CSE 485:
Introduction to Cognitive Science

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Outline

- What is Cognitive Science?
- Methodology
- The computer model of the mind
- Course Logistics

Cognitive Science?

- Cognition = the act or process of knowing; pertains to the mental processes of perception, memory, judgement, and reasoning
- Cognitive Science: A sub branch of AI
  - the study of the precise nature of different mental tasks and the operations of the brain that enable them to be performed, engaging branches of psychology, computer science, philosophy, and linguistics

(Random House Dictionary)

What is cognitive science?

- Cognitive science is the **science** of **mind and intelligence**.
- Originated around the mid-1950s

  TOP-DOWN APPROACH
  - Research focus in Artificial Intelligence (AI), Cognitive Psychology and Linguistics
  - Mental Representations +

    Computational Procedures = Thinking
- Mid-1970s

  Emergence of "Cognitive Science" as a discipline
  - *Cognitive Science Society* was formed
  - *Cognitive Science* Journal began

(Thagard, 2005)

Cognitive Science?

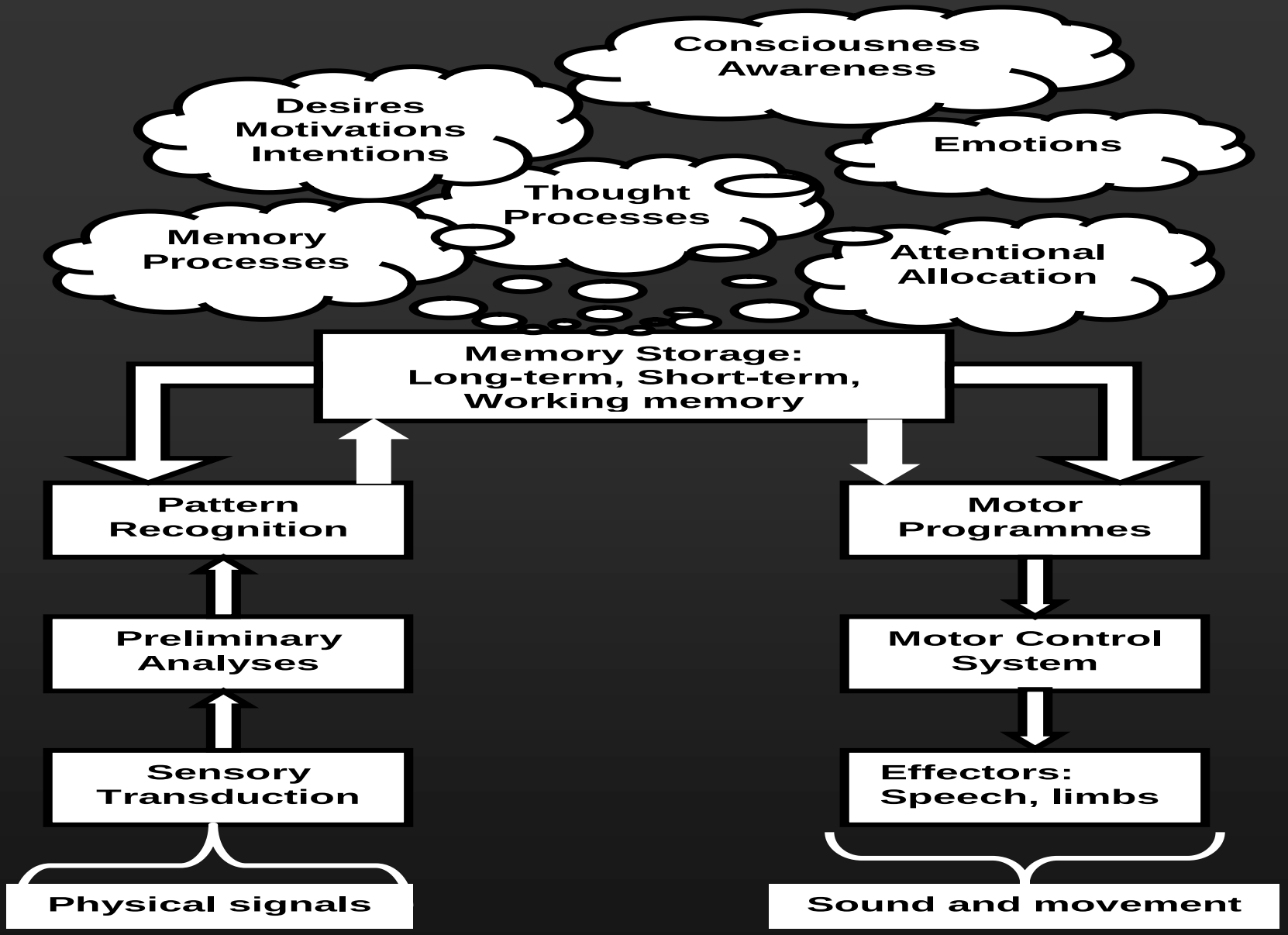
- The 80's saw a shift

  Emphasis on BOTTOM-UP APPROACH

  - Brain assumes importance
    - Technological and Methodological advances in neuroimaging (EEG/ERP, PET, fMRI, MEG)
    - Parallel Distributed Processing (Connectionist Computational) Paradigm

- Current era is one of integration of both Top-down and Bottom-up approaches

(Thagard, 2005; Bermúdez, 2010)



Human Information Processing System

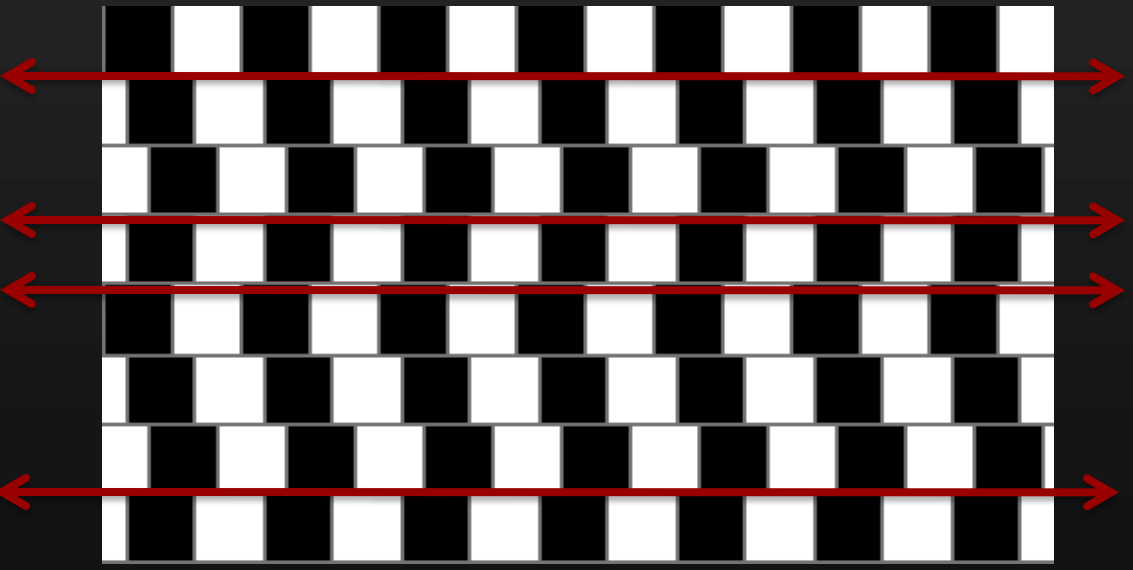
D. A. Norman (1985)

