

# What is Cognitive Science?

Introduction to Cognitive Science

# Some Definitions

- Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology.
  - Stanford Encyclopedia of Philosophy
- Cognitive science is most simply defined as the scientific study either of mind or of intelligence. It is an interdisciplinary study drawing from relevant fields including psychology, philosophy, neuroscience, linguistics, anthropology, computer science, biology, and physics.
  - Wikipedia
- An interdisciplinary science that draws on many fields (as psychology, artificial intelligence, linguistics, and philosophy) in developing theories about human perception, thinking, and learning
  - Merriam-Webster
- Cognitive science can be roughly summed up as the scientific interdisciplinary study of the mind. ... It results from the efforts of researchers working in ... philosophy, psychology, linguistics, artificial intelligence, robotics, and neuroscience.
  - In “Cognitive Science” by Friedenber and Silverman

# Some Academic History

- The term *cognitive science* was coined by Christopher Longuet-Higgins in his 1973 commentary on the Lighthill report, which concerned the then-current state of Artificial Intelligence research. In the same decade, the journal *Cognitive Science* and the Cognitive Science Society began.
  - Wikipedia
- Since then, more than sixty universities in North America, Europe, Asia, and Australia have established cognitive science programs
  - Stanford Encyclopedia of Philosophy



Logo used by the Cognitive Science Society and their journal *Cognitive Science*

# Cognitive Science: Aspects of Cognition

- Cognitive science is the science of cognition, which includes such things as:
  - perception
  - action
  - learning
  - memory
  - attention
  - reasoning
  - decision-making
  - language use
- What about consciousness? Emotions?

# Cognitive Science as one of the 'Basic' Sciences

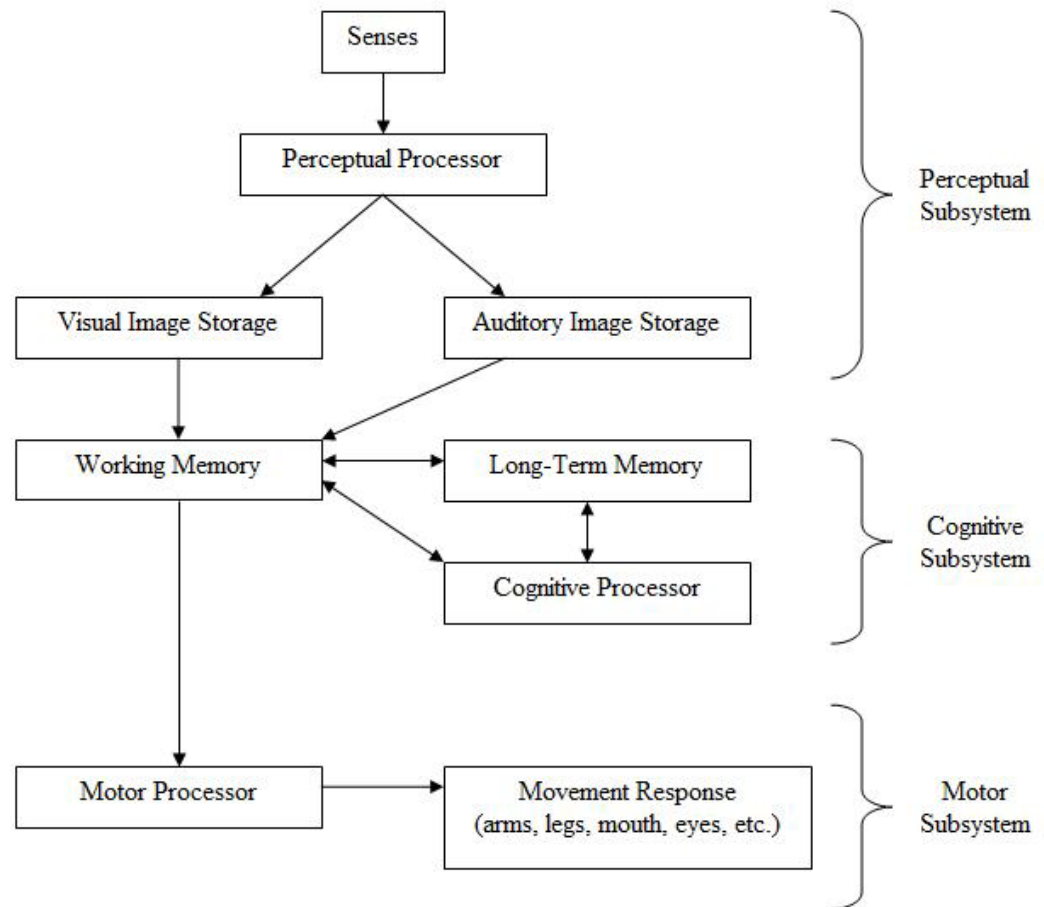
- I predict that at some point in the future, cognitive science will be regarded as one of the 'basic' sciences, in line with physics, chemistry, and biology.
- Indeed, I believe that cognitive technology is going to be the next 'revolution' in technology.
- We will have Cogno-Engineering (autonomous intelligent machines, brain interfaces) ... and Cogno-Ethics!
- These are exciting times!

