Chapter 12: Cognitive Science

The Decline of Behaviourism

Noam Chomsky (1928 -)
- attacked Skinner's ideas presented in *Verbal Behaviour*
- stimulus, response, & reinforcement are well defined in animal studies, but can't be extended to human learning

- stimulus – is stimulus defined as what affects behavior, definition is redundant (Iron Law of Explanation p. 11 of Leahey, 7th ed.) We can always find some stimulus that 'controls' behavior
- remote stimulus control – e.g reporting memory of an event
- stimulus as "self-observed private stimulus" which might arise from invisible motor movements (e.g. internal speech)

→ stimulus 'controlling' behavior can't be operationally defined in Skinner's discussion of language
- Note: Skinner is really discussing mental representations (e.g. memories, descriptions or images of events)

Early Theories in Cognitive Psychology: The New Structuralism

- human behavior Could be explained in terms of abstract mental structures (e.g. Piaget's schemata, Chomsky's language acquisition device (or LAD). Compare to Kant's Transcendental Categories of Experience (page 166) which mind imposes on the world.

Jean Piaget (1986 - 1980) - genetic epistemology – intellectual development described as having 4 stages, each of which is defined by different cognitive structures.
Stages: sensori-motor, preoperational, concrete operational, formal operational
- qualitative differences, not quantative
→Piaget's theory – alternative to behaviourism as an account of human development
- Piaget's ideas generated a lot of research on child development

- Noam Chomsky – linguistic theory, rule based
e.g. P (proposition) → S (subject) + P (predicate)
S → (D) (optional article) + A (optional adjective) + N (noun)
P → AV (optional adverb) + TV (transitive verb) + O (direct object)

Cognition in Social Psychology
- Leon Festinger – Theory of Cognitive Dissonance
- different beliefs may be compatible or not
- when a person has two incompatible beliefs (e.g. smoking is harmful to one's health, & I am a smoker) cognitive dissonance is created → discomfort which person tries to reduce

- described various ways to reduce cognitive dissonance; e.g. give up or reduce smoking, find evidence that smoking isn't very harmful (e.g. people who have smoked a long time but are still healthy) or read criticisms of research on smoking and health.

"New Look" in Perception

Jerome S, Bruner – perceiver takes an active role in perception, not a passive receiver of sensory information

- studies of perceptual defense → people require longer presentations to recognize "taboo" words or words with negative emotional connotations than neutral words in T-scope experiments
  - implies some type of 'repression'
  - implies both conscious & unconscious perceptual processes

Study of Thinking – Jerome Bruner's Concept-Learning Studies

- set of stimuli that varied along several dimensions (e.g. colour, shape, number)
- rule defining negative and positive instances of a concept (e.g. red circles were positive, everything else negative; or three of anything or anything blue is negative, everything else is positive)
- participant chose or was given examples & had to guess whether example was + or - & then given feedback.
- goal was to figure out the governing rule.
- Bruner studies the strategies people used to discover various types of rules.

The Rise of Cognitive Science: Purposive Machines

- steam engines developed in 1700s → problem in controlling power production
- 1788 James Watt (1736 – 1819) – developed centrifugal governor. See diagram in Leahey
- burning coal heats water which boils & becomes steam. Steam creates pressure which causes shaft attached to two balls to rotate. Height of the shaft controls the amount of fuel fed to the fire.
- governor has a goal: to keep the pressure within a certain range.

→ machines could act in purposive manner

– concept of feedback explained in 1943 – scientists developing guided missiles

→ feedback allows for purposive behavior

→ concept of information – different mechanical devices could provide same information; e.g. pressure sensor could replace Watt governor
  - what is important is the information that is provided (pressure in the boiler), not the specific mechanism that provides the information

→ idea of computation: possible to build a machine that can do many jobs such as control fuel to a fire or temperature in a room, or insulin dosage in a diabetic person etc using feedback.

Artificial Intelligence (AI)
- Alan Turing – mathematician who helped in WWII in Britain – decoding
- Turing Test – can a machine think? Yes, if its output is indistinguishable from that of a human being.
- goal of AI – create machines that can do the jobs that people do (e.g. translation from one language to another, sort documents, answer questions take messages, solve mathematical problems, play chess etc.)
  - machine may not do the job in the same way as people do; that is machines could use different algorithms
- goal of computer simulation – machines must do the job the same way as humans, that is, use the same "mental processes"

"Pure AI aims to imitate human behavior; computer simulation aims to imitate the human mind." (Leahey, p. 409)

Disentangling Mind and Body: Program and Computer
- 1950s – some psychologists started creating mechanical models for thought processes.
- Donald Broadbent – did research on multiple speech channels after WWII ended. Air traffic controllers received multiple radio messages simultaneously & had to focus on one. What would help them separate and attend to one message?
  - invention of stereo tape recorders --> work on dichotic listening & attention
- Broadbent: think of sensory information not as physical stimuli but as information
  - Information is real but is not a physical thing.

