Introduction to Cognitive Science

History, methods, and contributing disciplines

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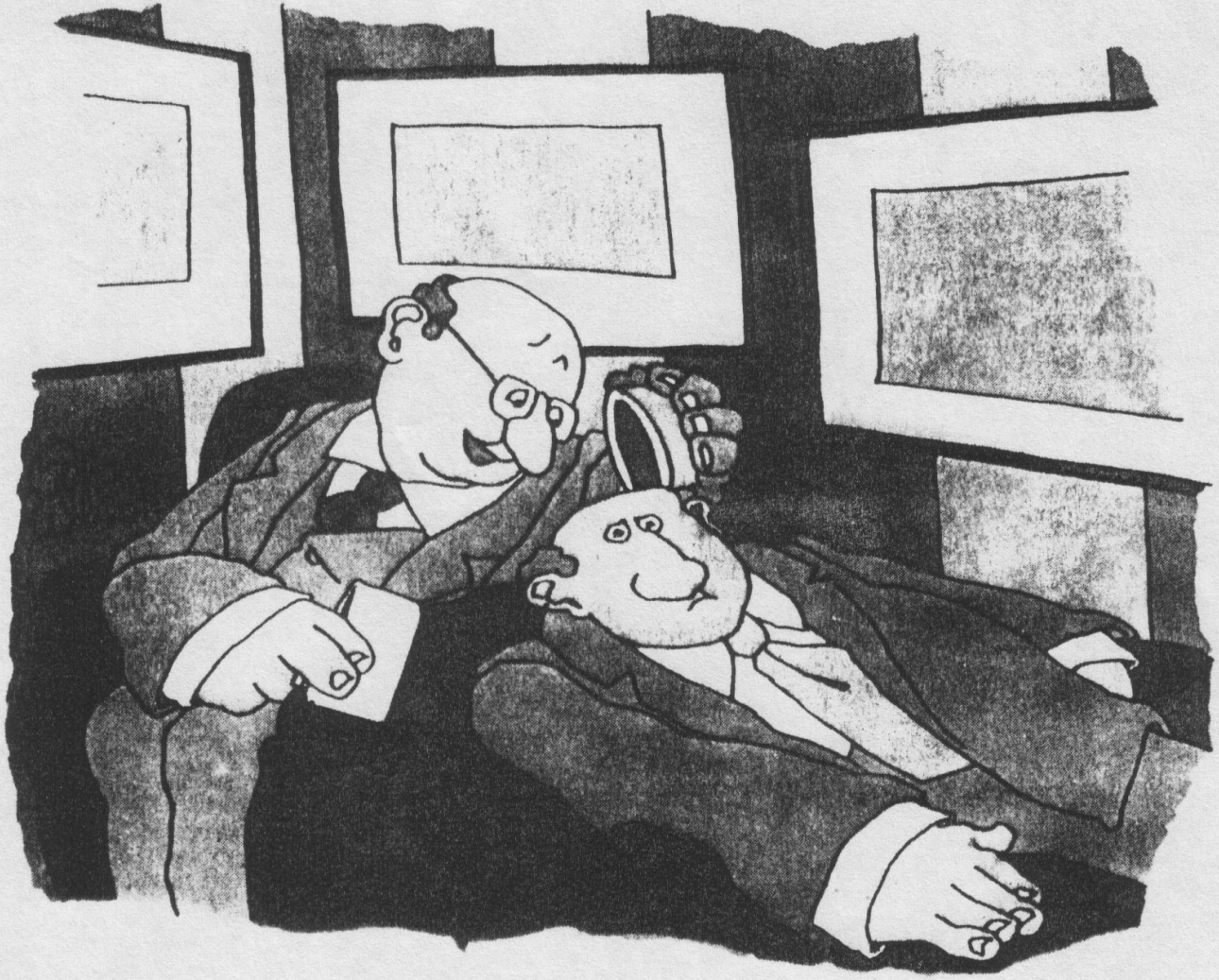
Outline

- Scope of Cognitive Science
- A Brief History
- Overview of Major Concepts
- Multidisciplinarity -Contributing Disciplines
- Concluding Remarks- How to Become a Cognitive Scientist?



"Looking good!"

What Is Cognitive Science?