# What can I do with Cognitive Science?

- Cognitive Science can be used to analyze, describe, predict, or even correct, augment, if not create minds. Some specific applications are:
  - Cognitive Modeling
  - Human Computer Interaction
  - Artificial Intelligence
  - Cognitive Robotics
  - Cognitive Engineering

# Cognitive Modeling

- Cognitive Models can analyze cognitive behavior at small time-scales, thus e.g. predict the effects of texting while driving



# Human-Computer Interaction

- Cognitive Science could lead to more effective and efficient Human-Computer Interaction.





# Artificial Intelligence

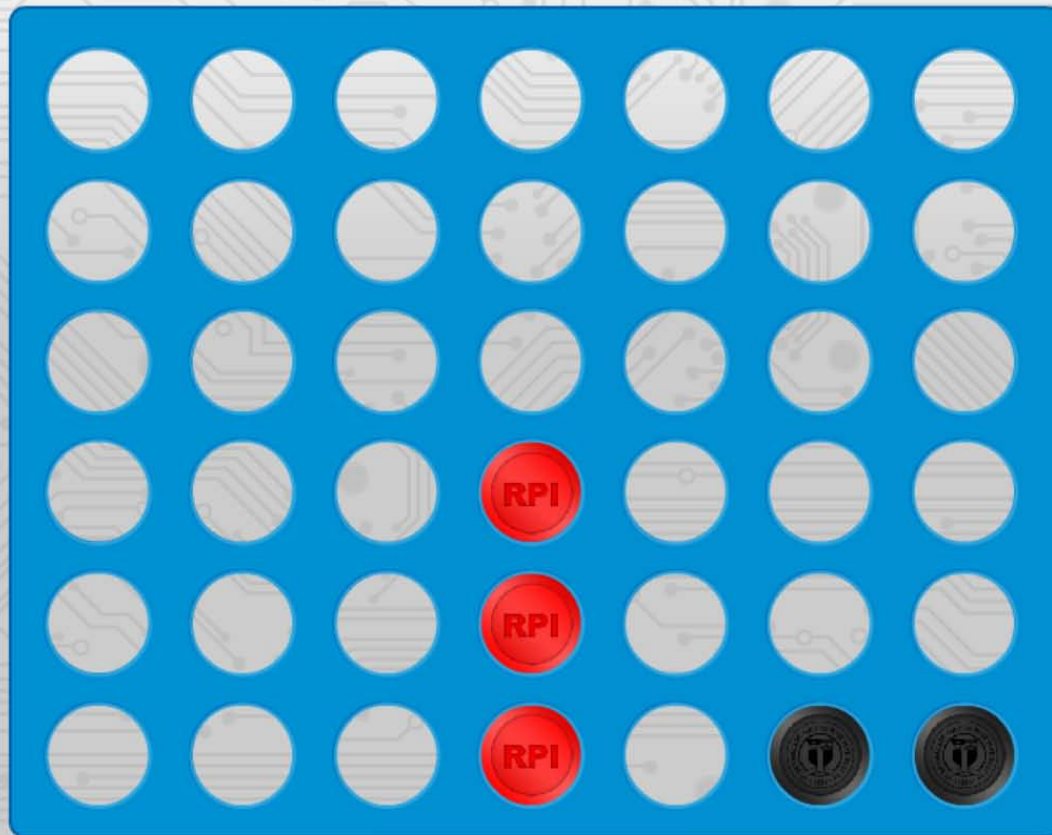
## FINAL FORTNIGHT



PLAYER 1  
BRUMD



PLAYER 2  
CHRIS



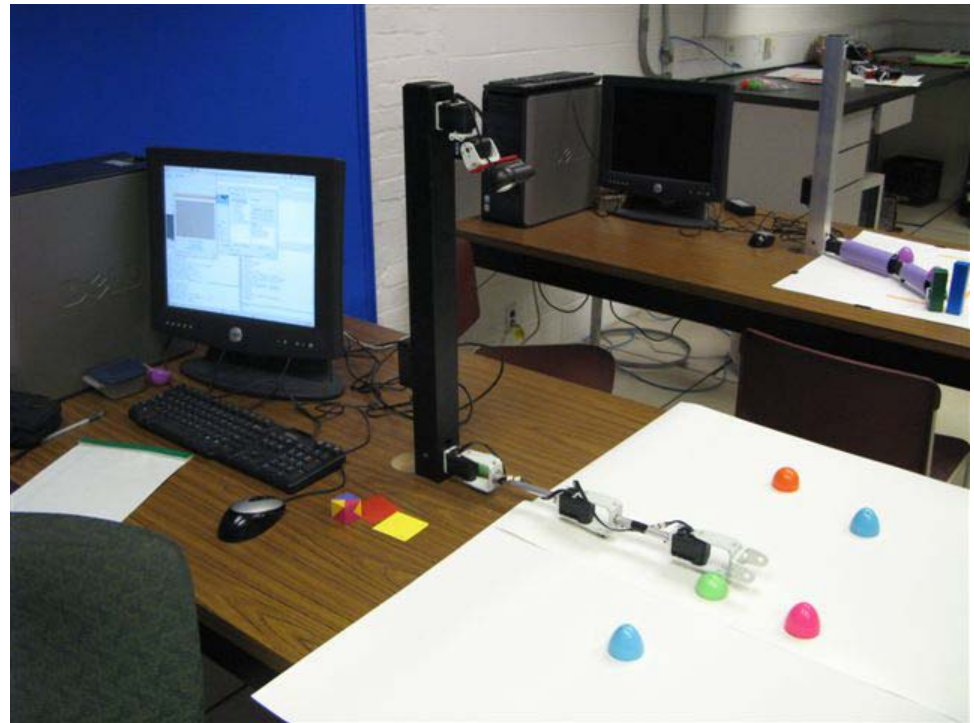
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*MINDS AND MACHINES*

# Cognitive Robotics



Robocup



Hand-Eye system in RPI's  
Cognitive Robotics Lab



The Create: the Roomba that doesn't suck!

# Cognitive Ergonomics

- Designing tools with an eye for our cognitive abilities (and hence the constraints it imposes on that technology): cognitive ergonomically designed tools should ‘fit’ our abilities to take in and process



‘Smart Cockpit’ (really?)



Better interfacing  
with Tom Cruise!



# Cognitive Prosthetics



Former blind, Jens Naumann can now see good enough to 'drive slowly around in a parking lot' thanks to a brain vision implant



Using EEG's (brain waves measured at scalp), patients that can't move their arms learn to control a cursor on a screen  
- Wadsworth Research Lab, Albany, NY

## Sensory Substitution



Seeing with Sound



See with tongue

# Cognitive Augmentation



Australian Art-Performer Stelarc has a third arm which he can control using his abdominal muscles

???