→ "Physical workings of a computer are controlled by the information contained in its running program, but the program is not a substantial soul. Thinking of the mind as information allowed psychologists to have a form of mind-body dualism that escaped the confined of physicalistic behaviourism." Leahey, page 410.

1956 – George Miller's paper "The Magic Number Seven plus or minus two…"
- drew attention to limitations of human attention and short term-memory

Note: Broadbent's model and Miller's paper – deviated from behaviouristic terminology and ideas.

- Leahey (p. 410): distinction between computer & program → cognition (program) could be separated from neurophysiology. A theory of the human mind could be simulated on a computer in any number of ways (e.g. different computer structures, different languages etc.)

→ people described as general-purpose computing devices, born with certain hardware & programmed by experience and socialization

→ Goal of psychology: specification of how humans process information
- information replaces stimuli; information processes replace mediating responses (fractional anticipatory goal responses)

Simulating Human Thought

Newell, Simon, Shaw – 1958 "Elements of a Theory of Problem Solving" – wrote computer programs that simulated human problem solving (problems in symbolic logic)

- the computer program was a "theory"; running the program generated predictions about behavior that could be tested empirically

- NSS built a heuristic strategy (means-ends analysis) into their program to simulate human problem solving (see handout)

- Means-Ends Analysis – program compared starting state (givens) and the goal state (what was to be proven) & found differences.

- program than tried to find an operator that would reduce eliminate the difference

- program had a set of operators (equations) that would eliminate parentheses, objects (letters) or negative signs from an expression

- subgoals permitted

- ran the program to see how it tried to solve problems & compared program's output to output from human participants

Impact of the Information-Processing Metaphor

Newell & Simon published *Human Problem Solving* in 1972. Newell et al's work not followed up immediately by psychologists, but…

- psychology becoming more cognitive in 1960s
  - distinction between long-term learning and short-term memory

  - *Journal of Verbal Learning and Verbal Behaviour* established (Later *Journal of Learning and Memory*)

  - Atkinson & Shiffren (1968) box theory of short-term memory

  - cognitive psychologists discussing mental processes (e.g. covert rehearsal in memory, attention in dichotic listening etc.)

- info. processing language (search sets, pattern recognition, retrieval) used even though programs weren't written.
- after Newell & Simon, people at Carnegie Mellon University did some simulation, e.g. Marcel Just & Patricia Carpenter

- New journals *Cognitive Psychology* (1970), *Cognition* (1972), *Journal of Experimental Psychology* divided into four different journals including *JEP: Human Memory & Learning*.

- 1979 - Lachman, Lachman & Butterfield published *Cognitive Psychology and Information Processing*
- argued that adoption of IP analogy "revolutionized" psychology in Kuhnian sense

<u>Myth of the Cognitive Revolution</u>
- Leahey argues that concept of mediation existed before computers were common→ IP paragdigm did not really add anything new.

- S-R psychologists argued that all mental processed could be modeled by hierarchies and sequences of covert stimuli (s^g) and responses r^g)

- Simon also argued that human behavior could be modeled by a small number of simple behaviours (comparing, noting differences and similarities, selecting a response that achieved a goal etc.)

Leahey: information processing paradigm is a form of behavioralism – we infer mental processes from behavior as did the S – R psychologists.

- I would argue that IP paradigm introduced a new "unit" of behavior – TOTE (test operate, test, exit) unit.

***REVIEW SECTION ON KUHN IN CHAPTER 1

- Miller, Galanter & Pribram – *Plans and the Structure of Behaviour*

- person has a goal & tests to see if goal has been achieved; if so, then exit to new activity.

- if goal has not been achieved, select operation (response) that in the past has either achieved the goal or led you closer.

- implement operation. Implementation may require setting up one or more subgoals in order to be able to implement the goal.

- Has goal been achieved? If no, then look for another operation or abandon the goal if you have exhausted all possible operations.