- The (interdisciplinary) study of mind and intelligence.
- The study of cognitive processes involved in the acquisition, representation and use of human knowledge.
- The scientific study of the mind, the brain, and intelligent behaviour, whether in humans, animals, machines or the abstract.

A discipline in the process of construction.

Cognition

- Cognition: from Latin base *cognitio* "know together"

  The collection of mental processes and activities used in perceiving, learning, thinking, understanding and remembering.

Cognitive Processes

- Perception – vision, audition, olfaction, tactition..
- Attention, memory, learning

- **Thinking (reasoning, planning, decision making, problem solving ...)**

- Language competence, comprehension and production
- Volition, intentional action, social cognition
- Consciousness
- Emotions
- Imagination
- Meta-cognition
- ...

Historical Background

- Cognitive Science has a very long past but a relatively short history (Gardner, 1985)

- Rooted in the history of philosophy

  - Rationalism (Plato, Descartes, Leibniz,...)
    vs.
    Empiricism (Aristotle, Locke, Hume, Mill, ...)

  - Arithmetic and logic (Aristotle, Kant, Leibniz, Peano, Frege, Russell, Gödel...)

Historical Background

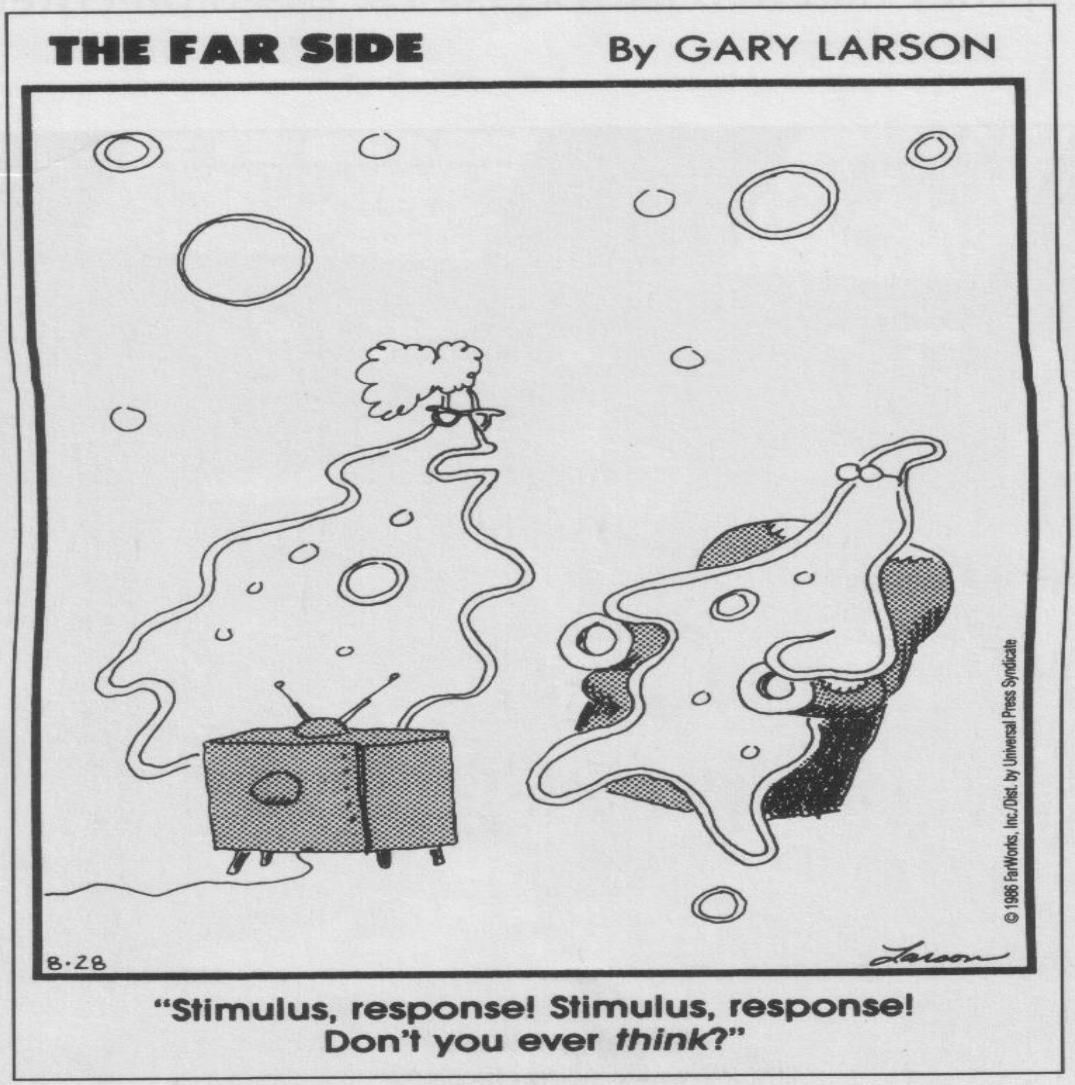
- Descartes (1596-1650):
  - Cartesian Dualism: Distinction between body and mind (soul).
  - A rationalist position: Reason (rational thinking) is the source of knowledge and justification.
- Reaction by empiricists (Locke, Hume):
  - The only reliable source of knowledge is (sensory) experience.

