Introduction to cognitive science
Session 1: Introduction

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What is cognitive science?

- **Cognitive science** is the interdisciplinary study of **mind** and **how information**, e.g., concerning perception, language, reasoning, and emotion, **is represented and transformed in the brain**. It consists of multiple research disciplines, including **psychology, artificial intelligence, philosophy, neuroscience, learning sciences, linguistics, anthropology, sociology, and education.** (Thagard, 2008)

What is cognitive science?

□ Stainton (in Contemporary Debates in Cognitive Science, 2006):

□ "It is the **multidisciplinary** attempt to understand the **mind,** most especially the human mind. [...] there are **behavioral** and **brain sciences** [...] **formal disciplines** [...] and parts of **philosophy.**"
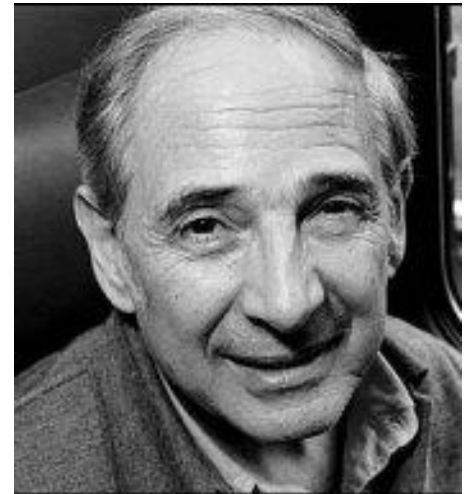
What is cognitive science?

- Simon (Foundations of Cognitive Science, 1989):
  - "Cognitive science is the study of **intelligence** and **intelligent systems,** with particular reference to **intelligent behavior as computation.**"

What is cognitive science?

□ Searle (Minds, Brains and Science, 1984) on cognitivism:

  □ "[...] the task of cognitive science is to **characterize the brain**, not at the level of nerve cells, nor at the level of conscious mental states, but rather **at the level of its functioning** as an **information processing system**."
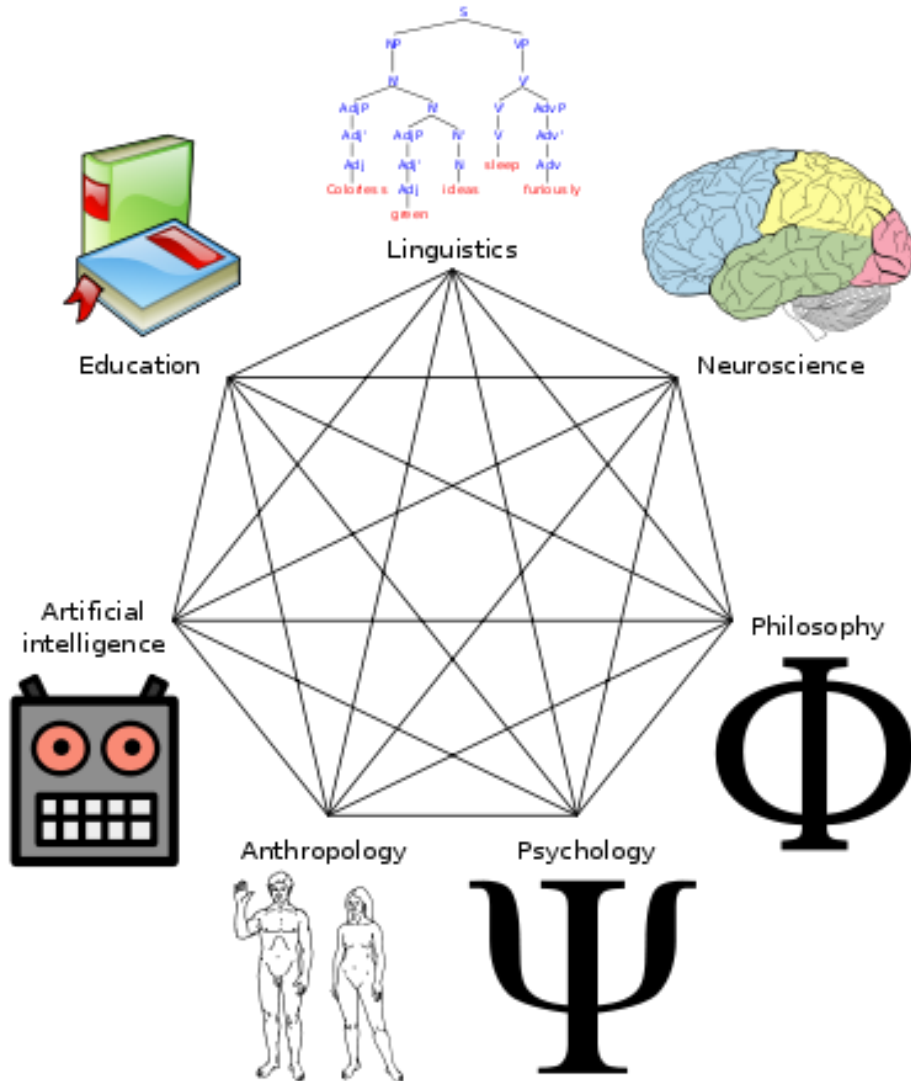
What do these definitions have in common?