- Kuhnian paradigm – dictates type of experiments that could be done, types of explanations that were acceptable, etc.
- cognitive research changed completely in 70s and moved to more complex tasks rather than simple learning and problem solving in simple situations.
    - e.g. reaction time used extensively as a dependent variable
- variables introduced that were intended to affect the duration or difficulty of various mental processes (e.g. the number of items that had to be checked to determine whether a particular stimulus had been in the study list)

<u>Informavores: The Subjects of Cognitive Science</u>
- assumption: information-processing systems (humans, animals & computers) operated according to the same principles and therefore constituted a single field study
- goal of human cognitive science was two-fold: (1) to explain higher mental processes in terms of basic information processing operations and their organization; and (2) to specify the neurological processes involved in these information-processing operations.

<u>Newest Definition of Functionalism</u>
- separates program and computer to include human beings – Psychologists can investigate the how the "program" works independently of the hardware (neurophysiology)

- "mind" – set of computational functions that runs the body just as computer program runs on a computer.

- psychologists can understand the programs (mind) without necessarily understanding the neurophysiology.

- computer programs operate on internally stored representations, just as mental operations act on internally stored mental representations. Mental operations are mechanistic rules implemented by neural "hardware"

<u>Challenges of Intentionalilty</u>
- Brentano: mental states refer to something beyond themselves; neurons cannot do this.
- Tolmanian representations (mental maps) represent something & have "intentionality"

- representations havs both semantics and syntax.
    - semantics = meaning (e.g. the meaning of a sentence or picture – what event object, emotion etc. it refers to)
    - syntax = form (e.g. structure of a sentence; composition of a painting)

- functionalism reduces meaning to syntax. Computers operate only on syntax of a representation
- computer doesn't understand words you type. It just enters the word into the Word file, italicizes or bolds it or changes the colour if you so instruct etc.

- e.g. playing chess – human being uses strategies and attempts to "trap" the king by getting certain pieces in certain positions around the king.
  - Chess- playing computer selects a certain move on the basis of programmed rules that dictate which of the permissible operations is the best.

  - person attributes emotions, goals, fears etc to a computer but computer doesn't have these feelings. Computers aren't intentional.

- functionalism – homunculus is replaced by a "committee". Each member of committee does a very simple job (e.g. detects redness or line at a certain angle)

- A computer is "a collection of ninintentional, stupid subsystems carrying out blind computations on syntactically defined representations, following mechanistic rules". Leahey p. 420.

→ Big Question: Can we account for human behavior in terms of functionalism, or do we need concepts like free will?

<u>Is the Turing Test valid?</u>

<u>Chinese Room</u> – person inside receives written questions in Chinese and answers them in Chinese but doesn't know any Chinese.
- Has a rulebook that shows how questions should be answered.
- behavior of person in the Chinese Room is indistinguishable from behavior of a real person.

→ According to Turing Test person in Chinese Room passes & is intelligent.

<u>John Searle</u>: Turing Test is not an adequate measure of intelligence because Chinese Room passes the test without understanding anything.

- weak AI: maintains the distinction between simulation and real intelligence, but strong AI doesn't: claims that simulation of intelligence is the same as real intelligence.
- computers are not biological creations and cannot perform biological functions
-e.g. they can simulate hurricanes or photosysthesis, but can't actually create hurricanes or perform photosynthesis.

- Formalism (a description of something in formal or mathematical terms) – holds that anything people do is a formal procedure and can be described fully in mechanistic terms.

- Formalism in psychology = final development of mechanization of the world picture.
- Searle's argument challenges formalism because it does not provide an understanding of language

Frame Problem also challenges formalism.

- Example of a computer whose goal was to survive. Computer's was informed that its essential spare battery and a bomb were placed on a wagon in a room. The bomb was about to explode.
- Computer decided to pull the wagon with the battery out of the room with the bomb, but ignored the fact that the bomb was also on the wagon.

2nd try – computer was programmed to deduce side effects of its possible actions,
- computer spent all its time deducing every possible side effect until the bomb went off.

3rd try - taught the computer to distinguish between relevant and irrelevant side effects and to ignore irrelevant effects. The computer was very busy ignoring irrelevant effects when the bomb exploded .

- humans and animals react quickly and often effectively to preserve life
- work intuitively (instinctively???) rather than computationally
- adaptive behaviours occur without thought!

The New Connectionism – 1986: *Parallel Distributed Processing: Explorations in the Microstructure of Cognition* by David Rumelhart & others.

- symbol-manipulation computers are single processors that carry out operations one at a time but can be very fast.

- developments in hardware and programming in the 80s that made possible a machine with multiple connected processors that work in parallel and can learn.

