Cognitive Information Processing

The Cognitive Revolution

Lecture 2

R Guha
2022

And this is…..?

Can the brain make machines work without moving a muscle?

The story of Grey Walter

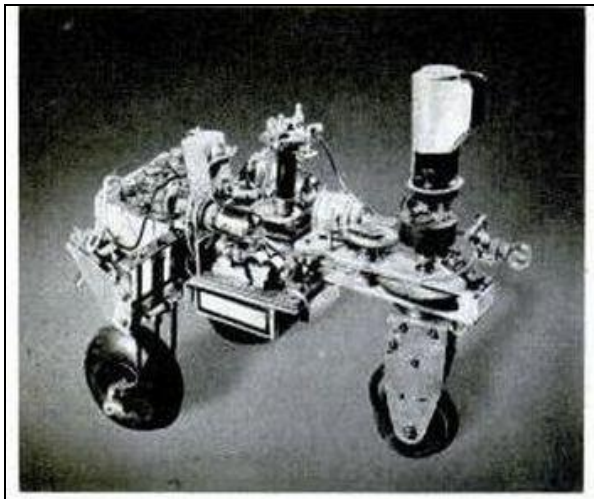
Grey Walter (1964) performed an experiment with patients in whose motor cortex he had implanted electrodes

He wanted to test the hypothesis that certain bursts of recorded activity were the initiators of intentional actions

He arranged for each patient to look at slides from a carousel projector. The patient could advance the carousel at will, by pressing the button on the controller

The jolt: The controller button was a dummy, not attached to the slide projector at all!

What advanced the slides was the amplified signal from the electrode implanted in the patient's motor cortex



Mechanical "Thinking" Turtles

With a couple of old gas meters, some batteries and electrical parts, a scientist has built a pair of unpredictable mechanical turtles which are aiding in a study of how animal and human brains work. Dr. Grey Walter of the Burden Neurological Institute, Bristol, England, made the robot tortoises. Each has a snout on its back containing a photoelectric cell. When the batteries are turned on, the snout slowly revolves, searching for the strongest source of light in the room. This action also revolves the front wheel of the tricycle undercarriage, and the turtle wanders from side to side. As soon as it "sees" the light, the snout stops revolving and the rear wheels start turning to move the turtle forward toward the light until it strikes a piece of furniture or some other obstacle. Then with a growling of machinery it moves at random from side to side until it once more "sees" a clear path to the light. The two turtles now have two simple reactions—response to light and avoidance of obstacles. Doctor Walter plans next to give them a 15-minute electronic memory, and a primitive learning ability. He won't predict exactly what they'll do then!

Popular mechanics

Fundamentals of human information processing

Communication or control requires peripheral nerves and muscles

- begins with the user's intent triggering a complex process in which certain brain areas are activated,

- **hence signals are sent via the peripheral nervous system (specifically, the motor pathways) to the corresponding muscles,**
- **which in turn perform the movement necessary for the communication or control task**

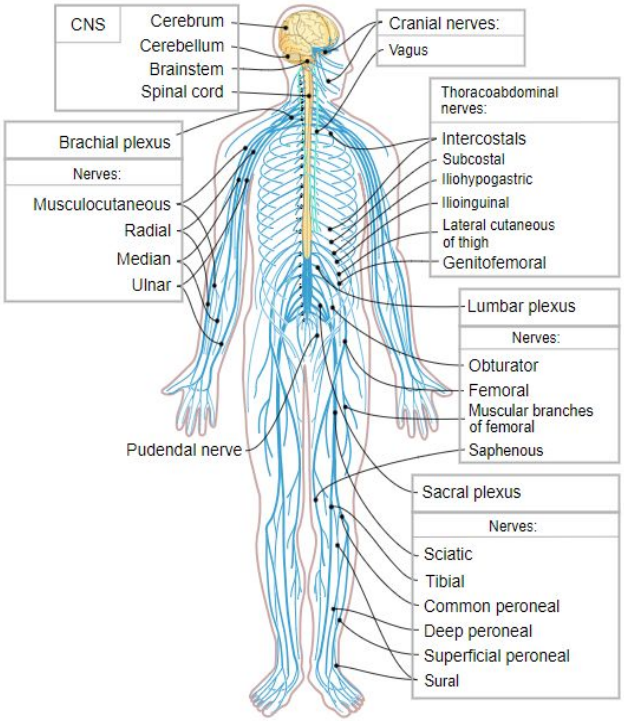
The activity resulting from this process is often called motor output or efferent output

Efferent conveying impulses from the central to the peripheral nervous system and further to an effector (muscle)

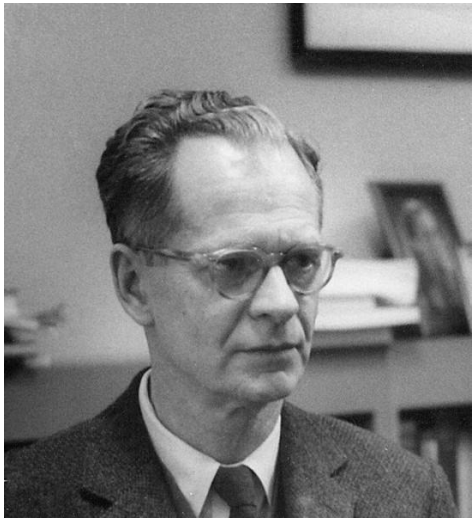
Afferent describes communication in the other direction, from the sensory receptors to the central nervous system

For motion control, the motor (efferent) pathway is essential

The sensory (afferent) pathway is particularly important for learning motor skills and dexterous tasks, such as typing or playing a musical instrument