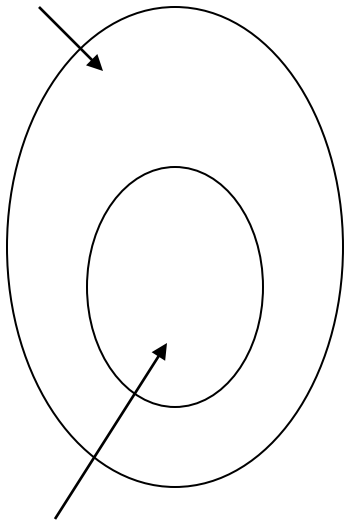


# Cognitive Science: Kinds of Minds

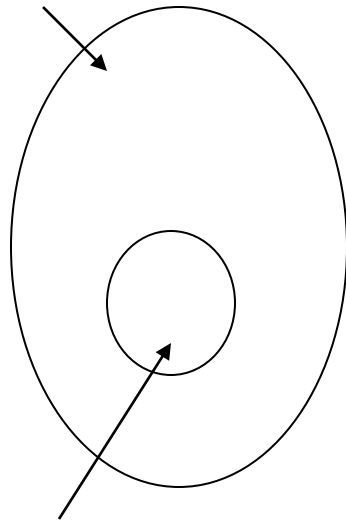
- Cognitive Science can be seen as the study of mind, but these minds can be:
  - human minds
  - animal minds
  - computer minds
  - robot minds
  - alien minds
  - group minds
  - or whatever minds
- In practice, human mind is studied mostly

# We Shouldn't Focus on the Human Mind Alone: An Argument

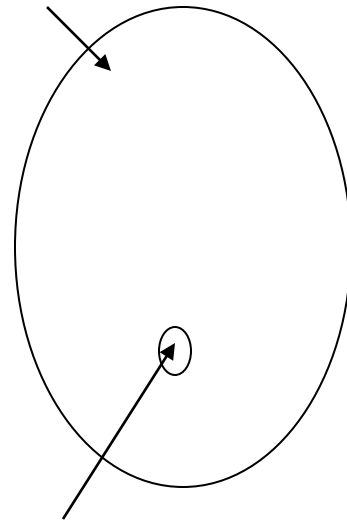
What is physically possible



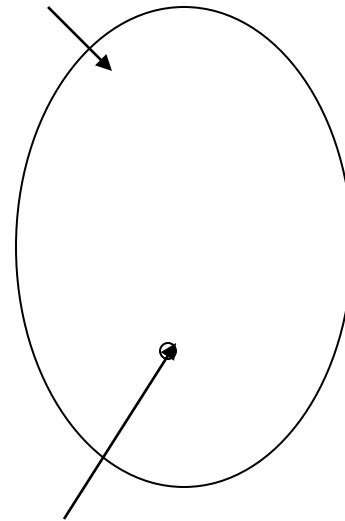
What is chemically possible



What is biologically possible



What is cognitively possible



What is physically actual

What is chemically actual

What is biologically actual

What is cognitively actual

In other words, if we merely focus on human cognition, we are focusing on only a very small part of the space of all possible cognition. A true cognitive science (certainly if it wants to be a basic science) focuses on the whole space.



# Further Reflections I

- Just as considering the place of carbon in the whole Table of Elements teaches us something about carbon that we probably wouldn't have figured out by looking at carbon alone, studying other forms of cognition can probably teach us more about human cognition.
- So, *even if* we just wanted to know about human cognition, it *still* makes sense to contemplate other forms of cognition.

# Further Reflections II

- Since the space of actual cognitive phenomena is (unfortunately) much smaller than the space of all possible cognitive phenomena, a true cognitive science is probably going to be more of an experimental science than an empirical/observational science.
- So, while Cognitive Psychology focuses on human cognition and, as such, runs experiments by bringing in human subjects, Cognitive Science proceeds with building and testing systems with cognitive powers quite unlike human cognition.

# Further Reflections III

- Are there going to be general principles of cognition that span much or all of the space of cognition? What would those principles look like? What are the dimensions, parameters, and units of cognition?
- I think that there is definitely room here for a 'Newton', 'Mendeleev', or 'Darwin' of cognitive science. Indeed, some people could become real famous by mapping the land of cognition. Again, these are exciting times!