Historical Background

- How to acquire knowledge about the mind?
  - Introspection (in philosophy and psychology until late 19th century): Self-reflection. Experimental psychology (19th century - Wundt and his students)
  - Behaviorism (as a reaction to the subjectivity of introspection)

  Psychological knowledge can only be acquired by observing stimuli and responses (virtually denying the mind.)

    - Watson (1913): Behaviorist manifesto.
    - Watson, Skinner: Psychology as a science of behaviour.


THE FAR SIDE
By GARY LARSON
8·28
Larson
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"Stimulus, response! Stimulus, response!
Don't you ever *think*?"

Historical Background

- Logical tradition and analytic philosophy
  - Axiomatization of artihmetic and logic as formal systems: Leibniz, Frege, Russell,...
  - Logical positivism: Russell, young Wittgenstein, Schlick, Carnap, Gödel ... (Vienna circle), Ayer (Britain)
- Analytic philosophy in support of behaviorism (early 20th cent.)
- Analytic philosophy inspiring cognitive science :
  - Contributions to computer science
  - logic and language as formal systems

Historical Background

- The dawn of computers
  - Alonzo Church (1936 thesis): everything that can be computed can be computed with recursive functions
  - Alan Turing (same time): Turing machine: An abstract machine capable of calculating all recursive functions -> a machine that can campute anything.
  - The first machines: early 1940s
  - McCulloch and Pitts (1943): "A Logical Calculus of the Ideas Immanent in Nervous Activity": Neuron-binary digit analogy

Historical Background

- The dawn of computers
  - John von Neumann (1945): Architecture for a stored-program digital computer
  - Shannon's information theory (1948): information as medium-independent, abstract quantity.
  - Turing (1950) “Computing machinery and intelligence“: Classical article in AI. –> Turing test.

Historical Background

- The cybernetics movement
  - The study of communication and control
  - Rosenblueth, Wiener, Bigelow (1943). "Behavior, Purpose, and Teleology”
  - 10 conferences from 1946 to 1953 in New York and Princeton
    - Thinking is a form of computation
    - Physical laws can explain what appears to us as mental

The Birth of Cognitive Science

- The first AI conference (1956): Dartmouth College
  - Newell & Simon: The first computer programme: The Logic Theorist
  - “Logic Theory Machine” (1956): "In this paper we describe a complex information processing system, which we call the logic theory machine, that is capable of discovering proofs for theorems in symbolic logic. “
  - 1st draft of Marvin Minsky's "Steps toward AI"

Birth of Cognitive Science

- Concensusal birthday: Symposium on Information Theory at MIT in 1956

  (Revolution against behaviourism)

THEME: *Is cognition 'information processing' (data+ algorithms)?*

- Newell & Simon (AI)
  The first computer program
- McCarthy, Minsky (AI)
  Modelling intelligence
- Miller (Experimental psychology)
  "Human Memory and the Storage of Information": magic number 7
- Chomsky (Linguistics)
  Transformational grammar

Contributing paradigms

- Gestalt Psychology
- Neurology
- Cognitive psychology
  Bruner et al. (1956)- A study of thinking

Subsequent developments

- Philosophy:
  - Putnam (1960) "Minds and machines" – functionalism
- Cognitive Psychology
  - First textbook by Neisser in 1967
  - Advances in memory models (60s)
- More AI programs
  - Weizenbaum (1967): ELIZA

    Simulation of a psychotherapist – simple pattern matching
  - Winograd (1972): SHRDLU

    AI system with syntactic parsing

Subsequent developments

- Arguments against AI:
  - Dreyfus (1972): “What Computer's Can't Do...”