1. The subject of study in cognitive science is usually **mind, intelligence, thinking or cognition.**

2. The nature of cognitive scientific investigation is **interdisciplinary.**

3. The subject of cognitive science is characterized in **computational-representational terms.**

- Broad definition 1+2
- Narrow definition 1+2+3
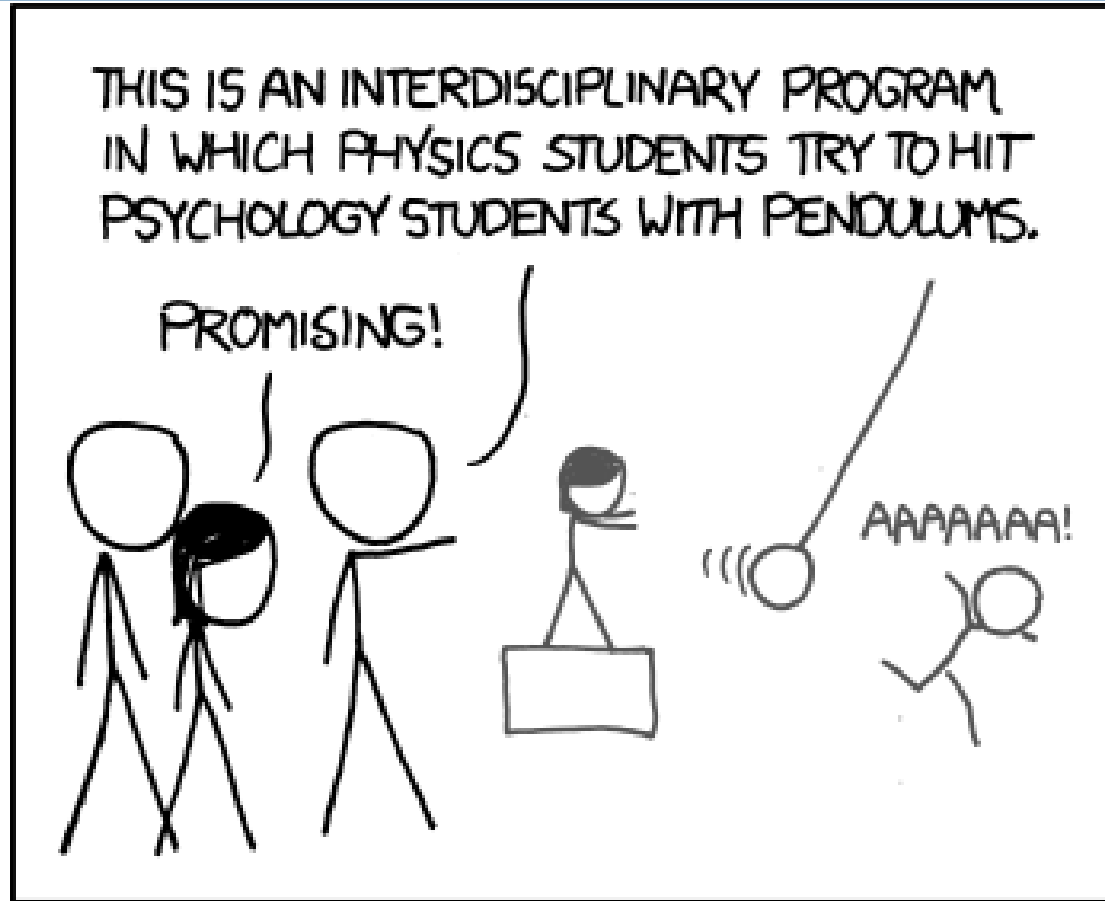
Interdisciplinarity

- Philosophy
- Psychology
- Artificial Intelligence
- Neuroscience
- Anthropology
- Linguistics

Interdisciplinarity or multidisciplinarity?