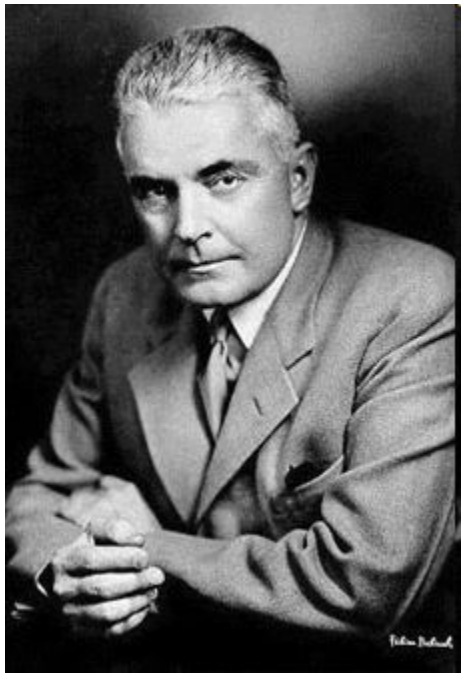


Emergence of Behaviorism:
enter the "black box"



B. F. Skinner: only observable phenomena are scientific

- **John Watson** the dominance of behaviorism 1900-1950



History of COGNITION studies

- **BEHAVIOURISM and LEARNING THEORY** □ dominated American psychology for half a century
- **Limitations:** Could not describe the challenges associated with information recall.
- Cognitive Information Processing (CIP) was not new to psychology, but its use as a learning theory allows us to address issues that behaviorism cannot

The Cognitive Information Processing model portrays the mind as possessing a structure consisting of components for processing (storing, retrieving, transforming, using) information and procedures for using the components

Like Behaviorism, the Cognitive Information Processing model holds that learning consists partially of the formation of associations between new and stored information

- http://www.labr.net/2016/10/01/cognitive-information-processing-and-memory/

How the nervous system controls behavior
The Hixon Symposium (1948)

- In **September 1948** at CalTech, a group of eminent scientists representing several disciplines met for a conference on

  "Cerebral Mechanisms in Behavior,"

  sponsored by the Hixon Fund

- **John von Neumann, mathematician** showed a striking comparison between the electronic computer (then a new discovery) and the brain

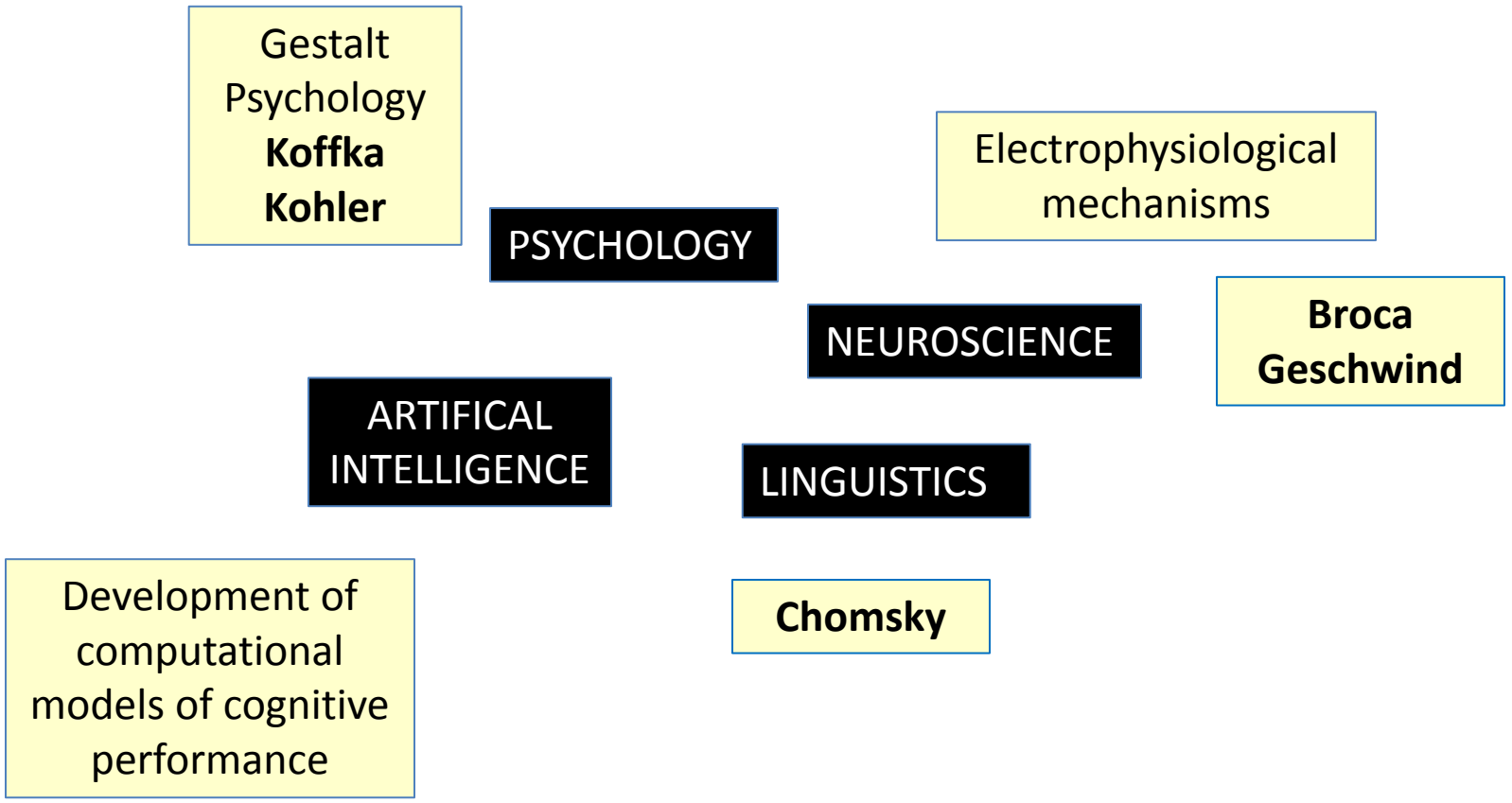
- **Warren McCulloch, mathematician and neurophysiologist**, talked about "Why the Mind is in the Head" to discuss on how the brain processes information - exploited parallels between the nervous system and "logical devices" in order to figure out why we perceive the world the way we do