Feature #1

- Cognitive science studies MIND AND BEHAVIOR
- Mental states and processes inside the brain
  - Emotions, knowledge of language, reasoning ...
- The behavior caused by these processes
  - Facial expressions, speech ...
- The normal mind
- The abnormal mind
  - Autism, Schizophrenia ...

Feature #2

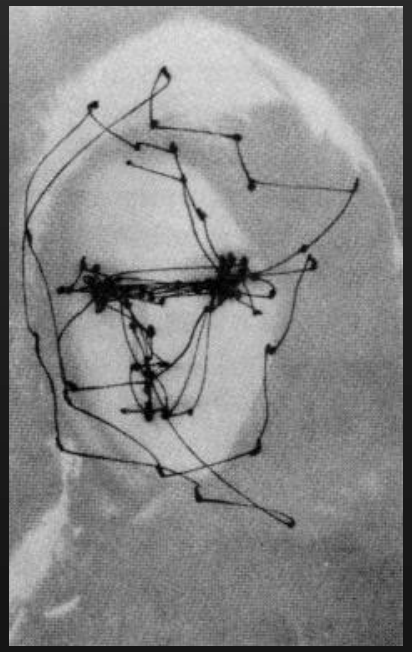
- Cognitive science is a SCIENCE.
  - Theories and hypotheses have to be tested.
  - How? Check whether they can explain the data from experiments and observations.



Face Perception

Face Perception: Yarbus (1967)
Saccadic Eye movements fixating *successively* at the most informative parts of the image



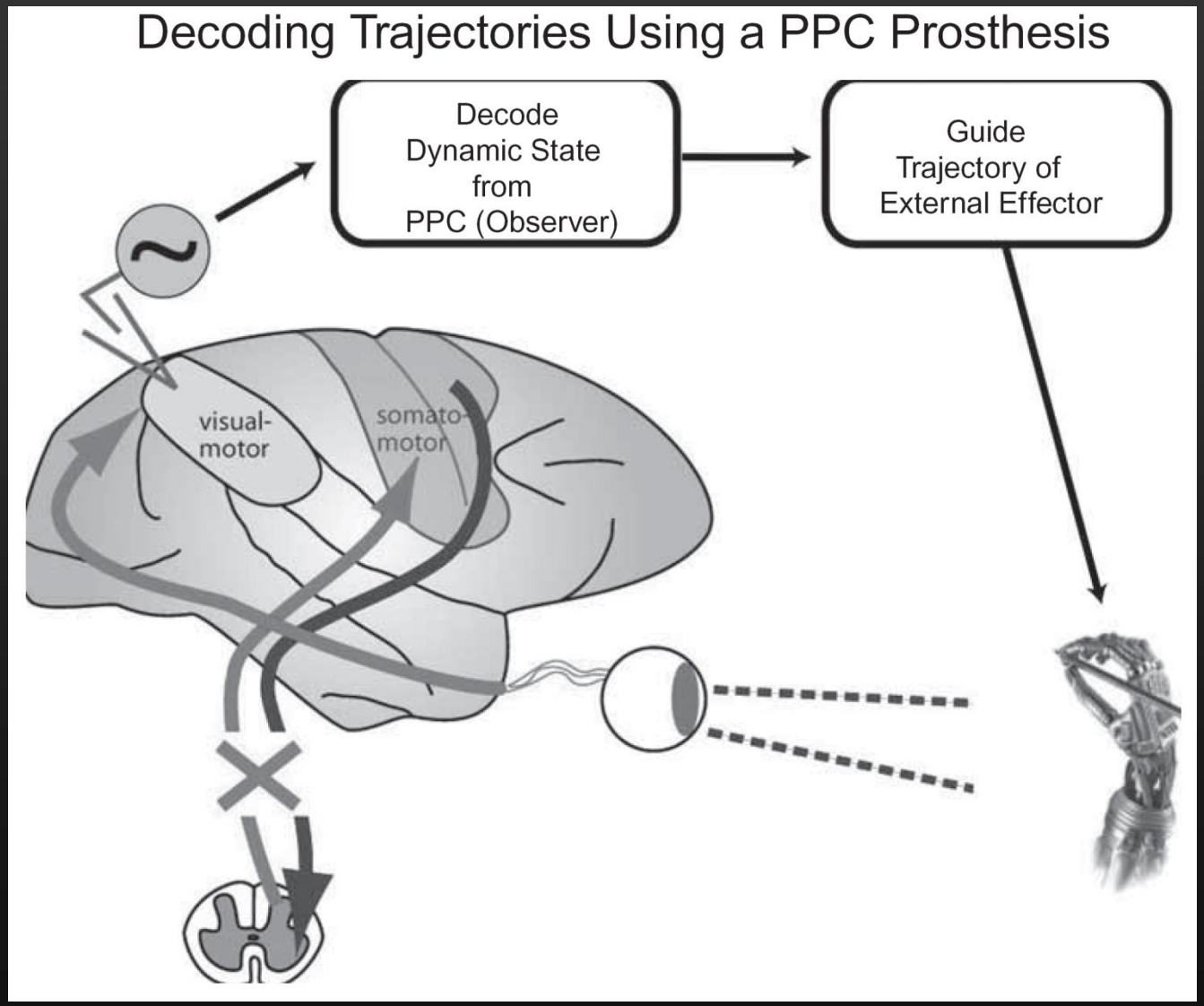
Why study cognitive science?

- Intellectual value
- Practical value
  - Education
  - AI and technology
  - Medical application
- Educational value
- Entertainment value!

Brain Computer Interface (BCI)

A spinal cord injury can render communication (afferent and efferent) between somatosensory and motor areas of cortex and the limbs useless.