Cognitive science or sciences?

□ Common **object of study**?

   □ Cognition (= information processing?)

   □ Mind (more than knowledge, includes emotions, etc.)

   □ Product of brain and neural activity

   □ Situated-embodied action, "life"

□ Common **methods**?

   □ Not shared by *all* disciplines

Cognitive science or sciences?

- "Cognitive scientists tend to take as objects of study of CS what they normally investigate in their own background disciplines: subjective experiences if they are philosophers, brain activations if they are neuroscientists, information processing if they are cognitive psychologists, and so on. And they use their own methods." (Greco, 2012)

Historical background

- **René Descartes** (1596-1650)
  - "cogito ergo sum"
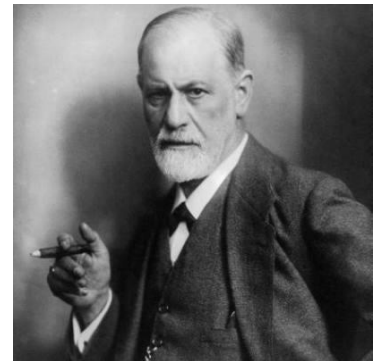   - Metodological scepticism – rejects any ideas that can be doubted
    - Cartesian Dualism – body works like a machine, mind is separate
    - Introspection as a method
    - $\Rightarrow$ **Cognition is conscious**
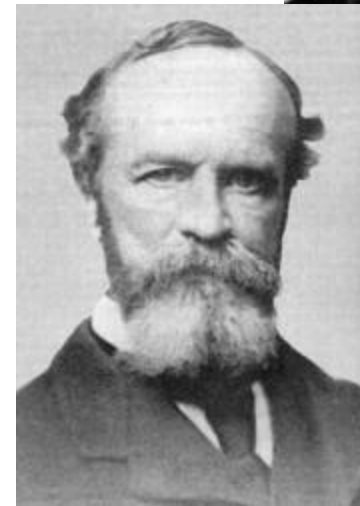
Historical background

- Hermann von Helmholtz (1821-94)

- Sigmund Freud (1881-1939)

- $\Rightarrow$ **Cognition is not only conscious**

Historical background

- 1879 Wilhelm Wundt – first psychological experiments
- 1890 William James – "Principles of Psychology":
  - four methods in psychology: analysis, introspection, experiment, and comparison

Behaviourism
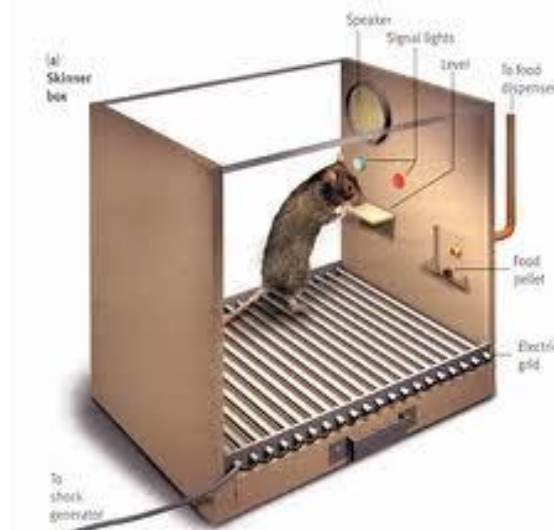
- Mind as a black box

- Mental states are unobservable
  - We don't need them

- Controled conditions
  - Measuring reactions

- Ivan Pavlov
- http://www.youtube.com/watch?v=Eo7jcI8fAuI

Behaviourism

- BF Skinner

- Operant conditioning

- $\Rightarrow$ **Mind (internal states) excluded from scientific consideration**