Karl Lashley, Psychologist **"The Problem of Serial Order in Behavior,"**

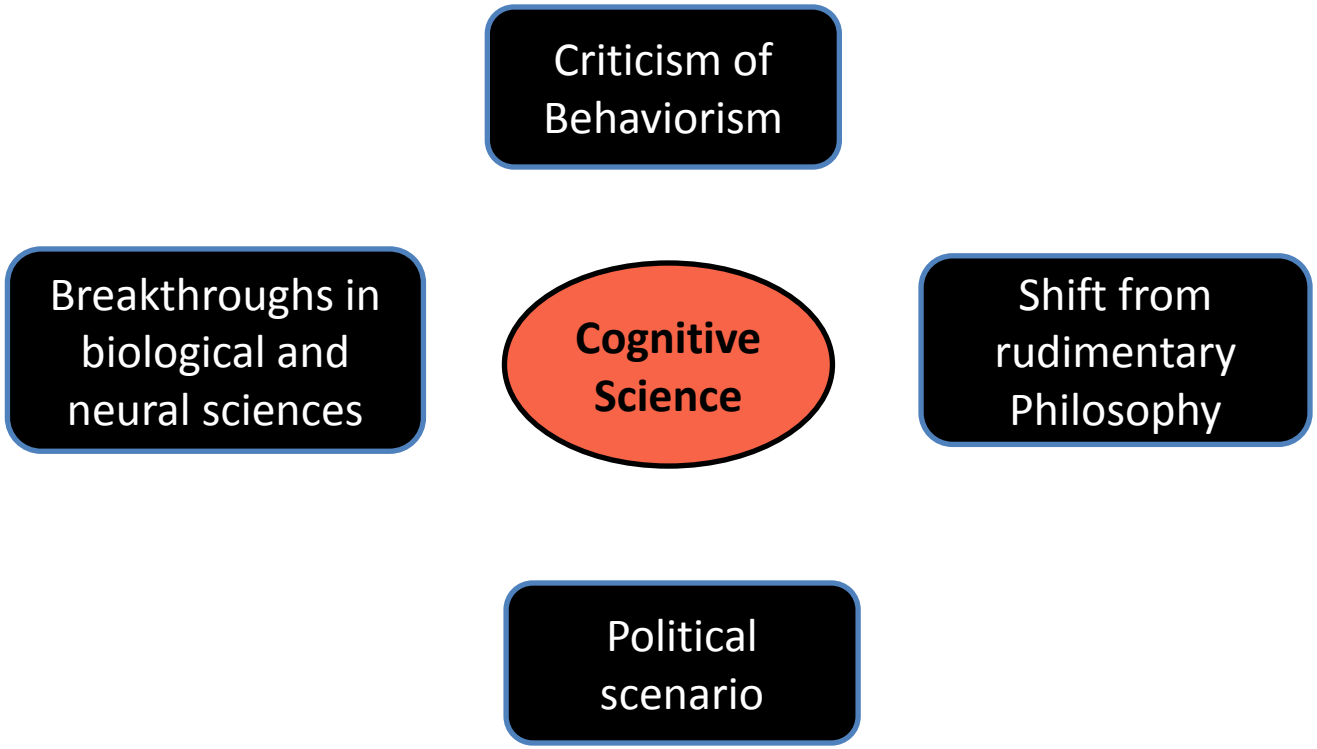
Lashley identified some of the major components needed for a cognitive science, even as he castigated those forces that had prevented its emergence before this time

Lashley: ***Rather than behavior being consequent upon environmental promptings, central brain processes actually precede and dictate the ways in which an organism carries out complex behavior***

Intellectual ancestors of Cog Science

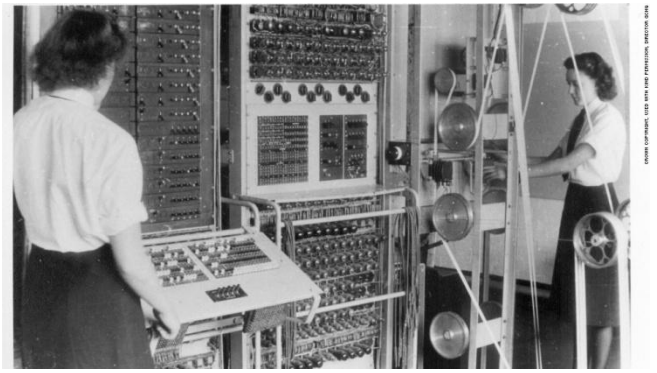


The emergence of Cognitive Science



WWI & II: Human/Machine interactions

- **Channel capacity**: how much info can be processed?
- **Computer analogy**: Do machines think like humans or do humans think like machines?
- Development of **empirical measures of cognition**, for example: **reaction time**



The political changes

War - stimulated scientific and technological activities

- demanded calculating machines that could "crunch“ large sets of numbers very quickly. Computers soon became a reality.

Norbert Wiener, Mathematician - asked to devise more accurate anti-aircraft machinery

- This work required ***"a good gun, a good projectile, and a fire control system that enables the gunner to know the target's position, apply corrections to the gun controls, and set the fuse properly, so that it will detonate the projectile at the right instant”***

- Wiener and his associate, Julian Bigelow concluded that:

there were important analogies between the feedback aspects of engineering devices and the homeostatic processes by which the human nervous system sustains purposive activity

CYBERNETICS

Weiner coined CYBERNETICS (1948)

- linkage of developments in understanding the human nervous system, the electronic computer, and the operation of other machines
  - the functioning of the living organism and the operation of the new communication machines exhibited crucial parallels

Based on **Claude Bernard's theory of feedback system** bringing stability in a changing environment