The integrity of the "vision for action" pathway may still be largely intact, which includes PPC. BCI can be devised based on the PPC pathways.



Mulliken & Andersen: In The Cognitive Neurosciences, IV Edn (2009), Gazzaniga

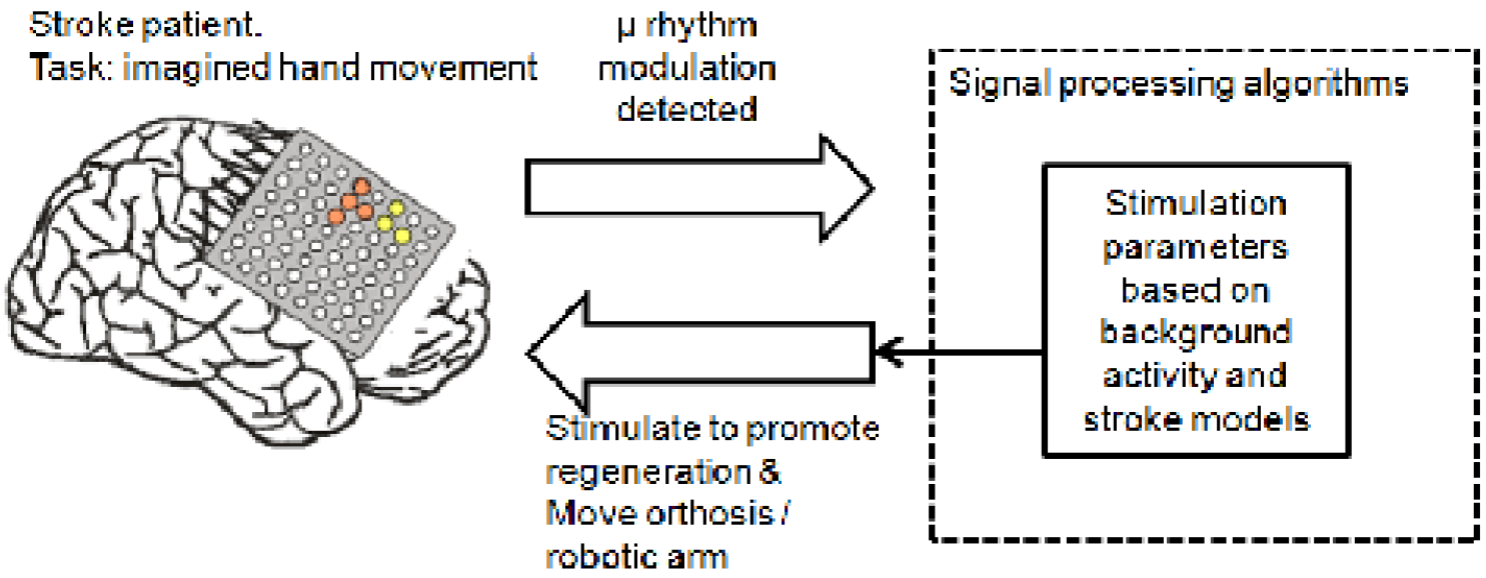
Bidirectional Cortical Communication Interface (BCCI)

Motivation:

Stroke: regain full movements (hand!)

Locked-in syndrome: regain movement control

Procedure:



Methodology of cognitive science

Methodology

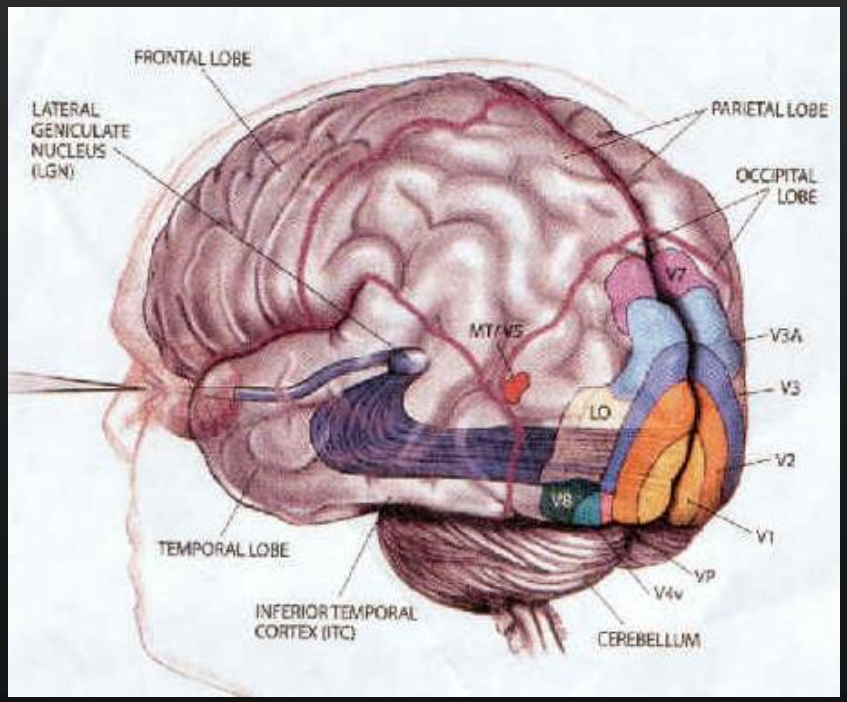
- Some distinctive features about research methods and explanations in Cogsci.
  - Brain-based explanations
  - Functional explanations
  - Interdisciplinary approach
  - The computational model of the mind