WILL PRESS LEVER FOR FOOD

(a) Skinner box — Speaker, Signal lights, Lever, To food dispenser, Food pellet, Electric grid, To shock generator

Historical background

- WWI – neuropsychology – lesions (Lurija).
- Cognitive psychology during WWII – noisy speech recognition, attention, vigilance, etc.
- Boom After WWII:
  - Computer science: visual perception
  - Linguistics: language acquisition in children
  - Ethology: social behaviour in animals
  - Neurophysiology, Anthropology…

Historical background

- Cybernetics: - Norbert Wiener, feedback

- Information theory: Shannon

- Neuropsychology: Donald Hebb

- Computer science: Von Neumann, Turing

- $\Rightarrow$ **Information-processing psychology**

Computer metaphor

- Software vs. hardware

- Church-Turing thesis

- Architecture similarities: processor, memory, I/O devices

- Mental representations ~ computer data structures

- Computational procedures ~ computational algorithms

Two methodological consequences of the computer model

- Computer models can be built to test theories of mental processes.

- There are different levels of analysis for a complex information processing system.
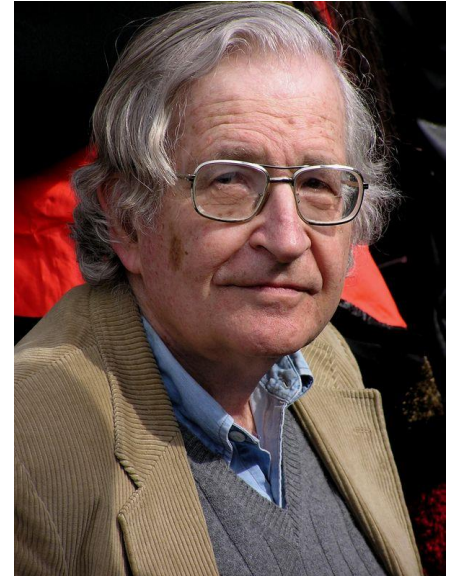
Three Levels of Description (David Marr)

- A complete understanding of a computational system has to involve three (kinds of) levels :
- **Computational theory**
  - What is computed and why.
  - What the system is capable of doing.
- **Representation and algorithm** (software)
  - What program is used.
  - What are the symbols and how are they processed.
- **Hardware**
  - Where in the brain?
  - What kind of neurons and how are they connected?

Historical background

- Formal lingusitics: Noam Chomsky
- Devices with internal states/memory computationally stronger than mere associations
- $\Rightarrow$ **Rejects behaviourism**

Artificial Intelligence

- 1956 J. McCarthy

- the study and design of intelligent agents

Dreams of AI

- Wolfgang von Kempelen
- Judah Loew
- Mary Shelley's Frankenstein
- Čapek's R.U.R.

Conference at Dartmouth College (1956)

- John McCarthy
  - "We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We think that a significant advance can be made in one or more of these problems if a carefully selected group of scientists work on it together for a summer." (McCarthy et al. 1955)

Other bold claims about AI

- Marvin Minsky (1967)
  - "within a generation… the problem of creating 'artificial intelligence' will substantially be solved"