Proponents: Wiener, Bigelow, Rosenblueth

The Cybernetic Synthesis

- Wiener (Prof of Maths, MIT) collaborated with Vannevar Bush (engineer) who in the 1930s had begun to develop an analog computer
- At the start of World War II, they designed a system for improving anti-aircraft fire in which feedback would play a critical role
- Information from radar would be employed to calculate adjustments to gun controls; after new shots were fired, information about the results would be used to readjust the gun controls
- They created a self-steering device; even if humans were part of the loop, the overall activity would count as one of self-steering by means of feedback

Cybernetics represented a first attempt at a broad, multidisciplinary endeavor to explain mental phenomena

The war and scientific investigations

- **Medical practitioners** – to evaluate which tasks could be carried out and which ones had been compromised by injury to the nervous system
- The study for the selection of men fit to lead combat units
- Studies on Propaganda and Personnel selection for combat units

Alan Turing and Kenneth Craik's interest in computers in England, to Alexander Luria's research with brain-injured patients in Russia during the war

Important agents in Cognitive Science

- Mathematics and computation
- The neuronal model
- The cybernetics synthesis
- The information theory
- Neuropsychological syndromes

Alan Turing

Turing (1950) suggested that one could so program a machine that it would be impossible to discriminate *its* answers from those by a living human being - a notion immortalized as the "Turing machine test."

If an observer cannot distinguish the responses of a programmed machine from those of a human being, the machine is said to have passed the Turing test (Turing 1963)

The implications of these ideas seized by scientists interested in human thought: ***if they could describe with precision the behavior or thought processes of an organism, they might be able to design a computing machine that operated in identical fashion***

The Neuronal Model

McCulloch and Pitts (1943) (Hixon Symposium Title: Why the mind is in the Head)

- the operations of a nerve cell and its connections with other nerve cells (a so-called neural network) could be modeled in terms of logic

- Nerves could be thought of as logical statements, and the all-or-none property of nerves firing (or not firing) could be compared to the operation of the propositional calculus (where a statement is either true or false)

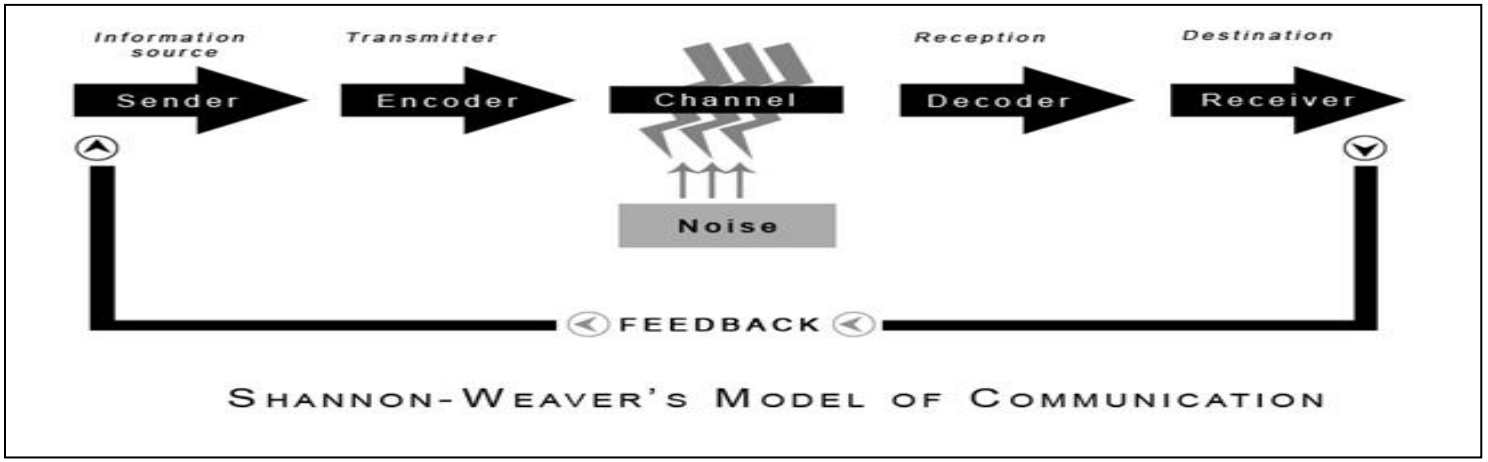
- This model allowed one to think of a neuron as being activated and then firing another neuron, in the same way that an element or a proposition in a logical sequence can imply some other proposition: thus, whether one is dealing with logic or neurons, entity A plus entity B can imply entity C.

- Moreover, the analogy between neurons and logic could be thought of in electrical terms-as signals that either pass, or fail to pass, through a circuit

Information Theory

Claude Shannon, an electrical engineer at M.I.T:

- saw that the principles of logic (in terms of true and false propositions) can be used to describe the two states (on and off) of electromechanical relay switches
- Shannon provided an early suggestion that electrical circuits (of the kind in a computer) could embody fundamental operations of thought
- During the next ten years, working in part with Warren Weaver, Shannon went on to develop the key notion of information theory:
  - **information can be thought of simply as a single decision between two equally plausible alternatives**



SHANNON-WEAVER'S MODEL OF COMMUNICATION

Neuropsychological Syndromes

- During WWI &II, research on aphasia (language deficit), agnosia (difficulty in recognition), and other forms of mental pathology consequent upon injury to the brain

- Considerable convergence across cultural and linguistic boundaries (New York, Oxford, Paris, Berlin, and Moscow)

Findings:

- Aphasia assumed similar forms despite wide differences across languages
- More regularity seen in the organization of cognitive capacities in the nervous system than by environmental influences
- The neuropsychological breakdown unexplained through simple stimulus-response disruption

Eg: In certain forms of aphasia, the general sentence frame was preserved, but subjects could not correctly slot individual words into the frame

In other aphasias, the sentence frame broke down, but individual content words carried meaning