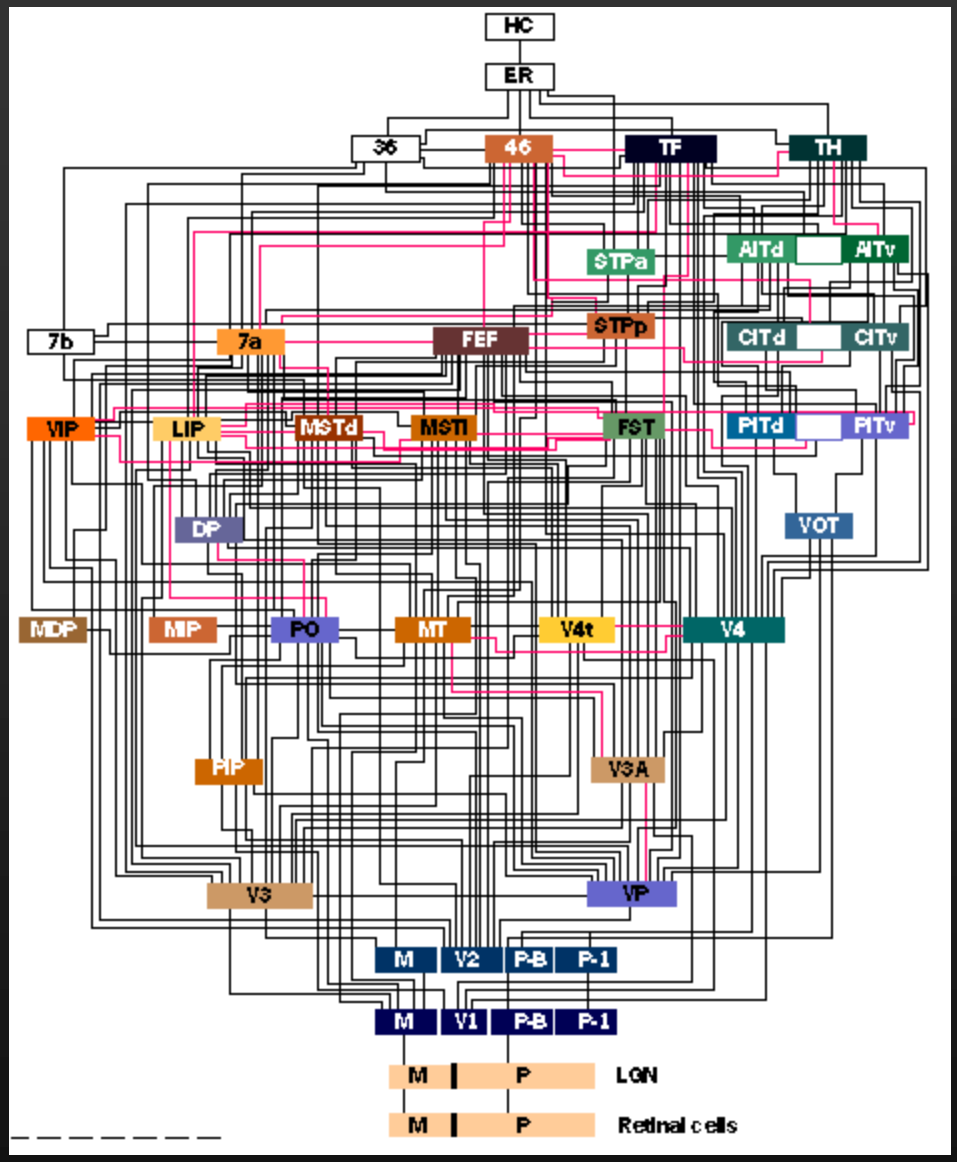
Brain-based explanations

- The mind is explained in terms of **physical processes** in the **brain**.
- Dualism?
  - Dualism – Distinction between mind and brain (Philosophy of Mind).
  - Not to be decided *a priori*. Need experiments.
  - BBE is the default hypothesis because it has been more successful and has better predictive power.

The brain is a very, very, very complex system. (100 billion neurons vs. 6 billion people)

Some of the connections between the different visual systems.





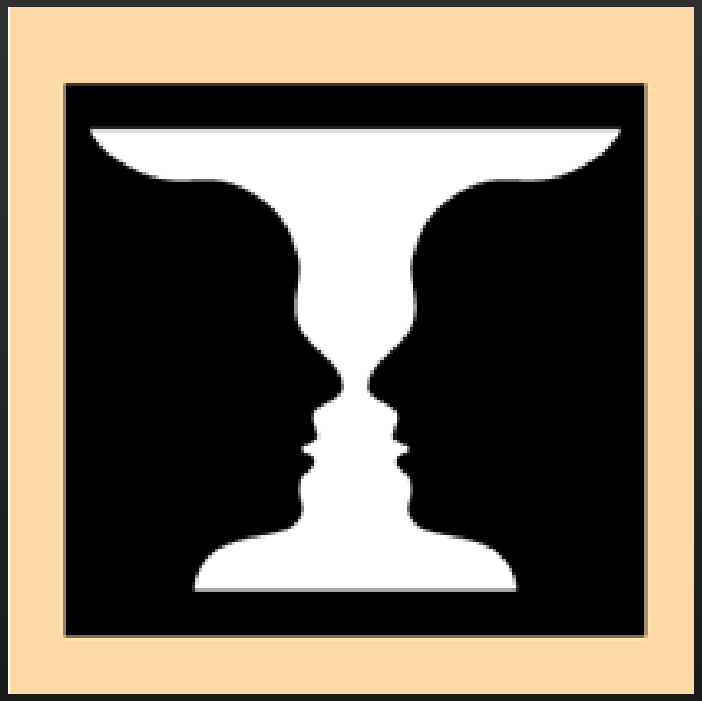
How to deal with this complex system?

- **1. Functional approach**
  - Understand the functions of different systems of the brain and see how they interact.
    - Visual areas, language, emotions …
  - Cognitive science is like *reverse engineering*.
- **2. Inter-disciplinary approach**

INTERDISCIPLINARY approach

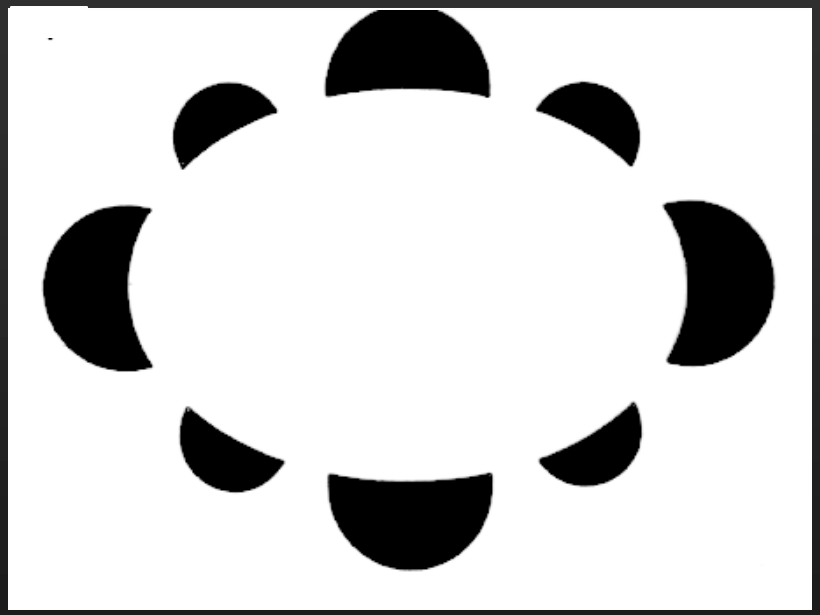
- Division of labour
  - Psychology – cognitive psychology, developmental psychology ...
  - Linguistics – syntax, semantics, phonology ...
  - Neuroscience – brain structures, localization ...
  - Computer science – AI, computer models ...
  - Philosophy – theoretical foundations ...