- Herbert Simon (1960)
  - "machines will be capable, within 20 years, of doing any work a man can do"
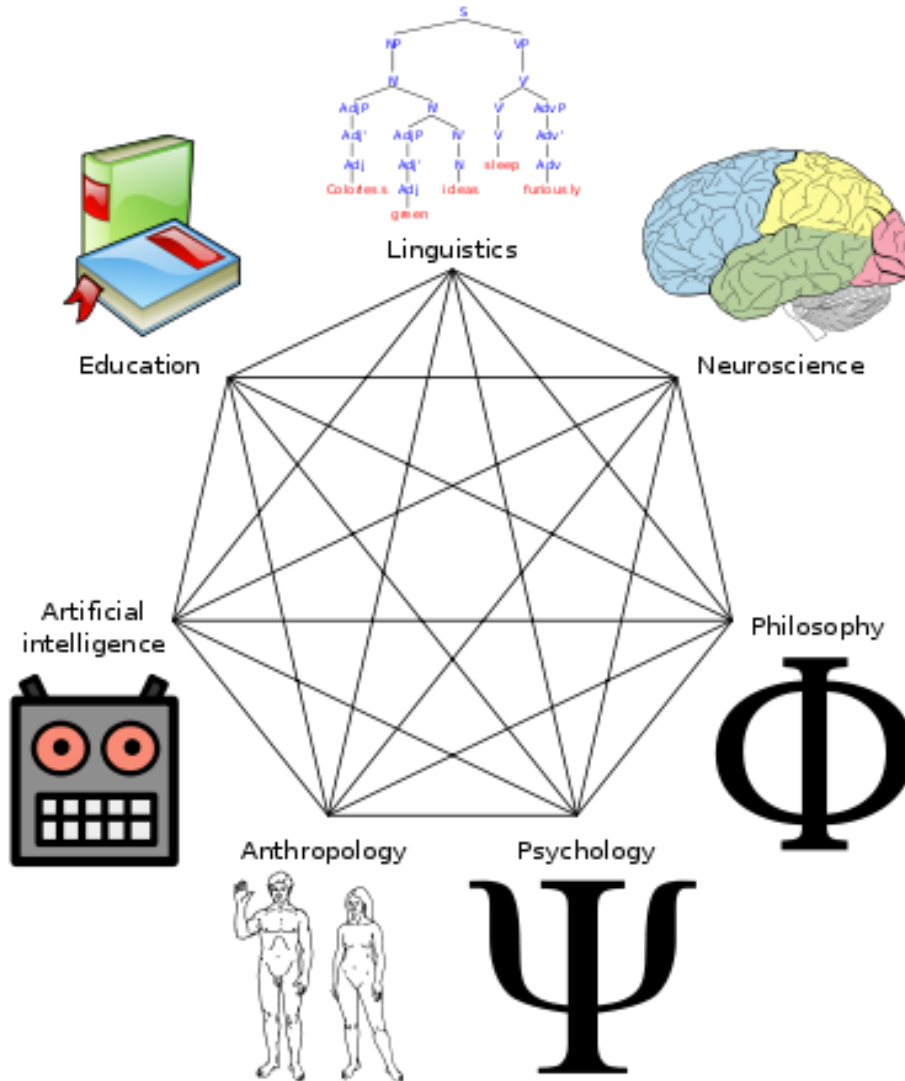
(https://quoteinvestigator.com/2021/03/04/ai-solved/)

Origin of the term Cognitive Science

- George Miller after the MIT conference on Shannon's information theory (1956).

- Christopher Longuet-Higgins (1973).

- Journal *Cognitive Science* since 1975

Interdisciplinarity

- Philosophy
- Psychology
- Artificial Intelligence
- Neuroscience
- Anthropology
- Linguistics

Philosophy

- Theoretical / methodological questions
  - What is mind?
  - How can we study it?
    - First person perpective vs. third person perspective
  - How can we know anything in principle?
    - Philosophy of science

  - Thought experiments
    - Brain in a vat
    - Mary the color scientist,…
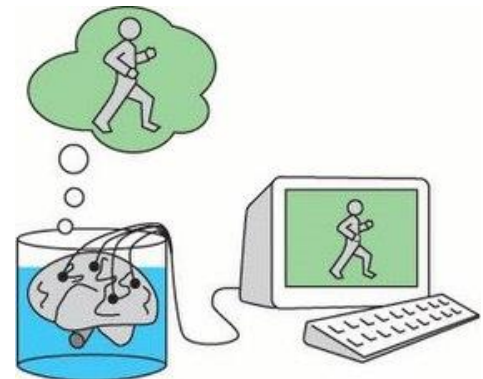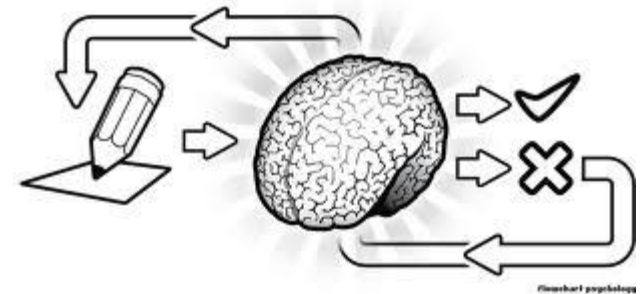

Image source: Wikipedia

Psychology

- How can we structure the mind?