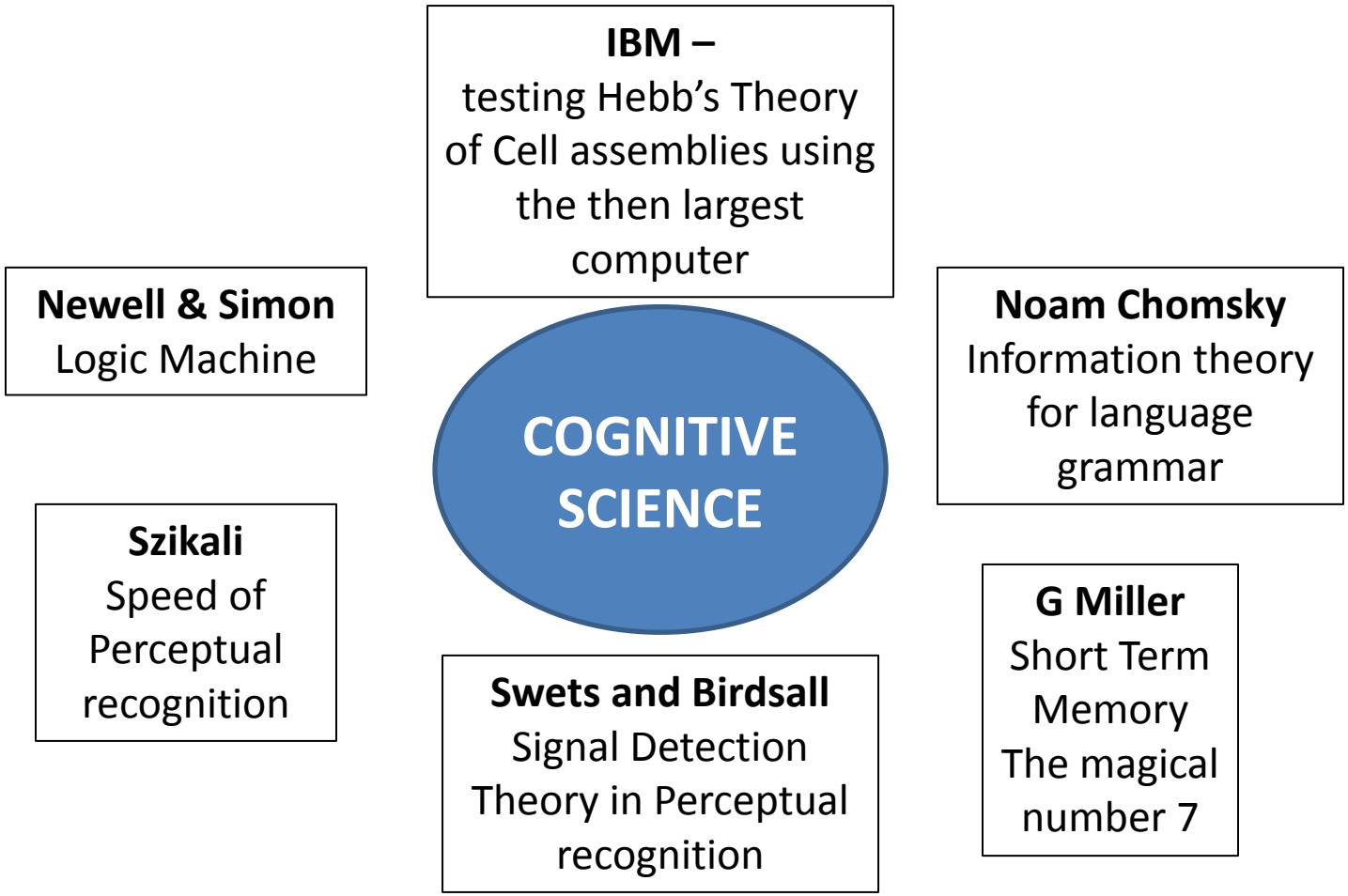
□ Criticism against reflex-arc models of thought (Pavlov)

W. Ross Ashby and a few others

Ashby's *Design for a Brain* (1952): ***"My aim is simply to copy the living brain. In particular if the living brain fails in certain characteristic ways, then I want my artificial brain to fail too. I have attempted to deduce what is necessary, what properties the nervous system must have if it is to behave at once mechanistically and adaptively"***

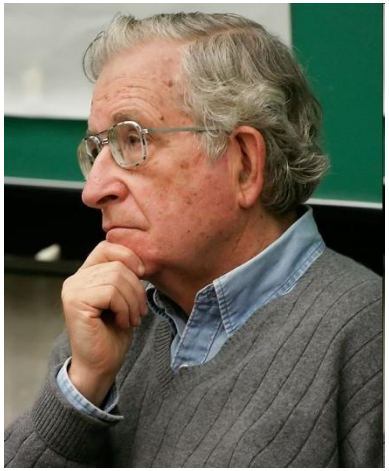
- Ashby's work intrigued young **scholars** **George Miller, Marvin Minsky, Allen Newell, and Herbert Simon** – architects of the cognitive revolution
- In **neuropsychology**, **Donald Hebb** - the developing nervous system responsible for many aspects of visual perception and also to illuminate processes of learning and the growth and subsequent decline of intelligence (Hebb 1949)
- In **anthropology**, **Gregory Bateson** introduced his notions about **feedback systems in social systems**
- New **mathematical innovations**, such as **Markov processes and stochastic models**, quickly came to the attention of young workers in the social sciences