    Critique of AI from a phenomenological perspective.
  - Searle (1980) "Chinese room" scenario

    Does a symbol-manipulation system really understand symbols?

Subsequent developments

- Chomsky's increasing influence (until lately).
- Cooperation among linguists and psychologists.
- Cognitive Science Journal (1976)
- Cognitive Science Society (1979-Massachusetts)
- Cognitive science programs in more than 60 universities around the world.

Strict cognitivism

- Humans possess mental representations.
- Mental representations are symbols.
- Thinking involves rule-governed transformations over symbols.

-> Cognition is symbolic computation

Rosch: "strict/philosophical cognitivism"

Gardenfors: "High-church computationalism"

Strict cognitivism

- Newell and Simon (1976): "Computer Science as Empirical Inquiry: Symbols and Search"

  "a physical symbol system [such as a digital computer, for example] has the necessary and sufficient means for intelligent action."

- Fodor: Representational Theory of the Mind (RTM)

  Language of thought (LOT) hypothesis: Mentalese

  Symbols manipulated formally (syntactically):

  'Meaning ' is not relevant (or boils down to syntax).

Inter-/multidisciplinarity

"Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology."

(Stanford Encyclopedia of Philosophy)

Disciplines in Cognitive Science

- **Philosophy**
- **Computer Science - Artificial Intelligence**
- **Psychology – Cognitive Psychology**
- **Linguistics**
- **Neuroscience**
- Anthropology, Psychiatry, Biology, Education, ...

Multidisciplinarity

- Computer science and cognitive psychology have been dominant.
- Neuroscience had a big impact on the growth.
- Still, only 30-50% of the work are multidisciplinary
- Nature of multidisciplinary collaborations differ

Multidisiplinarity

- (Von Eckardt, 2001)
  - Localist view: A field is multidisciplinary if each individual research in it is multidisciplinary.
  - Holist view: A field is multidisciplinary if multiple disciplines contribute to its research program (a set of goals directed at the main goal).

Philosophy

- Philosophy of mind
- Philosophical logic
- Philosophy of language
- Ontology and metaphysics
- Knowledge and belief (Epistemology)
- Defining the scientific enterprise of cognitive science (Philosophy of science)
- Phenomenology

Philosophy

- Metaphysics / philosophy of mind
  - materialism/idealism/dualism/identity theory/functionalism

    Materialism*: Ultimate nature of reality is material/physical*

    Idealism*: Ultimate nature of reality is mental/ideal*
- Epistemological position
  - *Rationalism vs. empiricism*
- Scientific methodology / ontology
  - *Realism (w.r.t mental phenomena) vs. positivism*

    Empiricism: experience

    Positivism: perception (sense data)
- Phenomenology
  - *Method for studying properties and structures of conscious experience*
  - *Husserl's (1900) call: "Back to things themselves!"*

Linguistics

- Major Components of Analysis
  - Phonology
  - Morphology
  - Syntax
  - Semantics
  - Discourse and pragmatics

Linguistics

- Areas of cognitive relevance in linguistics:
  - Psycholinguistics
    - Language acquisition
    - Language production and comprehension
    - Discourse processing and memory
  - Neurolinguistics
    - Neurological underpinnings of linguistic knowledge and use
  - Computational Linguistics
    - A major component of AI
  - Cognitive Linguistics
    - Prototypes, background cognition, mental spaces, imagery
    - Cognitive Grammar

Linguistics

- Areas of cognitive relevance in linguistics (cont.):
  - Language Universals and Universal Grammar
    - The functionalist perspective – language-external explanations
    - The formalist perspective – language-internal generalizations
  - Competence vs. performance (I-language vs E-language)
  - The relation between language and logic
    - Grammar as a generative system (axiomatization)
    - Knowledge representation and reasoning
  - Symbolic representation vs. action
    - Semantics vs. pragmatics
    - Intentionality
    - Speech acts

Artificial Intelligence

- Study of intelligent behaviour
- Automation of intelligent behaviour
- Machines acting and reacting adaptively
- How to make computers do things which humans do better
- Study and construction of rational (goal and belief-directed) agents