- What are the cognitive processes/mechanisms behind it?

- Empirical research

- Behavioral experiments

  - reaction times

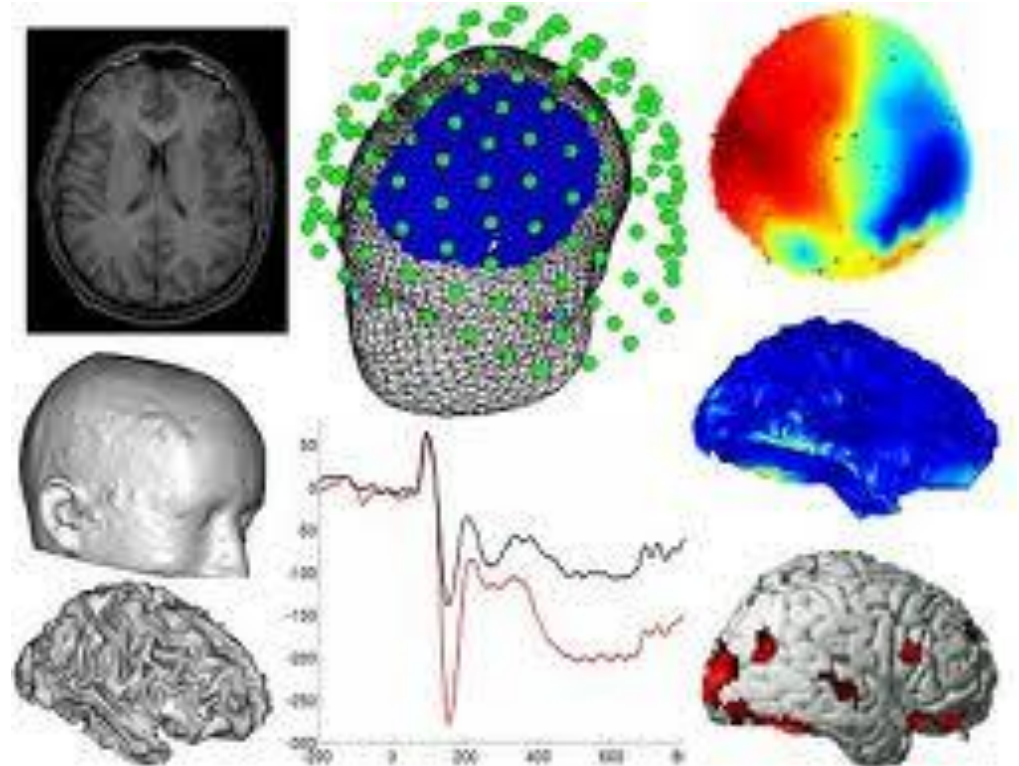 - psychophysical responses

  - eye tracking

Neuroscience

- ☐ Implementation in the brain
  - ◻ Brain imaging
    - ▪ PET
    - ▪ EEG
    - ▪ FMRI
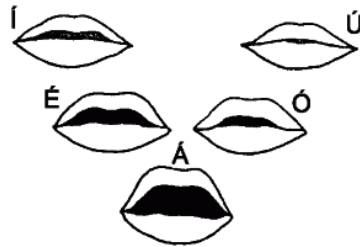   - ▪ MEG
  - ◻ Neurobiology
    - ▪ single-cell recording
    - ▪ animal models
    - ▪ lesion studies