Conception of Cog Sc – Symposium at MIT – 1956 Sept 11th



Cognitive Sc: 1956 Proponents

Noam Chomsky: linguistics

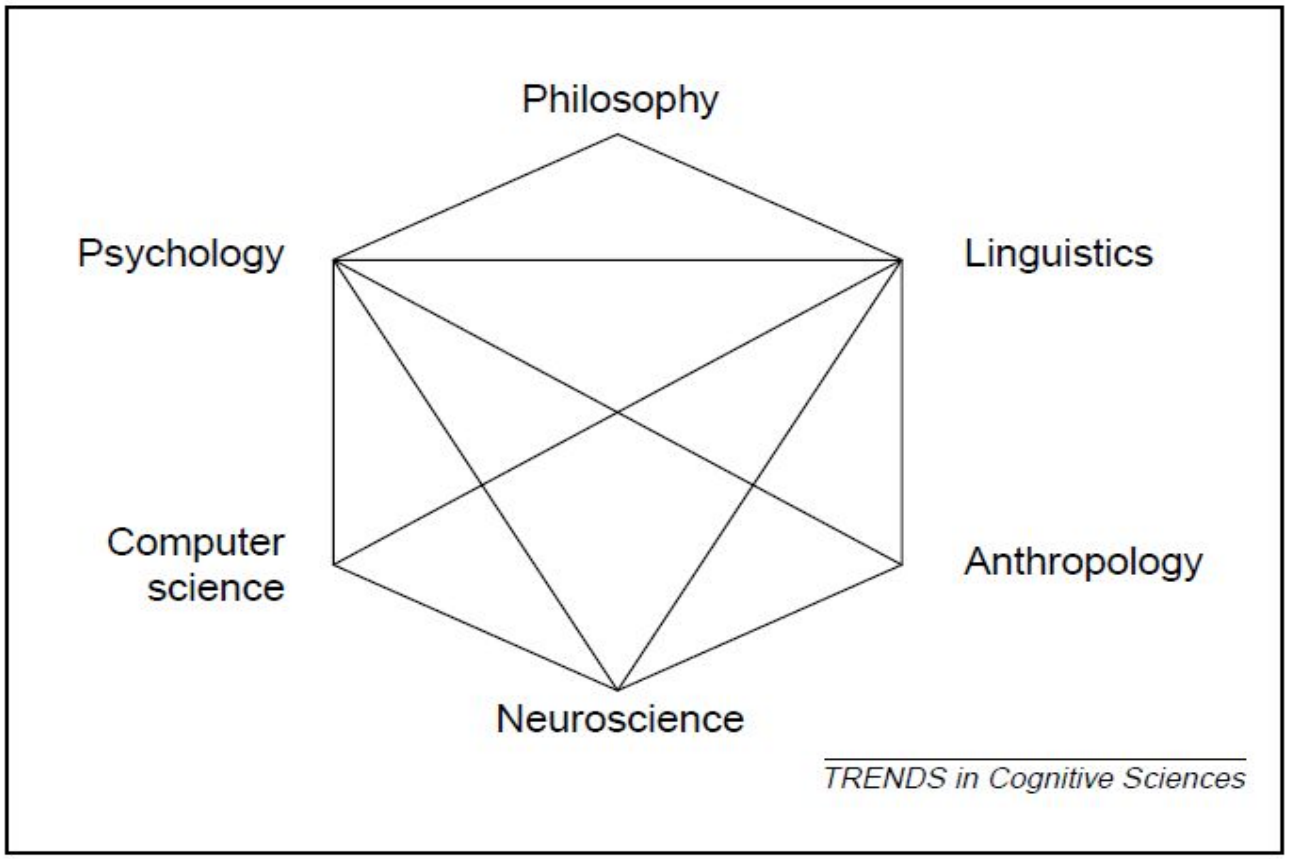


George Miller: magical #7

Newell & Simon: problem-solving

Jerome Bruner: categorization

COGNITIVE SCIENCE – INTERDISCIPLINARY ACTIVITIES



Cognitive science in 1978
Each line joining two disciplines represents interdisciplinary inquiry

COGNITION RESEARCH TODAY

- **Take a look, and you'll see, into your imagination**
- Kyoto University : Using fMRI signals and Deep Neural Network AI, researchers decode and predict what a subject is seeing or imagining
  - https://www.sciencedaily.com/releases/2017/05/170531094850.htm
- **Click-on arm prosthesis controlled by patient's thoughts**
- Radboud University Nijmegen Medical Centre: Last Friday, the first patient in the Netherlands received his click-on robotic arm. By means of a new technique, this robotic arm is clicked directly onto the bone. A unique characteristic of this prosthesis is that it can be controlled by the patient's own thoughts
  - https://www.sciencedaily.com/releases/2017/04/170425093016.htm
- **Controlling turtle motion with human thought**
- Korea Advanced Institute of Science and Technology: Researchers have developed a technology that can remotely control an animal's movement with human thought
  - https://www.sciencedaily.com/releases/2017/03/170323085038.htm
- **Can a brain-computer interface convert your thoughts to text?**
- University of Bremen: Recent research shows brain-to-text device capable of decoding speech from brain signals. While this might enhance the capabilities of already existing speech interfaces with devices, it could be a potential game-changer for those with speech pathologies, and even more so for "locked-in" patients who lack any speech or motor function
  - https://www.sciencedaily.com/releases/2016/10/161025114035.htm
- **Mind-controlled toys: The next generation of Christmas presents?**
- University of Warwick: The next generation of toys could be controlled by the power of the mind, thanks to new research
  - https://www.sciencedaily.com/releases/2016/12/161215105247.htm

STUDY OF COGNITION TODAY

Today the study of the human mind is among the most exciting frontiers of science

Practical applications:

- Designing software
- the diagnosis of neurological disease
- the formation of public policy

To summarize…

The study of COGNITION is a child of the 1950s, the product of a time when psychology, anthropology and linguistics were redefining themselves and computer science and neuroscience as disciplines were coming into existence