- traditional AI unable to get computers to do "simple" tasks that people do easily, in particular to learn

- the brain is a parallel processor with "processing units" in different parts of the brain working on very specific tasks but also co-ordinating efforts so that we perceive a meaningful world

SHOW DIAGRAM OF PDP MODEL HERE

Levels of Computation

- *Cognitive Level*: specified the task to be done (e.g. statistical procedures, word processing etc.)

- *Algorithmic Level*: specifies the type of processing that will be carried out, for example, in a flow diagram.

- *Implementation Level*: specifies how the hardware device will carry out the program instructions (e.g. the same program (e.g. a game) is implemented differently on Iphones and Android devices.

- at algorithmic level, the nature of the hardware is irrelevant; it is the sequence of operations & decisions that is importance

→ Psychologists can talk about mental operations at the algorithmic level without worrying about the implementation (neurophysiological) level.

My App for Teaching Children to Read

1) A short sentence is read to the child first slowly word-by-word, and then again but more quickly and with good expression. Child has the option to repeat or move to the next step.

2) Each new word in the sentence is spelled for the child and the word is spoken. Child has the option to repeat or move to the next step.

3) A word recognition test is given in which the child has to match a spoken word to a written word or a phrase or sentence to a picture. Child has the option to repeat or move to the next step.

4) A spelling test is given on the new words plus some words that had been learned earlier. Child has the option to repeat or move to the next step.

5) Step 1 is repeated. Child has the option to repeat or move to the next step.

Conscious & Intuitive Processors

- consider someone learning a skill (skiing, playing the piano, riding a bike, learning to do arithmetic, coding in a computer language)

    - at first, the task requires a lot of effort, hints are needed & a good instructor helps, learner often has to refer to manual, many errors are made etc.

    - with practice – task requires less effort, hints & reference to a manual not needed, errors are reduced
        - and attention is given not to specific responses, but to the bigger picture

- Smolensky – distinguished between the conscious and intuitive processors

- some processes of the intuitive processor are not conscious and never were; e.g. learning the rules of language
    - admire vs admiration; divine vs divinity, resign vs resignation, inspire vs inspiration
    - lingistic rule operating - many dyslexics don't apply the rule when learning to read

- Rule-following behavior: Newton's laws of motion: planets follow the rules (Newton's formulas) but the planets don't "calculate" their paths and then use the calculations to guide their movement.
    - children learning language: One zag → two ? One weet → two ?
    → children & adults usually not aware of the rule they are following

- as scientists we assume that human behavior is rule-governed (determined) and that we can figure out what the rules are. (If not, there is no science of psychology.)

- according to symbol-system view (information processing view), both conscious and intuitive processors are both rule governed and rule following

- according to connection theorists, human behavior is rule-following only at the conscious level; in the intuitive processor something quite different happens

    - e.g. doing a statistical test – consciously follow the procedures taught in stats course.

- "According to connectionism, the intuitive processor lies between the conscious mind—the conscious processor--and the brain that implements human intelligence" (Leahey, p 428).

Cognitive Neuroscience

- human mind = combination of conscious & intuitive processors

- conscious problem solving (Type 2 thinking) involves conscious serial processor
  - rational, slow, systematic step-by-step thinking
  - usually learned through instruction
  - usually symbolic (verbal or mathematical)

- Type 1 thinking – intuitive, rapid, not linear, not symbolic (not systematic, step-by-step)

- virtual calculator on your computer is a program to do calculations, but is not a physical machine

Daniel Dennett: conscious is a virtual machine installed by socialization on the brain's parallel processor.
- socialization gives us language – we speak, hear and think one word at a time; i.e. language is a serial processor

- animals more likely than humans to rely on instinct & built-in behaviours (e.g. spiders building webs) whereas human more likely to adapt to environment by changing their programs (ie, learning new skills)

Embodied Cognition – opposes the Cartesian Paradigm

Tenets of Cartesian Paradigm
Computationalism: cognition consists of digital manipulation of representations by formal logical rules
Neurocentrism: cognitive processes located exclusively in the brain
Bodily Indifference: the physical structure of the computational system has little bearing on its cognitive processes
Separability Thesis: mental processes are completely separable from the physical device that executes them

- followers of embodied cognition: intelligence is based on bodily interactions with the world. Brain processes alone do not explain animal intelligence.

- Aglioti et al. (2008) –showed videos of basketball players shooting free throws
    - video stopped at various points
    - participants: skilled basketball players, basketball coaches, sports journalists.
    - only skilled players could predict whether shot was good & could predict it if video stopped before ball left shooters hand

→ only players had the "bodily" knowledge to "feel" the movement & judge correctly
- "…the body intuitively *knows*; it does not compute."