodmann.

Techniques for Studying Brain Functioning

- Single unit recordings  
  - Hubel and Wiesel (1962, 1979)
- Event-related potentials (ERPs)
- Positron emission tomography (PET)
- Magnetic resonance imaging (MRI and fMRI)
- Magneto-encephalography (MEG)
- Transcranial magnetic stimulation (TMS)
The spatial and temporal ranges of some techniques used to study brain functioning.

**Single Cell Recording**
(usually in animal studies)

Measure neural activity with probes. E.g., research by Hubel and Wiesel:

Hubel and Wiesel (1962)
- Studied LGN and primary visual cortex in the cat. Found cells with different receptive fields – different ways of responding to light in certain areas.

Example:
- LGN On cell (shown on left)
- LGN Off cell
- Directional cell
EEG / ERP

- EEG: Electroencephalography
- ERP: Event Related Potentials
- Electrodes placed at the scalp; measuring changes in voltage
- For ERP, measure changes after presentation of stimulus
- High temporal resolution
- Poor spatial resolution (current passes through scalp)

Example of EEG

Event Related ("evoked") Potentials
PET

- Positron Emission Tomography
- Traces path of radioactive substance put in blood
- Measures changes in blood flow
- More invasive than fMRI
- Reasonable spatial – poor temporal resolution

fMRI

- Functional Magnetic Resonance Imaging
- Measures oxygenation in blood flow (known as hemodynamic response)
- High spatial resolution (good for localizing), poor temporal resolution (poor for investigating the timing of processes)
A typical fMRI BOLD experiment

BOLD response = Blood Oxygenation Level Dependent response

Typical Time Course of BOLD Response

Subtraction Logic

- Analysis is usually based on signal differences, e.g.:
  - Signal( task ) – Signal( rest)
  - Signal( task2 ) – Signal( task1)

- Issues:
  - How do we know when a difference is significant?
  - What threshold to use?
  - What can we conclude from such differences?
What is a suitable threshold on fMRI BOLD activity?

Number of brain areas active during performance can vary wildly depending on threshold level.

How should we interpret the differences?

- measures magnetic fields produced by electrical activity in the brain.
- Fairly good spatial resolution, excellent temporal resolution (can be used both to studying the time-course and localization of cognitive processes)
- Possible to work out the sequence in which different brain areas contribute to processing.

MEG: Magnetoencephalography

med.m.u-tokyo.ac.jp/research/MEG.html
Transcranial Magnetic Stimulation (TMS)
- Stimulation with a strong magnetic pulse
  - temporary focal brain disruption; simulates temporary brain lesion
- Pros:
  - Reversible, repeatable and (relatively) non-invasive
  - Might allows causal conclusions
- Cons:
  - Not clear what its doing or exactly where the ‘disruption’ is

Example Study with PET & TMS
- Kosslyn et al. (1999). Science
- Question: can we reveal the part of brain that is necessary for visual imagery?
- Task: study picture on right and then imagine display
- Measure PET activity during visualization
Example question: Which quadrant had more stripes lengthwise, 1 or 3?

PET Results
- Main activation in area BA17: primary visual cortex
- But, is this activation epiphenomenal or is it functionally related to visually imagery?
  - TMS study can address this issue
TMS results

• With TMS stimulation right before imagery trials, performance decreases

→ Suggests a causal link between visual imagery and area 17

Analyzing Individual Differences

• In many imaging (and behavioral) studies, results are averaged over subjects

• Pro: averaging reduces amount of noise in observations

• Cons: induces artifacts when individuals are systematically different.

Question: how different are our brain responses when the stimulus is the same?

Hasson et al. (2004), Science

• Instead of the typical fixed set of experimental stimuli, participants simply watched an uninterrupted 30-min segment of a film (The Good, the Bad, and the Ugly)

• The investigators asked whether fMRI signals in one person's brain could predict signals in another person's brain.

• Close to 30% of the cortical activation of one person's brain could be predicted by the fMRI signals from another individual's brain
Hasson et al. (2004), Science

- They went back to the movie clips to find the common feature that may have been driving the intersubject consistency

Scenes with faces drive Fusiform area

Scenes with usage of hands for motor tasks drive post-central sulcus