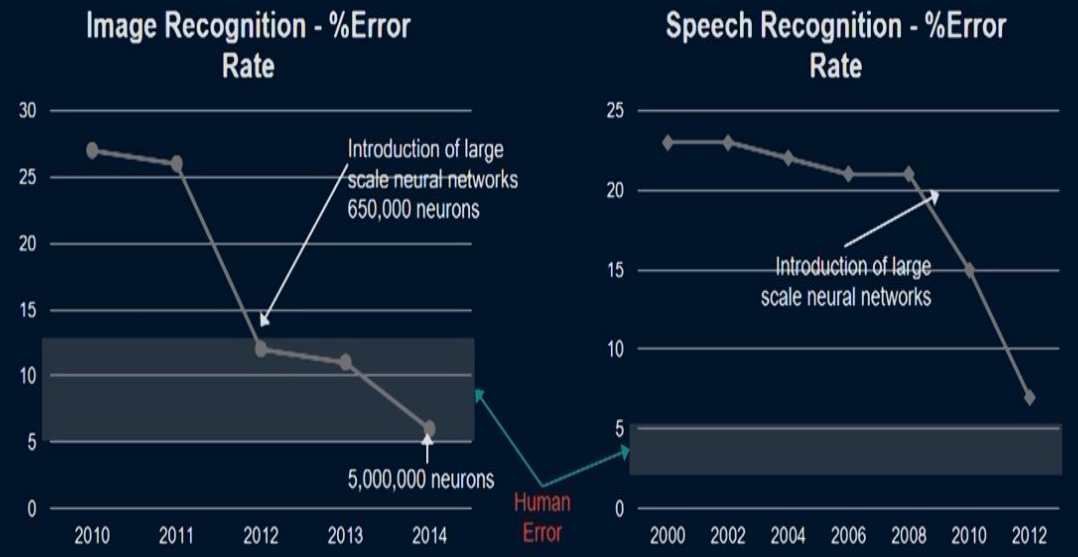
Several disciplines realised that the solution to some of their problems depended crucially on solving problems traditionally allocated to other disciplines

- IBM shoebox 1962
  - –Recognized 16 spoken words
- Speech recognition
  - –1995: 43% error rate
  - –2004: 15,2%
  - –2015: 8%
  - –2016: 6,9%
  - –2017: 5,5%

  - –humans at 5,1%

Cognition and technology

Software neural networks are approaching human accuracy on sensory problems

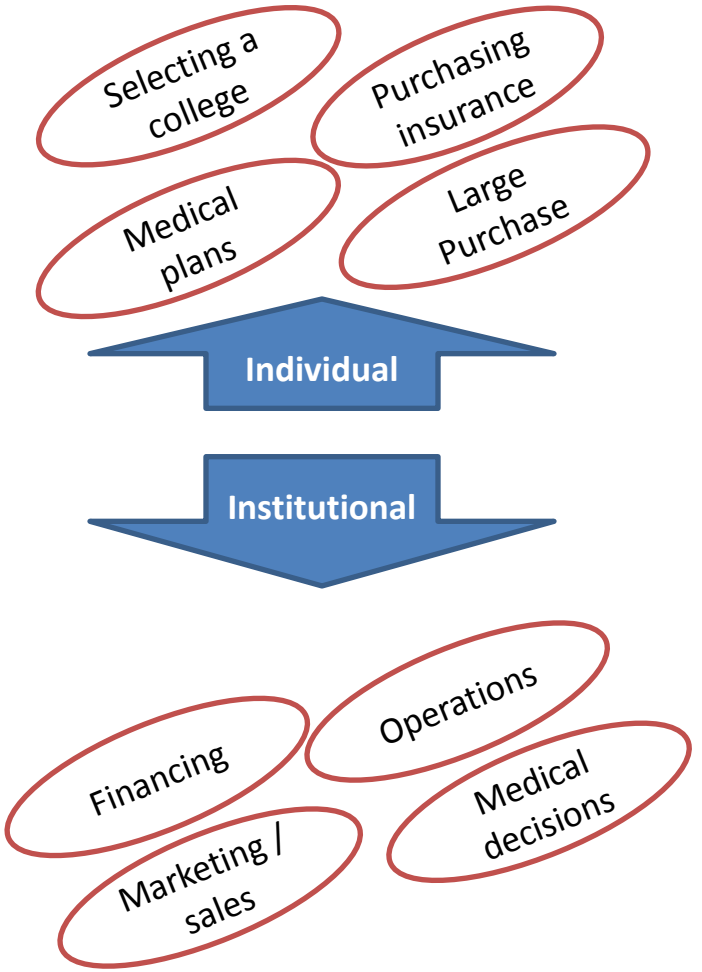


The next cognitive revolution?

To augment human cognition

Strengths

HUMAN	MACHINE
Human expertise	Digital Knowledge
Self Directed Goals	Large scale Maths
Common sense	Pattern discovery
Value Judgment	Statistical Reasoning



Using Computer's skills to help in daily living
- For decisions requiring a higher degree of cognitive complexity

Development of information processing psychology

Cognitive Revolution in Psychology – breaking from Behaviourism

Limitations of Shannon's Information Theory in its application to human information flow

Shannon's analysis of Language based on Markov Processes could not be applied to psychological processes

Popularity of Syntactic theory of Language processing to understand cognitive processes in Language structure

1960
Harvard Centre for Cognitive Studies
(Bruner and Miller)

Cybernetics
(Weiner)

Cognitive Anthropology (Bateson)

AI
(Minsky & McCarthy)

Computers to stimulate cog processes (Simon & Newell)

Cognitive/Neuro Psychology
(Miller Bruner)

Computers and Artificial Intelligence

Of all the research fields that would come to play a major role in cognitive science, ARTIFICIAL INTELLIGENCE, usually classified as a branch of computer science, was the newest, having to await the invention of the computer itself.

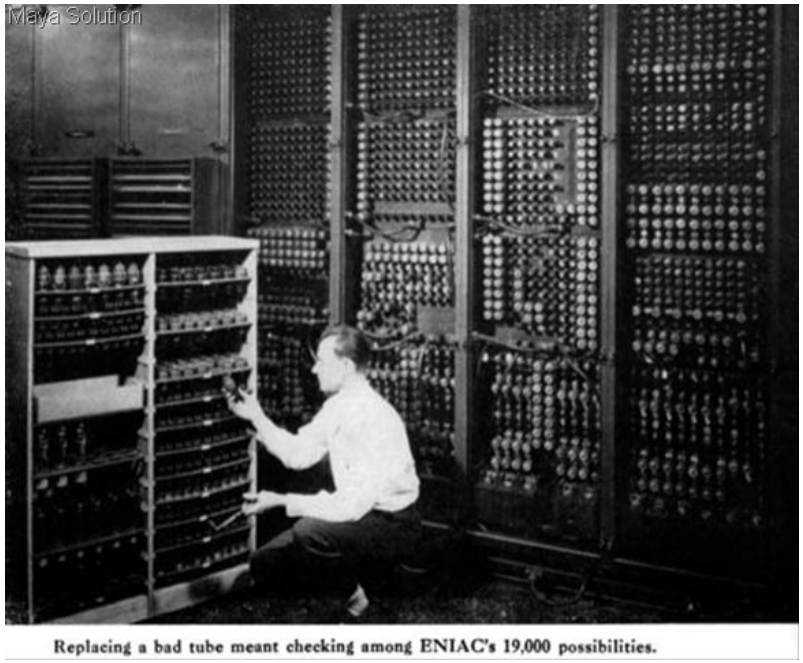
The role of the computer in the birth of cognitive science

