Course Logistics

- Two lectures a week
  - Slides available before lectures
  - Many lectures will include practice multiple-choice questions, which will not be made available online
  - Leave time for questions at the end of each lecture
- Assessment will be made up of
  - 20% for take-home assignments
  - Straightforward, to help understand material, with discussion in class, and a serious effort will earn a (near) perfect grade
  - 30% for mid-term
  - 50% for final
  - Both exams will be primarily multiple-choice, with some short answer questions
  - Details on on class web page, and see especially the FAQs

Cognitive Science Content

- The content areas, or phenomena, that cognitive science deals with are attempts to understand how humans (and animals)
  - Perceive the world
  - Act in the world
  - Learn about new or changing information
  - Encode, store and organize information in the mind
  - Make decisions based on available information
  - Reason and solve problems
  - Communicate and develop
- Cognitive science deals with perception, action, learning, memory, decision-making and problem-solving
Cognitive Science Methods

- Cognitive science is inherently multi-disciplinary, involving research from (at least) the fields:
  - Psychology
  - Computer science
  - Machine learning
  - Statistics
  - Cognitive neuroscience
  - Linguistics
  - Philosophy
  - Education

Building computer models of human cognition

- To understand how the brain works
- To understand the mental representations and processes that produce behavior
- To understand limits of theories
- To understand structure of language

We focus mostly on insights from Cognitive Psychology

Cognitive Science Methods

- These data are old, but the dominance of psychology and computer science remains true, with cognitive neuroscience growing in the last decade.
Cognitive Science Applications

- Any area that benefits from understanding and predicting how people perceive information and make decisions has the potential to apply knowledge from cognitive science
  - "Artificial intelligence" type applications
    - Search engines, decision-support systems, ...
  - "Human-computer interaction" type applications
    - Information visualization, interface design, ...
  - "Psychometric" type applications
    - Measurement of cognitive abilities, detection and diagnosis of impairment, ...
  - "Social cognition" type applications
    - Marketing, collaboration, ...

History of Cognitive Science
History: Philosophical background

- The study of human cognition traces its history back to the philosophers of Greece: Aristotle, Socrates, Plato
- Two philosophical standpoints:
  - empiricism: all knowledge comes from experience
  - nativism: we come into the world with innate knowledge

Introspection

- Early cognitive research studied the connection between physiological (neural) processes and cognitive processes
- Wundt established the first psychology laboratory in 1879 and studied conscious experience using introspection
  - e.g., Mayer and Orth (1901) free association task
    - Experimenter would say a word, and subject would report the thoughts that occurred in response to the word
- Introspection shows it is possible to study mental processes without studying physiological processes

Ebbinghaus

- Hermann Ebbinghaus (1885) conducted the first "contemporary" behavioral psychological experiments, focusing on memory:
  - he created about 2,300 nonsense syllables (e.g., ZUG REN), and organized them into random lists
  - he learned the lists, and tested himself at various time intervals
  - he recorded his accuracy in remembering, and the time needed to re-learn the lists
Behaviorism

- By the 1930s, there was a reaction to the German introspectionist school, particularly in the form of the US behaviorist school
- Behaviorism is (was?) a form of associationism (empiricism), viewing the structure of the mind as having been formed through interaction with the environment
  - Watson (1930) “give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I’ll guarantee to take any one at random and train them to become any type of specialist”
  - Skinner believed studying S-R relationships was preferable to the description of thinking as mental activity

Methodological flaws

- Cognitive scientists want to explain and predict behavior, and this needs to make some reference to mental processes
  - perception, memory, understanding, intentions
- Both methodologies are inadequate
  - introspection: many mental processes are not available to conscious experience
    - a bit like trying to catch yourself in the mirror without looking
  - behaviorism: S-R relationships do not explain behavior that is guided by an understanding of the stimulus
    - e.g., the creative use of language

Functionalism

- The current methodological approach in cognitive psychology is consistent with the philosophy of functionalism
- Use as empirical data observable ‘facts’, as both input and outputs
  - e.g., type of stimuli presented, length of presentation, presence of a distraction, ...
  - e.g., accuracy of recall, time to make a decision, confidence in a decision, ...
- Attempt to develop models that explains, describes, and predicts these sorts of observations
  - i.e., what must the mental world be like in order for that observation to have been made
Functionalism

- The goal is to model what happens inside the "black box", to describe, explain and predict the relationship between input and output
  - Describe: fewer nonsense syllables on the list are remembered after a long time period between study and test
  - Explain: the syllables are over-written by other syllables learned on other lists
  - Predict: if the length between study and test is doubled, the number of syllables remembered will be halved

Challenges in Understanding Cognitive Phenomena

- Understanding the phenomena of cognitive science using functionalism generally extremely challenging
  - It is hard to measure relevant variables accurately or directly
  - It is often expensive or impossible to collect extensive relevant information
- Analogous to determining the physical layout of a library
  - based on simple surveys about book searches and successes
  - given to students entering and exiting the main doors

Birth and Growth of Cognitive Science

- Spurred by rapid growth in computing technology
  - The metaphor of the mind as a computer led to
    - the information processing view of cognition
    - the creation of the field of Artificial Intelligence
  - The metaphor of the mind as a parallel network of neuron-like computing elements
    - leading to neural network or connectionist approaches
  - Most recent has been the rise of
    - modern machine learning and statistical methods, especially Bayesian methods
    - cognitive neuroscience based on brain imaging
Marr’s (1982) Levels of Analysis

- **Implementation**
  - How is perceptual and cognitive processing, the remembering of information, and so on, actually done with neural hardware in the brain?
  - Often this is the focus of cognitive neuroscience

- **Algorithmic**
  - What processing steps are made to make a decision, or produce behavior, or so on?
  - Often this is the focus of cognitive psychology

- **Computational**
  - Why does the cognitive capability behave like it does? What is its goal or purpose?
  - Often this is the focus of artificial intelligence or machine learning

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Levels of Analysis for an Arithmetic Problem

1. **Computation**
   - Description of computation steps

2. **Algorithm**
   - Steps to solve the problem

3. **Implementation**
   - How the algorithm is executed in practice