# CS 6795 Cognitive Science

## Welcome

* + Sapir-Whorf Hypothesis: the differences in human cognition are impacted or shaped by the differences in their language speaking.
    - * Linguistic Relativity
      * Linguistic Determinism
  + Cognitive Science holds negative against the Sapir-Whorf Hypothesis
    - Thoughts determine the language.
    - While languages do not determine the thoughts

This leads to the question of **“what is thought?”**

* + - What is the mechanism of the mind working?
      * Brain structure
      * Dualism: Mind, as an abstract brain
    - Can we build a Mechanism for the human mind?
      * Metaphor: The flashlight components and how it works
  + Where are the cognition Boundaries?
    - Within this course, we are talking about **“Computational Cognition.”**

## Week 1

### Lesson 1: Representation and Evaluation

* Talking about the **mind** as an abstraction of the **brain**, we are going to understand the output **behaviours**.
* Human-computer analogy
* Community and society immerse as a factor to the final behaviour.
* **CRUM: Computational-representational understanding of the mind**
  + The mind contains/holds/manifests “mental representations.”
  + The mind performs procedures on those representations, affecting changes to those representations.
* Research Methods applied by difference disciplines:
  + Psychology: Control/Experimental Groups
  + Artificial Intelligence: Computational Models
  + Linguistics: Grammar pattern across languages
  + Neuroscience: Brain Imaging and Ablation Studies and Ablation Studies
  + Anthropology: Is-Situ Observation & Ethnography
  + Philosophy: Structured arguments, normative method
* Tri-level Hypothesis by David Marr:
  + Computational level: understanding the problem.
    - Task Analysis
    - Problem Specification
  + Algorithmic level: Identify the data structures, input, algorithm/sequence of steps, and outputs.
  + Implementation level: Physical realization of the system
* Evaluation: testing the quality of the theory
  + Does it have a computational form?
  + what are its representation and processes?
    - How expressive are the representations?
    - Is it scalable?
  + Is it psychologically plausible?
  + Is it Neurological Plausible?
  + What is the Practical Application?

### Lesson 2: Logic and Probability (as theories of cognition science)

* *What are the inner languages of the mind?*
* **Logic:** as in 1st theory of cognition science relating to a very specific type of computational process and representation
  + Deduction: Causes -> Effect
  + Abduction: Effect -> Causes
  + Induction: Observation of a sample -> infer its neighbourhood (popular in Machine Learning)

**Inference Behaviours:**

* + Modus Pollens: P(m) -> Q(m)
  + Modus Tollens: ~P(m) -> ~Q(m)
* **Probability:** as in 2nd theory of cognition science
  + Common in AI and robotics
  + It is not the major school in cognition science as it cannot explain much human thinking.
  + Bayes' theorem: Make a calculation about the probability of other logic expressions.
* Bounded rationality
  + Incomplete information
  + Limited computational power – memory, reaction and so on.
  + Result: we do not come up with a solution that is not optimal but good enough to proceed.

### Lesson 3: Rules and concepts (another representation of knowledge)

* **Rules:** the form of the representation is the same (rules), but the content varies (domain knowledge and control knowledge)
  + **Domain Knowledge (explicit):** the rules about the world.
  + **Control Knowledge (tacit):** the strategies to solve the problem.

There is no Modus Pollens or Modus Tollens-like logic in Rules, and the inference is relatively simple in rules: antecedents -> consequences.

* + - Heuristic Knowledge: one useful type of control knowledge
      * “Muscle Memory” leads to a fast reaction.
      * Availability Heuristics can lead to errors by jumping to conclusions (Mental Shortcuts) too quickly.
* **How to learn a new rule:**
  + **Generalization:** Gather specific examples and summarize them by forming a role to generalize examples for similar future scenarios.
  + **Compilation: combining two rules into one**
  + **Specialization:** we tailor the general rule to deal with specific situations.
  + **Chunking:** simplify and bring the pieces of small rules into a higher-level rule to avoid unnecessarily detailed overlooks.
* **Concept:**
  + **What:** abstract representation
  + **Why:** the world is full of complex sensations and concepts that allow us to categorize the perceptions of the world
  + **What role:** it helps index actions.