# Further Reflections IV

- When we do start to have a good grasp of cognition from a scientific point of view, the application of this knowledge will probably be immediate: cognitive technology!
- Neural Implants? Cognitive Enhancement Tools? True Artificial Intelligence? Science fiction now, but all of this may be here sooner than we think!

# Further Reflections V

- Notice that we are now in the midst (probably, more the beginning) of bio-technology now, which is exciting, but at the same time a bit frightening... Just look at the ethical questions that bio-technology has raised.
- Well, wait until you see what cognitive technology can do. While we won't address ethical issues in this course, I do think they are important issues, and we raise them in the course Minds & Machines.

# Cognitive Science as an Interdisciplinary Study

- Again, there is no fixed list of fields that people think should be included. However, certain fields are more consistently included than others. Here is how I see it:
  - Primary:
    - Philosophy
    - Psychology
    - Computer Science
  - Secondary:
    - Linguistics
    - Neuroscience
    - Anthropology
  - Tertiary
    - Biology
    - Education
    - Mathematics

# The Fields of Cognitive Science: Philosophy

- Philosophers have thought about the nature of mind for thousands of years.
- Philosophy, like science, tries to understand things. In fact, it was in the 17<sup>th</sup> or 18<sup>th</sup> century that science grew out of 'natural philosophy', which was a branch of philosophy that tried to understand the nature and working of the world around us. Thus, philosophy is what we can call 'pre-scientific': philosophers are trained to ask fruitful questions, to approach a subject from various kinds of perspectives, and to develop the concepts, ideas, and vocabulary to support those different points of investigation. It is only once such questions and concepts have been identified, that the scientist takes over and, through quantifying and measuring, is able to formulate theories that make testable predictions.
  - Cognitive science, being a young discipline, is still very much in a pre-scientific stage

# The Fields of Cognitive Science: Psychology

- Psychology, which originated in the 19<sup>th</sup> century, was the first ‘science of mind’.
- Psychology has several branches (clinical psychology, developmental psychology, behavioral psychology, etc.), but the one that mostly influences cognitive science is cognitive psychology, which originated in the 1950’s and 60’s. Cognitive psychologists try and make functional models of the mind, which can be used to make predictions of human behavior.
- In fact, much of cognitive science is driven by cognitive psychology:
  - In practice, the work of many cognitive scientists is sometimes hardly distinguishable from cognitive psychology
  - Many textbooks on “Cognition” or “Cognitive Science” are for the most part texts on cognitive psychology



# The Fields of Cognitive Science:

## Computer Science

- Computer Science has a very important role in Cognitive Science as well:
  - Computers can be used as tools to create, run, and test models of human cognition
  - Additionally (and probably more importantly), computer science has offered the information-processing concepts and vocabulary that frames much of the current thinking and theorizing in cognitive science
  - Artificial Intelligence is a branch of computer science trying to build computational models that are claimed to be cognitive themselves.

# The Fields of Cognitive Science: Linguistics

- Researchers have long suspected a deep link between cognition and the use of language:
  - Language can be used to represent information, and cognition is often seen as involving the representation and manipulation of information.
  - One striking difference between humans and animals is the complexity of human language: does this account for the other differences in cognition between animals and humans?

# The Fields of Cognitive Science: Neuroscience

- Clearly, the nature of our mind has a lot to do with the nature of our brain, and studying the anatomy and workings of the brain can provide us insight about the mind.
- But what exactly is the relationship between the mind and the brain? Are they the same? Does knowing everything about the brain tell us everything about minds? Do all minds even require brains?

# The Fields of Cognitive Science: Anthropology

- Anthropologists have all kinds of interests and insights into cognition:
  - Cognition and Communication
  - Cognition and Social Groups
  - Cognition and Evolution
  - Cognition and Culture
- Unfortunately, this area has been long neglected by practicing cognitive scientists (e.g. cognitive linguistics has traditionally paid little attention to this area!), but some more recent theoretical developments have the potential to change this.