Perception



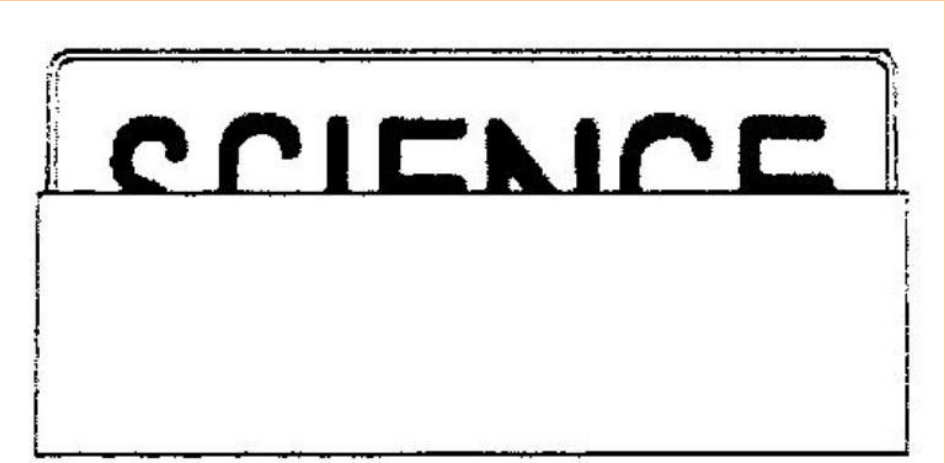
- You can see a white vase as figure against a black background, or two black faces in profile on a white background

Perception



- Without any frame an oval is perceived just based on the special shapes of the surrounding elements

What do you see?



Now what do you see?

The computer model of the mind

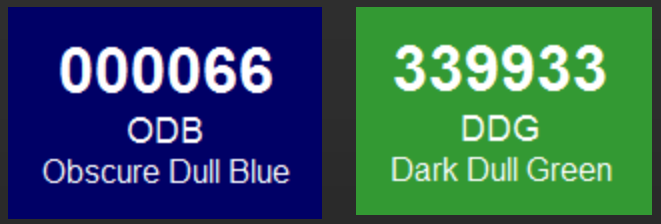
- The mind is like a computer.
- Information Processing View of the mind
- A distinctive feature of cognitive science.

What is the computer model?

- The mind is an information processing system.
- Information processing is best explained by computations and symbols.
  - Information processing in the computer = **programs** operating on **symbols**.
  - Information processing in the brain = **neural computations** involving **mental representations**.

A typical computer

- Inside a computer, we have :
  - **Symbols**
    e.g. HTML color codes



    symbols are objects to which meaning can be assigned.

  - **Programs**
    e.g. Str_replace(“I have a cat” , ”c” , ”h”)

    programs are procedures for manipulating symbols.

Mental representations

- Mental representations are symbols in the brain that have meaning or encode information.
- Thinking P ~ Activating a mental representation that means P.

Information processing in the mind

- Perception
  - acquiring real-time information about the surrounding environment.
- Language use
  - making use of information about syntax, semantics and phonology.
- Reasoning
  - combining different sources of information, deriving new information, testing consistency of information, etc.
- Action
  - making use of information in action planning and guidance.
- Memory
  - storing and retrieving information

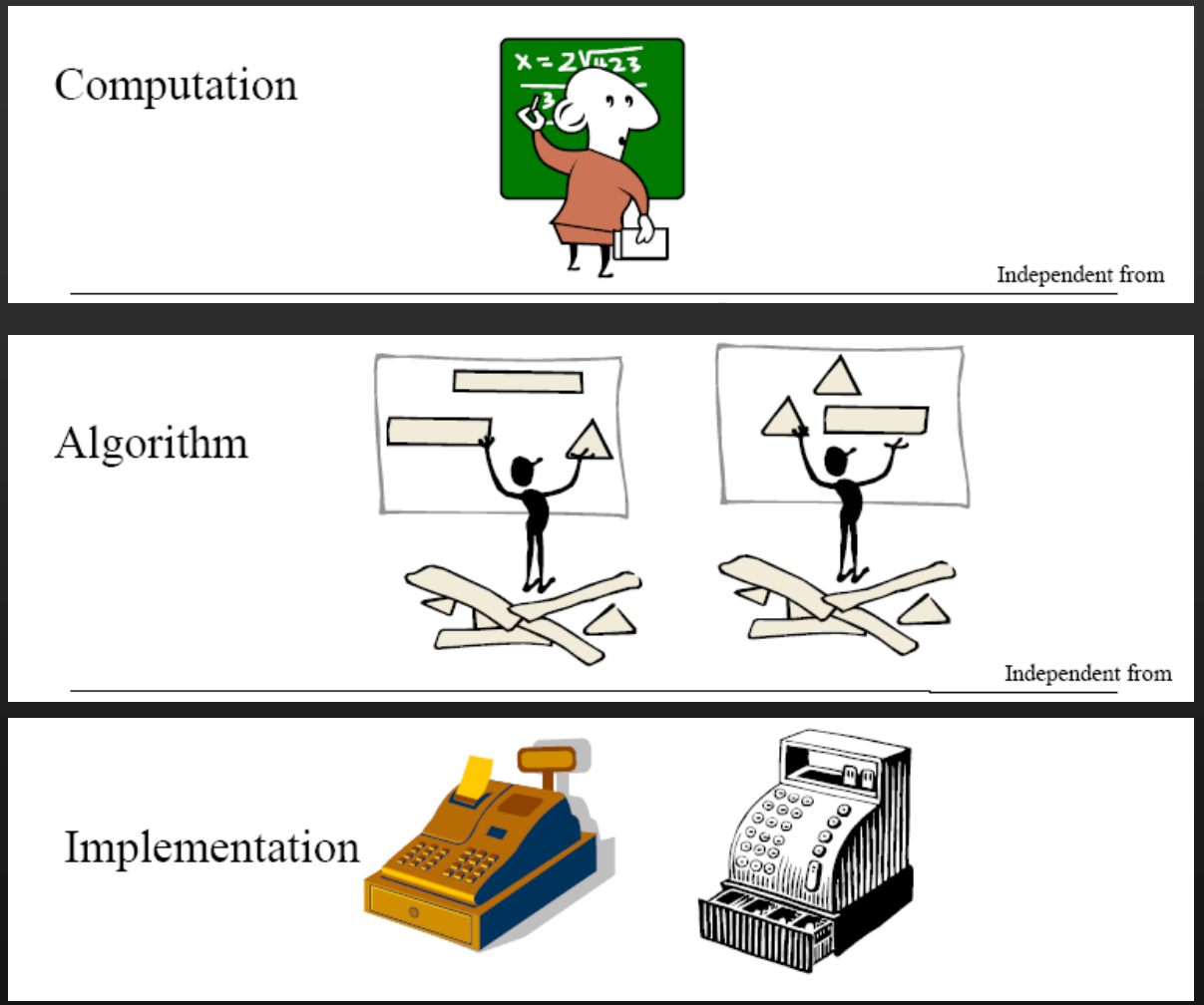
Marr's Three Level Analysis

Three Levels of Description (David Marr: 1945-1980)