Linguistics

- Phonology

- Morphology

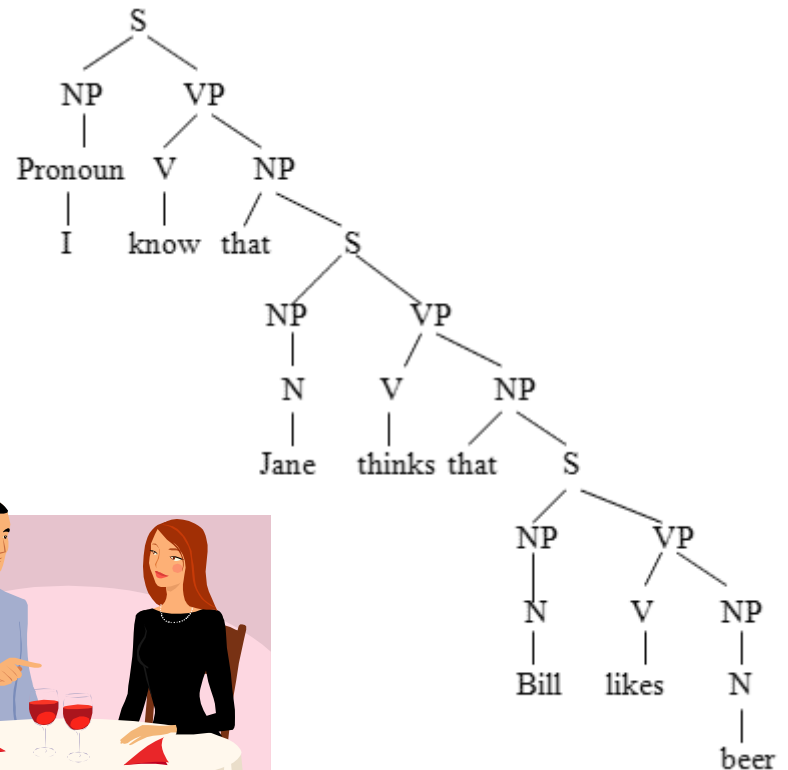 *naj-vy-ruka-vičkova-nejší*

- Syntax

- Semantics

- Pragmatics

Anthropology

- Núñez & Sweetser (2006):
  - Analyzed gestures when speaking about events
  - Aymara speakers look towards the past and have future behing their backs
    - Nayra = past (eye, sight, ancestor)
    - Q"ipa = future (back, behind)
    - Q"ipüru = tomorrow = q"ipa + uru (day behind one's back)

Artificial intelligence

- Application-oriented approach
  - How to make effective intelligent technologies?
  - Little interest in the "nature" of meaning and understanding
- Modeling approach
  - How to model mind / cognitive functions?
  - "Is a model of" is a weaker claim than "is".
  - Usually partial models
- Philosophical approach
  - Can an artificial system understand?
  - What is the nature of meaning in it – can they be made intrinsic?

Artificial intelligence

- Strong AI vs Weak AI
  - John Searle: "according to strong AI, the computer is not merely a tool in the study of the mind; rather, the appropriately programmed computer really is a mind"
- Nowadays very often confused with **General AI vs Narrow AI**

Types of AI

- **"narrow AI"**: programs **carrying out specific tasks** like playing chess, diagnosing diseases, driving cars and so forth (most contemporary AI work falls into this category.)

- **AGI:** systems that possess a reasonable degree of **self-understanding** and **autonomous self-control**, and have the **ability to solve a variety of complex problems** in a variety of contexts, and **to learn to solve new problems** that they didn't know about at the time of their creation.

Artificial general intelligence

- AGI has ability to:
  - Autonomously and interactively **acquire new knowledge** and skills in real time, **make decisions** with limited information and in uncertainty.
  - **Use language, judge contextually,** logically and abstractly, explain its conclusions.
  - Remember recent events and interactions, understand the meaning of actions (even observed **– theory of mind**).
  - Dynamically **manage multiple potential conflicting objectives,** be able to select relevant stimuli and focus on relevant tasks.
  - Recognize and **respond adequately to human emotions** (EQ) and understand one's own cognitive states (**introspection**).

Paradigms in Cognitive Science

Scientific paradigm is a set of assumptions, theories, research methods and established standards for what constitutes a valid research.

Paradigms in Cognitive science:

- Cognitivism
- Connectionism
- Embodiment
- Dynamical systems
- Enactivism

Methods in Cognitive Science

- empirical (observation, experiment)

- computational modeling

- neuroimaging

- philosophical analysis

Next week's topic: Functionalism

- ☐ Multiple realizability argument

- ☐ Church-Turing

- ☐ Turing test of intelligence

- ☐ Criticism:

  - ☐ Chinese room argument

Questions?

Discussion

- What is cognition? Where to draw the line?
  - Hunger, emotions, memory, attention, reflexes, drives…
- What is the connection between mind and brain?
- What do you think of the computer metaphor of mind?
- Why the predictions from Dartmouth College Conference were not fulfilled?
- Strong AI vs. weak AI