# The Fields of Cognitive Science: Biology

- Biology can provide important insights into cognition as well:
  - Seeing cognition as subservient to the evolutionary survival of biological organisms and species
  - Biologists can provide insights about the brain and other physical aspects underlying cognition (nervous system, whole body?)
- But what can cognition be without evolutionary pressures?

# The Fields of Cognitive Science: Education

- The relation between Education and Cognitive Science is reciprocal:
  - Researchers in education reveal things true about cognition
  - Vice versa, the findings of cognitive science can be applied to improve education

# The Fields of Cognitive Science: Mathematics

- This relation has been little explored so far, but there may be some deep connections between cognitive science and mathematics:
  - Obviously, mathematics can be applied to analyze cognitive models
    - Discrete mathematics in planning and reasoning
    - Calculus and differential equations in perception and action
  - But it is possible that the complexity found within cognitive science requires different kinds of mathematics (e.g. to analyze and get a grasp on complex neural networks). Indeed, just as other branches of science pushed the creation of new branches of mathematics, so may cognitive science.
  - Also, cognitive science can inform us about the nature of mathematical thinking

# Robotics:

## A Good Candidate for Integration?

- While cognitive science is informed by many fields, it is important to try and integrate all the results of these fields into one unified whole.
- Also, as argued earlier, cognitive science will probably have to rely heavily on the experimental approach. Hence, it is important to build various different kinds of cognitive systems that can be analyzed from all these different perspectives.
- Robotics seems to be a good candidate for this!
- The Cognitive Science department has a Cognitive Robotics Lab and (occasionally) offers a Cognitive Robotics course



# Cognitive Science at RPI

- In 1991-1992, RPI's Philosophy and Psychology Departments merged to form the Department of Philosophy, Psychology, and Cognitive Science.
- In 2003, this became the Department of Cognitive Science, one of only about 15 in the world
- In 2004, we created a PhD program in Cognitive Science
- In 2010, the B.S. in Cognitive Science was approved.
- About 20 faculty
- Several Laboratories:
  - CogWorks Lab (Cognitive Modeling)
  - RAIR Lab (Artificial Intelligence and Reasoning)
  - PandA Lab (Perception and Action, Virtual Reality)
  - Human-Level Intelligence Lab
  - Cognitive Architecture Lab
  - Cognitive Robotics Lab
- And various research groups



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# Majors, Minors, and Concentrations

- Majors:
  - PSYC
  - PHIL
  - COGS
  - When you dual major with PHIL or PSYC or COGS, required courses can count towards H&SS requirement
- Minors:
  - ‘Cognition’ minor in PSYC
  - ‘Logic, Computation, and Mind’ minor in PHIL
  - ‘Cognitive Science’ minor in COGS
- Concentrations:
  - IT has Cognitive Science concentration
  - GSAS has Cognitive Science Concentration

# Core Curriculum for BS in Cognitive Science

- Minds & Machines
- Introduction to Cognitive Science
- Introduction to Logic
- Experimental Methods and Statistics
- Cognitive Psychology
- Behavioral Neuroscience / Cognitive Neuroscience
- Introduction to Artificial Intelligence
- Cognitive Modeling / Programming for AI and Cog Sci
- Sensation and Perception / Structure of Language
- Philosophy of AI / Knowledge, Belief, and Cognition /  
Metaphysics & Consciousness
- Undergraduate Thesis

# What Can I do With a Cognitive Science BS?

- Rich Skill Set:
  - Programming/Modeling
  - Empirical Data Collection and Evaluation
  - Complex Systems Analysis
  - Critical Thinking
  - Communication
- Careers (industry, academics) in Computer Science (AI, robotics), Psychology (Cognitive Modeling, Human Factors), Philosophy (Cogno-Ethics?!), IT (HCI), Decision Sciences, Economics, Anthropology, Social Sciences, Education, Law, etc.

# Possible Dual Majors

- COGS / CSCI
- COGS / MATH
- COGS / GSAS
- COGS / PSYC

# I am interested in the B.S. in Cognitive Science. What should I do?

- Talk to the Director of Undergraduate Studies in Cognitive Science:
  - Bram van Heuveln
  - [heuveb@rpi.edu](mailto:heuveb@rpi.edu)