- A complete understanding of a computational system has to involve three levels:
- **Task** : what the system is capable of doing (capacities)
- **Algorithm** (software) : which computational procedures are used
- **Implementation** (hardware) : how the computations are implemented

Marr's Three-Level Approach

- Computation
  - Specifies the problem
- Algorithm
  - Specifies the way the problem is solved
- Implementation
  - Specifies the medium or physical substrate in which the problem-solving procedure is executed



How to think about cognitive science

	Language	Vision	Reasoning	Other areas
Task				
Algorithm				
Hardware				

Summary

- Cognitive science as an inter-disciplinary science of mind and intelligence.
- The computational approach : using computations and representations to explain mental processes.

Finally, to end …

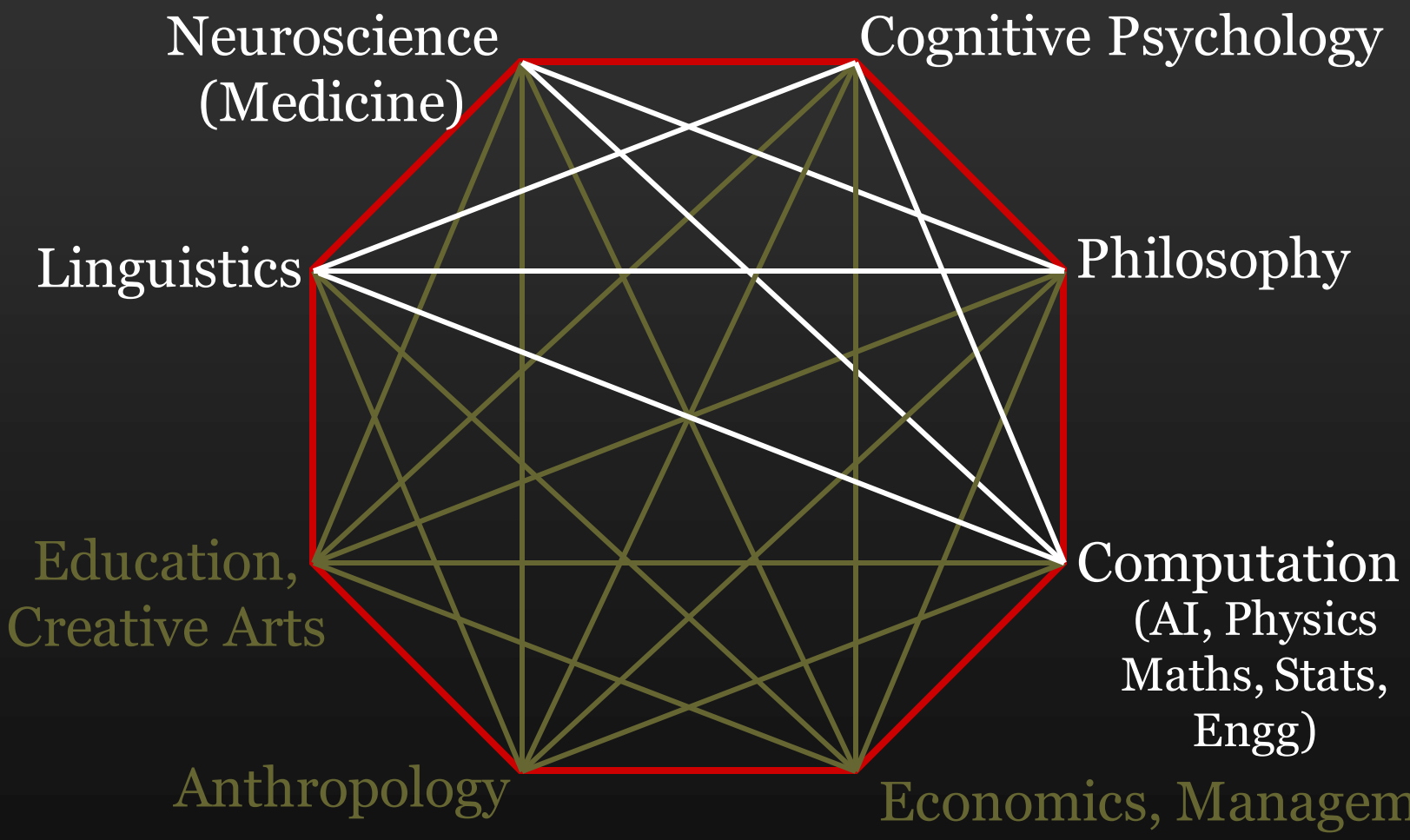
Scope of the computer model?