Types of concepts:

* + Axiomatic: defined by a formal set of necessary and sufficient conditions.
    - E.g. triangles
  + Prototypical: defined by a typical example with overridable properties
    - E.g. chair
  + Exemplar: defined by implicit abstractions of instances, or exemplars, of the concept.
    - E.g. Justice, Beauty
  + Qualia: about Raw sensation, very subjective and hard to communicate
    - “sour”

Learning a new concept:

* + **Generalization:** Gather and summarize specific examples by forming a new concept to generalize examples for similar future scenarios.
  + **Compilation:** combining two concepts into one
  + **Specialization:** we tailor the general rule to deal with specific situations.
  + **From experience:** Learn from the

### Lesson 4: Scientific Thinking and Virtual Experimentation Research Assistant (VERA)

* Rationalist: Gain new knowledge from innate knowledge -> intelligent behaviour
* Empiricist: accumulate the experience of interacting with the physical world -> intelligent behaviour
* **Observe -> Create Model -> Evaluate Model -> Revise Model.**

### Lesson 5: Analogies reasoning

**Retrieval -> Adaption -> Evaluation -> Storage**

* Long memory
* Short/working memory

Karl Duncker’s experiment

Analogy Reasoning:

* Retrieval -> mapping -> Transfer -> Evaluation -> Store

Biologically inspired design.

### Lesson 6: Image and connection

Image

* Rational school: we do not actually think in pictures.
  + Extract the information from images to form representations.
  + Operations will apply to those symbols.
* We think in pictures.

Connection

* A theory based on the notion of association.
* Experience-specific and individual-dependent.
* A simple unit of nodes:
  + Activation threshold
  + Links to other nodes

### Lesson 7: Review of Cognitive Science

Start from questions: 1. How can we explain behaviour; 2. How you and I can seemingly produce intelligent behaviours (non-basic needs or feelings).

To answer those questions and understand cognitive behaviours, we come up with an abstract word: Mind – beyond the structure of the brain.

Our Hypothesis to explain intelligent behaviours is CRUM – Computational-representational Understanding of Mind. Then, what are the right mental representations and processing? There are many schools of it.

* **Logic**: Humans are born with innate knowledge and then use inference (Modus Pollens and Tollens) to gain new knowledge.
* **Rules**: Humans are born with innate knowledge and then use production systems and rules to generate behaviours, which are activated when the antecedents match with the working memory content
* **Concepts**: indicates for actions in this world
* **Analogies**: Similar action mapping to generate behaviour
* **Images**: iconic representation
* **Connections**: experience stored as node in memory and when is activated, the activation spreads to other nodes in the network.

Common Critiques of CRUM: Brains and emotion, consciousness, and culture factors are left out.

What are these universal constructs that can explain the intelligent behaviour of not just humans but also animals as well as other types of agents. Universal question: How can you tell which one is human and which one is a robot?

### Lesson 8: Brains and Emotion

Critique of CRUM from the brain perspective.

**Brain Theory**

Key takeaways from "The neurons that shaped civilization" YouTube Video:

* **Mirror Neurons:** These are useful for imitation behaviours and empathy, which accumulate to be Civilisation.
* **Biological Evolution** -> Cognitive Evolution -> Culture Evolution

A diagram of a different way of thinking

Description automatically generated

Revise and extend CRUM with Brain Theory.

**Emotion Theory**

An emotion is a mental and physiological state associated with a wide variety of feelings, thoughts and behaviours.

Six basic emotions: happiness, sadness, fear, disgust, anger and surprise.

Robert Plutchik’s Wheel of Emotion: Feelings placed on the opposite side of the wheel cannot be experienced simultaneously.

Four basic theories:

* James-Lange: Event -> Physiological Arousal -> Emotion
* Cannon-Bard: Event -> Physiological Arousal & Emotion
* **Schachter-Singer: Event -> Physiological Arousal -> think -> Emotion**
* Lazarus: Event -> think -> Physiological Arousal & Emotion

Types of Stress:

* Eustress: short-term positive stress that provides immediate strength
* Distress: short- or long-term negative stress that provides anxiety or concern
* Hyperstress: stress that occurs when an individual is pushed beyond what he or she can handle.
* Hypostress: stress that occurs when an individual is bored or unchallenged.

**Appraisal, Focus, Action Mechanism**

A diagram of a process

Description automatically generated

CRUM Expansion will involve:

* New representations of emotions
* Computational procedures to act upon the representation.