Cognitive Science 140C

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Course Logistics

- Two lectures a week
  - Slides available before lectures
  - Many lectures will include practice multiple-choice questions, which will not be made available on-line
  - 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

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.
From the 2004 “Cognitive Science” Journal Report
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
• 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
Levels of Analysis for an Arithmetic Problem

Computation

Algorithm

Implementation