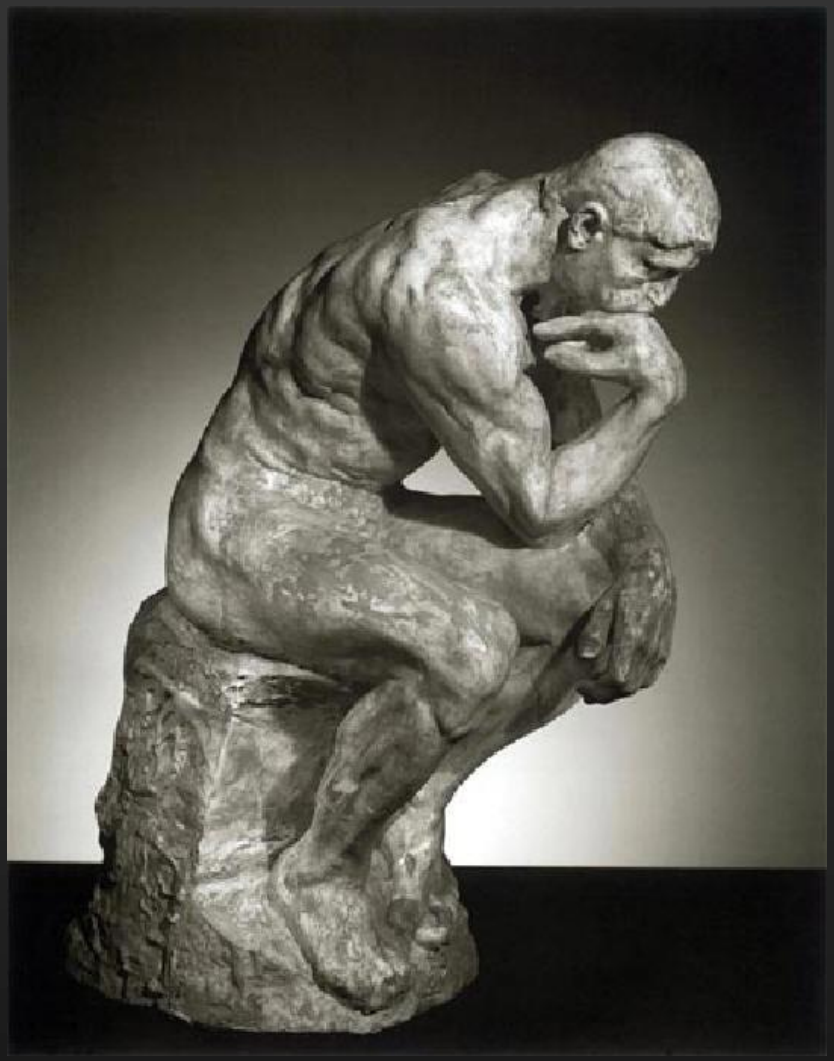
- Computations are NECESSARY for understanding the mind because the mind processes information.
- Are computations SUFFICIENT for understanding everything about the mind?

What about consciousness?

Cognitive Science

An interdisciplinary endeavour





The Thinker

The Thinker (French: Le Penseur) is a bronze **sculpture** by Auguste Rodin, usually placed on a stone pedestal. The work shows a nude male figure of over life-size sitting on a rock with his chin resting on one hand as though deep in thought, and is often used as an image to represent philosophy.

Course Content & Logistics

- Major Domains Covered:
  - Brain and Nervous System
  - Vision and Color
  - Sensation, Sensory systems, and Perception
  - Vision, Attention, and Perception
  - Learning, Memory, and Forgetting
  - Mental Imagery
  - Language and Cognition
  - Emotion and Motivation - Guest Lecture
  - Judgement and Empathy
  - Consciousness and Self, Metacognition, Self-regulation
  - Philosophy of Mind, AI, and Cognitive Science

Course Content & Logistics

- Learning Outcomes:
  - Broad knowledge and Appreciation of CogSci
  - Acquaintance with the Research issues in CogSci and be able to develop a long-term research / design project in CogSci in interfacial domains such as Computer Vision, Assistive Systems, Robotics, Machine Learning, Human Computer Interaction, Cognitive Computing (Language Engineering), Speech Technologies, etc.
  - Familiarity with the Research interests of CogSci faculty!

Learning Assessment

- Quiz: 20%
- Assignments: 20%
- Project (Group): 30%
- Term Paper: 25%
- Other (Class participation, etc) 5%

Cognitive Science Research Focus

- Faculty: Bapi Raju, Priyanka Srivastava, Kavita Vemuri, Vinoo Alluri

- Understanding Cognition
  - Spatial Cognition (Navigational abilities of visually impaired vs. sighted people, 360° vision)
  - Sensory Systems (Visual and Auditory)
  - Functional and Structural Analysis of the brain networks involved in functions such as Language, Memory, Emotion, Empathy, etc.

Cognitive Science Research Focus

- Simulation Systems
  - Large-scale models of the brain
  - Connectomics: Resting state network analysis using fMRI, MEG, EEG
  - Intelligent data analysis methods using Structural and Functional Neuroimaging data
  - Structure-Function relationship in health and disease using Computational Modeling

Cognitive Science Research Focus

- Assistive Systems
  - For Dyslexia and Dementia
  - Human-Machine Interface (Gesture Recognizers, Game Interfaces, Vehicle Control Systems, Virtual Reality, etc.)
  - Neuro-Rehabilitation

Work in progress in our group

- Faculty: Bapi Raju, Priyanka Srivastava, Kavita Vemuri, Vinoo Alluri
- Time Perception
  - Behavioral, EEG, Patient Studies, Computational Models
- Sense of Number
  - Behavioral, Computational modeling
- Motor Sequence Learning
  - Hand-motor / Oculomotor using Behavioral, fMRI, Computational modeling on Normal, Hearing-handicapped, etc.

Work in progress in our group

- Action Representation and Learning
- Large Scale Models of Brain

Work in progress in our group

- To add other research projects being pursued…
  - NeuroRehab / Training using Games
  - Auditory representation of space and navigation
  - 360° Vision
  - Functional and Structural Connectivity
    - Dementia and other disorders
    - Neuroplasticity in Cortical Stimulation