- By the early 1950s the theoretical foundations for artificial intelligence had been established; what remained was to actually build systems that exemplified aspects of human thinking. This task fell to a younger generation of investigators who were just then launching their careers. The team that set the prototype for the new enterprise of modeling intelligence of producing an artificially intelligent system consisted of Herbert Simon and Allen Newell. Neither Simon nor Newell was initially oriented towards computer science.

- Simon's background was in political science, and his appointment was in the Graduate School of Industrial Administration at Carnegie Tech (now Carnegie Mellon University); he first made his reputation, and later won a Nobel Prize, in economics for his analysis of the functioning of human organizations. This work led him to challenge one of the tenets of modern economics, the assumption that agents are perfectly rational in the choices which they make

Discussion Questions

- How did the invention of the computer contribute to the perception of cognitive science?



Replacing a bad tube meant checking among ENIAC's 19,000 possibilities.

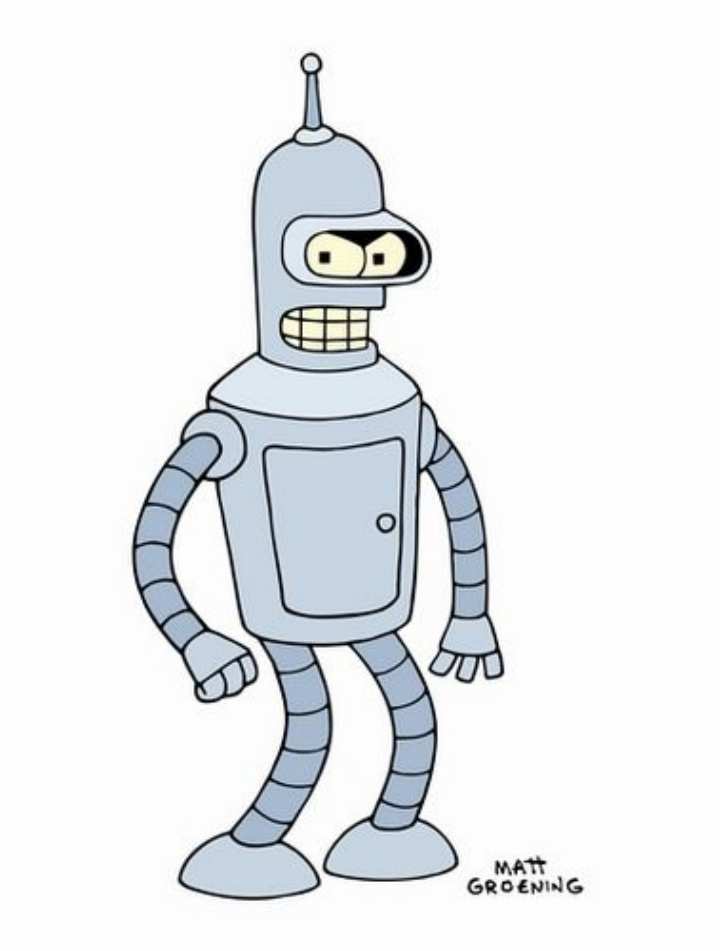
ASSIGNMENT – (2 pages max)

- Write a research problem in Cognitive Science that is relevant in today's world

- Enumerate how you would like to conduct the research?

Artificial Intelligence

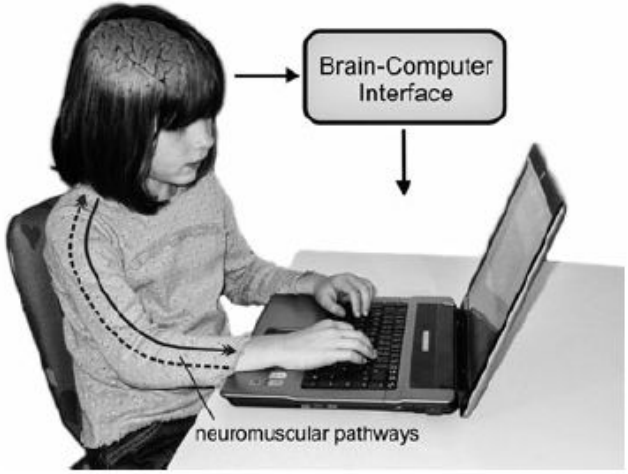
- Do you think it is possible to advance Artificial Intelligence to the point where it accurately mimics life?
- Are there any aspects of human cognition that you believe are unable to be replicated?



What's the difference between BCl and HCl?

What is BCI?

- A BCI offers an alternative to natural communication and control
- It is an artificial system that bypasses the body's normal efferent pathways, which are the neuromuscular output channels
- Instead of depending on peripheral nerves and muscles, a BCI directly measures brain activity associated with the user's intent and translates the recorded brain activity into corresponding control signals for BCI applications
- This translation involves signal processing and pattern recognition
- Since the measured activity originates directly from the brain and not from the peripheral systems or muscles, the system is called a Brain–Computer Interface



What about EEG MRI Eye tracker etc - are they BCIs?

The development of BCI

The role of Cognitive Science

What about Cognitive Information Processing?

How does it all fit in?