Artificial Intelligence

- Modeling for Study of Cognition
  - Strong AI (duplicating a mind by implementing the right program) vs. Weak AI (machines that act as if they are intelligent)
  - aI (the study of human intelligence using computer as a tool) vs Ai (the study of machine intelligence as artificial intelligence)
  - Artificial Intelligence and Cognitive Science: a history of interaction

Artificial Intelligence

- Advantages of Computational Modeling
  - More formal, precise specifications
  - Enhance predictive aspects of a theory
  - Computer programs are good experimental participants

Cognitive Psychology

- Perception, pattern recognition
- Attention
- Skill acquisition, learning
- Memory
- Language and thought processes
- Reasoning and problem solving

Cognitive Psychology

- Methods of investigation
  - Experimental Methods - lab studies
  - Simulations
  - Case studies on acquired and developmental deficits
    - Dyslexia, autism, agnosia, aphasia, amnesia
    - Other disorders, e.g. schizophrenia

Neuroscience

- Neurocognition/
  Cognitive neuroscience/
  Cognitive neuropsychology:
  - The study of the neurological basis of cognitive processing.
- Computational neuroscience:
  - Detailed simulation of neuronal mechanisms.

Neuroscience

- The Nervous System
  - Peripheral (nerve fibers, glands) vs. Central nervous system (brain, spinal cord)
  - Brain:
    - Cerebral cortex ('gray matter')

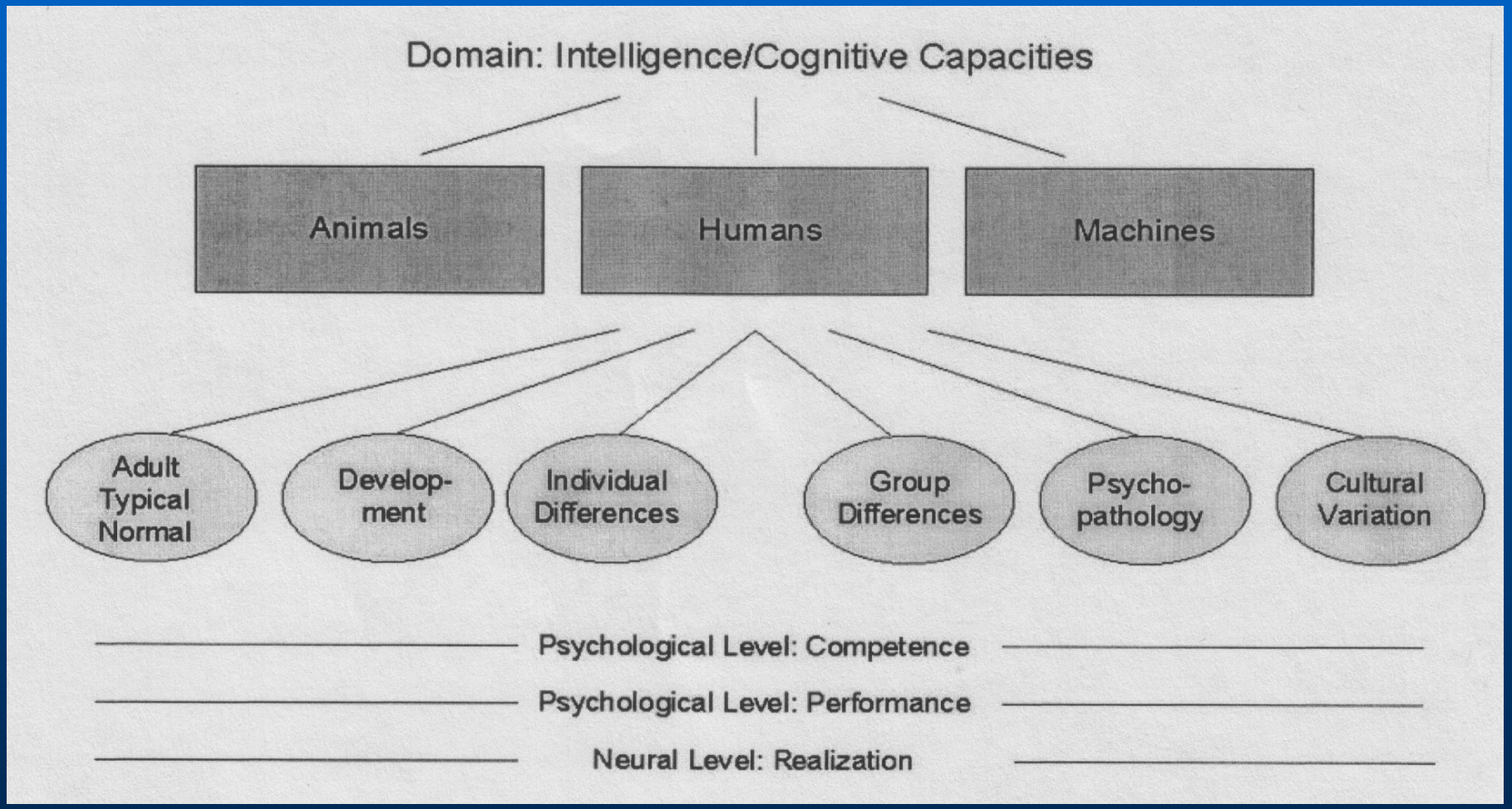
  vs.