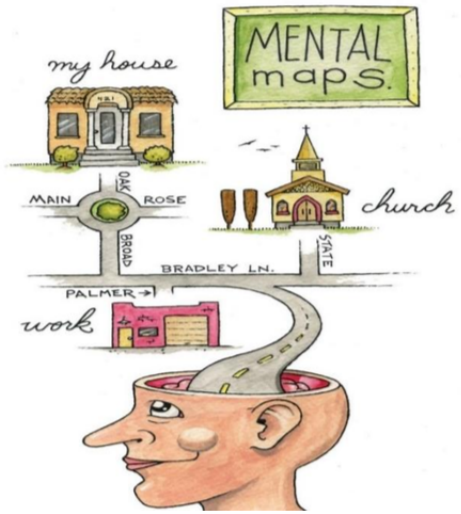
Work at CogSci Lab

Sight Without Light Enhancing Vision

Priyanka Srivastava

Creative Thinking

Research Focus



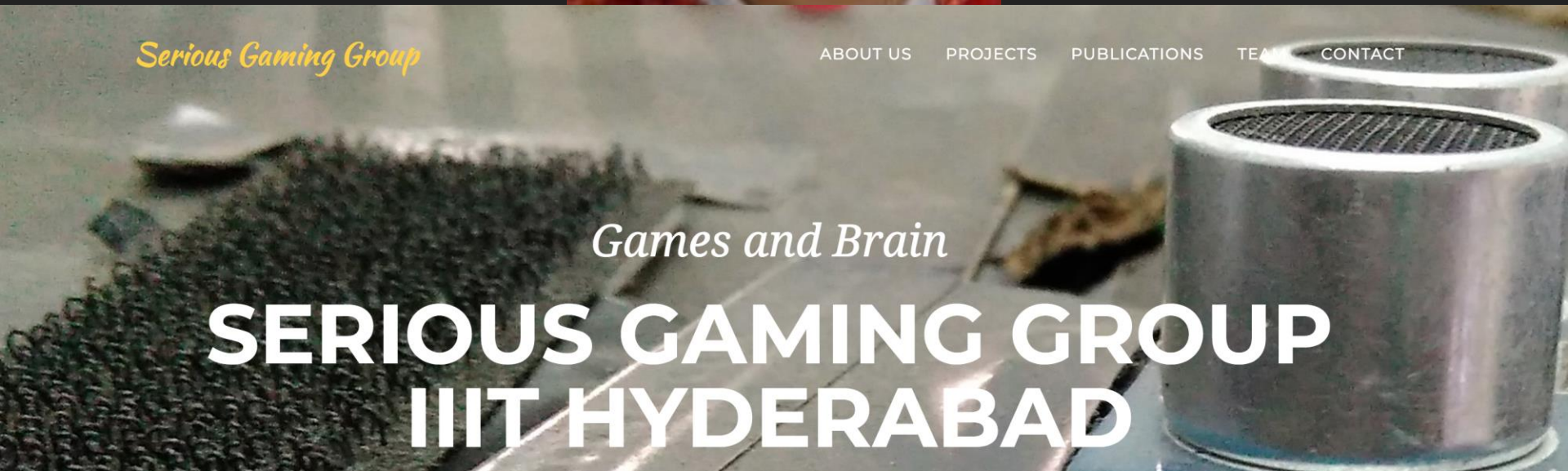
Spatial Cognition

- How do we perceive, represent and act in the spatial-world around us.
- What determines our spatial ability, specifically navigational ability?
- Research shows that we differ in our spatial abilities. What causes these differences?
- What is the role of vision in making sense of space or spatial representation? How compensatory channels, specifically auditory cues, enable them to perform navigation and way-finding activities?
- How do visual limitations, such as field of view, affects spatial awareness?

Can technology be an aid to reduce the sensory limitations and enhance the spatial cognitive ability? Current technological aid for visually impaired, such as auditory-based navigation system, as well as sighted people such as Night Vision Devices and 360-degree vision, are changing the face of sensory limitations and further the cognitive abilities. We are interested in realizing the strength and limitations of the course of such interactions.

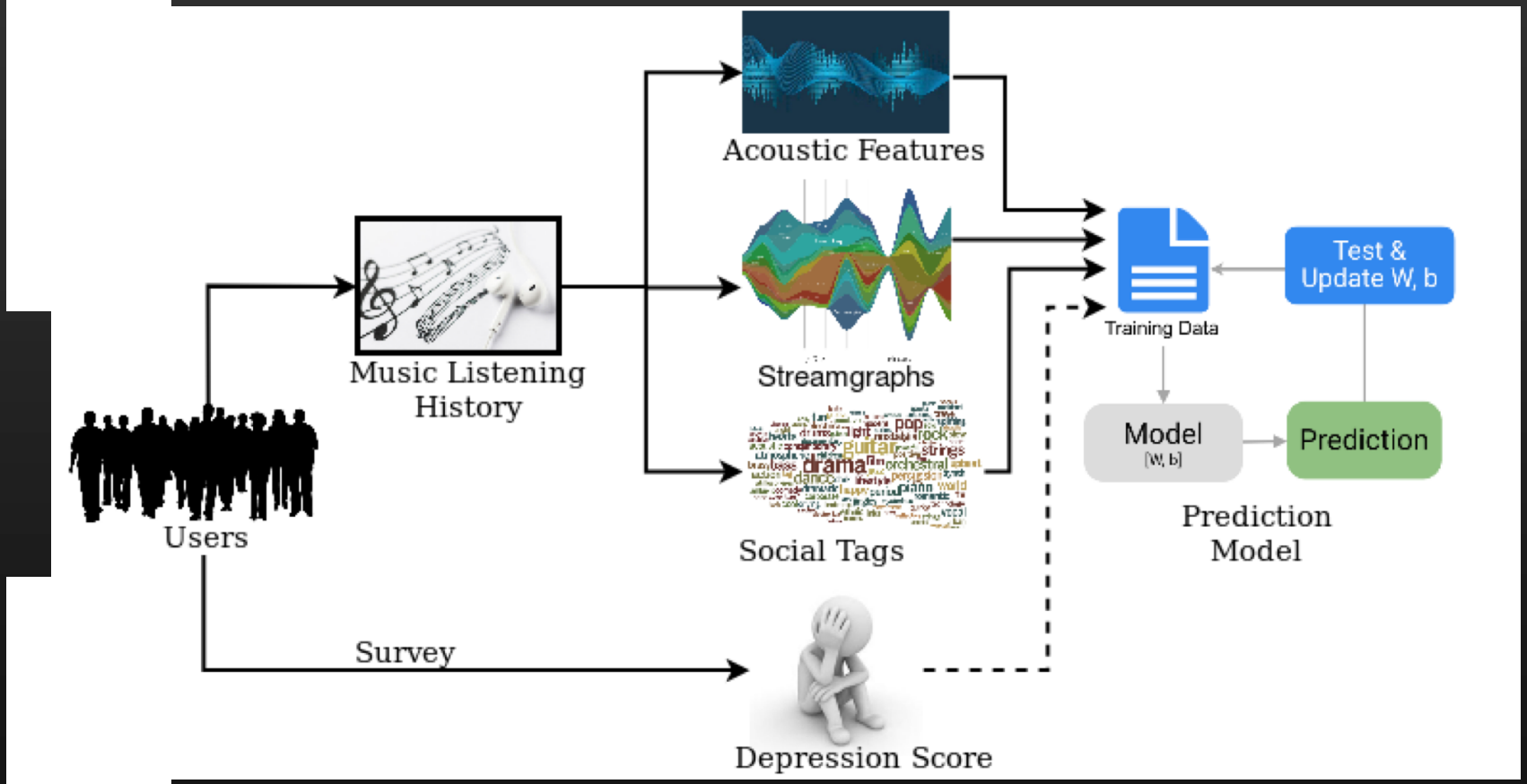
Neurorehabilitation through games

Kavita Vemuri



Predicting Depression from Music Listening Habits

Vinoo Alluri



Individual traits modulate brain connectivity

Vinoo Alluri

Empathy

MUSICAL TRAINING

Familiarity

Decoding brain states at rest in Cocaine users

Vinoo Alluri