    - Subcortical areas
  - Two hemispheres (left-right); four lobes (frontal, parietal, occipital, temporal)

Neuroscience

- Methods of Investigation
  - Structural techniques: CAT scan (Computer Axial Tomography); MRI (Magnetic Resonance Imaging)
  - Functional techniques: PET scans (Positron Emission Tomography); fMRI (Functional MRI)
  - Temporary lesions-> TMS (Transcranial Magnetic Stimulation)
  - Electrophysiological Techniques:
    - EEGs (Electroencephalograms)
    - ERPs (Event Related Potentials)
  - Used in combination with neuroimaging techniques
  - Used in conjunction with behavioural methods

Research Tracks within Cognitive Science



Methods in Cognitive Science

- Building theories vs. acquiring data
  - Philosophical background: Setting up the domain of discourse / Logical argumentation
  - Formalization and mathematical modeling
  - Computational modeling
  - Hypothesis formation

  - Behavioral experiments
  - Linguistic data
  - Ethnographic data
  - Investigating the brain

Relatively Recent Developmens

- Connectionist models of cognition:

A challenge to symbolic models

  - Artificial networks of interconnected units ("neurons").
  - Parallel rather than serial processing of information.
  - Learned associations rather than strict/innate rules
- Non-symbolic concept formation
  - Prototype theory of concepts (Rosch)
  - Representing information with geometrical/topological structures (Gardenfors)
- Dynamic and statistical models of cognition
  - e.g. versions of Optimality Theory in Linguistics
- Theory of multiple intelligences (Gardner 1983)

Relatively Recent Developmens

- Increasing role of neuroscience
  - On philosophy of mind – Churchlands
  - Emergence of new subdisciplines: cognitive neuroscience, computational neuroscience
- Embodied brain
  - Cognition is not only in the brain. It needs the body.
- Re-consideration of the context
  - Situated cognition: The brain needs the body + the surrounding world.
  - Cognitive anthropology, cognitive informatics
- Tackling *hard* subjects
  - Consciousness

Unified Theories of Cognition

- Unity behind diversity: The aim of science.
  - "... positing a single system of mechanisms- a cognitive architecture- that operate together to produce the full range of human cognition." (Newell, 1990)
  - Bring all parts together.
  - Increase rate of cumulation of knowledge.
  - Increase applicability.

  - Not everyone agrees this is how cognition should be studied.

How to Become a Cognitive Scientist?

- No fast and definitive answers.
- Be as general and objective as possible in the beginning.
- Read, read and read. Develop critical (and fast) reading skills. Read broadly across a number of areas of cognitive science
- If possible, form a regularly meeting reading group (can be a general cognitive science reading group or a special interest group).
- Develop practical experience with different methods in cognitive science as much as possible.
- Read past theses of this department and of other Cogs departments; use the handout as starting point for extra readings. Get reading lists for the PhD specialization exam.
- Specializations and indepth expertise comes later, may be in your PhD studies. Do not look upon your Master's work as final but as foundational.

Concluding Remarks

- All these will take time; be patient; do not get discouraged.
- Take relief in that you are getting into a very interesting discipline.
- Pay attention not only to the results (such as grades) but also to the processes of becoming a cognitive scientist.