PSYCO 457
Week 4: Situated Cognition and Bricolage

The Classical Sandwich
From Planning to Action
The Leaky Mind
Bricolage

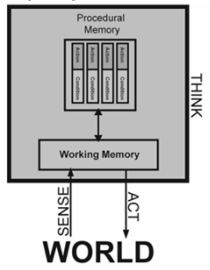
Preliminary Discussion

- **Seeking comments or questions concerning the main themes of readings to this point in "From Bricks To Brains" and in "Embodied Cognition"**

A Classical Architecture

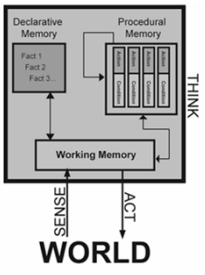
- **One of the most prototypical architectures of classical cognitive science is the production system developed by Newell and Simon**

Herbert Simon and Allen Newell



Classical Evolution

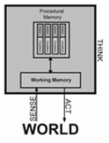
- **Anderson modified Newell and Simon's work by introducing a declarative memory and a mechanism for learning.**
- **The resulting production system was called ACT (for *adaptive control of thought*)**

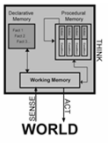


John R. Anderson

Sense-Think-Act

- **The early production systems of Newell, Simon, and Anderson are all prototypical examples of the sense-think-act cycle that defines classical cognitive science**
- **Sensing and acting are external to thinking. Thinking processes inputs from senses, and then decides what actions to execute**
  - **"One problem with psychology's attempt at cognitive theory has been our persistence in thinking about cognition without bringing in perceptual and motor processes" (Newell, 1990, p. 15).**
  - **The ACT architecture "historically was focused on higher level cognition and not perception or action" (Anderson et al., 2004, p.1038).**





The Primacy of Planning

- **The primacy of planning in classical cognitive science is seen in early robotic research**
- **For example, most of the computer hardware for Nilsson's robot Shakey used the STRIPS language to plan the robot's next actions**
- **Shakey took extremely long to solve its various tasks, illustrating the cost of extensive planning**

Nils Nilsson

Shakey

The Classical Sandwich

- Shakey, production systems, and classical cognitive science in general emphasize thinking or planning at the expense of sensing and acting
- Sensing and acting are peripheral processes that sandwich (the more important) thinking
- Hurley called this the classical sandwich
- The classical sandwich is now being challenged by alternative views, such as those of roboticist Rodney Brooks
- What if the purpose of cognition is not to plan, but rather to control our actions?
- Why plan with a costly model of the world, when we can act on the world that is there for us to sense?


Susan Hurley


Rodney Brooks

The Logic of Action

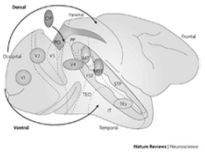
- Why should action become more important in cognitive theories?
- Theories of cognitive development, which culminate in formal processes that are swayed by logicism, have long argued that cognition is derived from action
  - Piaget concluded that formal abilities like classification and seriation are "closely linked with certain actions which are quite elementary: putting things in piles, separating piles into lots, making alignments, and so on" (Inhelder & Piaget, 1964, p. 291).
  - "The starting-point for the understanding, even of verbal concepts, is still the actions and operations of the subject" (Inhelder & Piaget, 1964, p. 284).


Bärbel Inhelder


Jean Piaget

The Acting Brain

- Cognitive neuroscience supports the notion that the brain is an organ of control
- Goodale has studied brain injured patients who cannot classify or recognize objects, but can still act upon them with exquisite precision
- His duplex theory challenges the old what/where distinction between dorsal and ventral pathways in the brain
  - "The functional distinction is not between 'what' and 'where', but between the way in which the visual information about a broad range of object parameters are transformed either for perceptual purposes or for the control of goal-directed actions" (Goodale & Humphrey, 1998, p. 187).

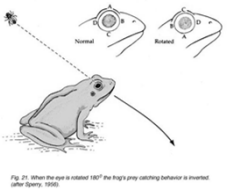



Mel Goodale

Visuomotor Modules In The Brain

- Sperry surgically rotated a frog's eye, and then let retinal connections regenerate
- An inversion of the eye produced an inversion of prey catching behavior, indicating a rewiring of a vertical module
  - "The visual system of most animals, rather than being a general-purpose network dedicated to reconstructing the rather limited world in which they live, consists instead of a set of relatively independent input-output lines, or visuomotor 'modules', each of which is responsible for the visual control of a particular class of motor outputs (Goodale & Humphrey, 1998, p. 183).


Roger W. Sperry

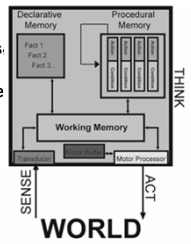


Productive Actions

- The importance of sensing and acting have caused them to be modeled more explicitly in modern production systems, such as Meyer and Kieras' EPIC
- Note, though, that EPIC still employs the classical sandwich!


David Kieras


David Meyer



Beyond The Sandwich

- Cognitive neuroscience supports the claim that at least some processing is sense-act, not sense-think-act
- Behavior-based roboticists attempt to remove thinking or representation to speed processing up
- Both of these streams recognize that the world (outside of agents) can support computation – a huge reaction against classical cognitive science
  - "In particular I have advocated situatedness, embodiment, and highly reactive architectures with no reasoning systems, no manipulable representations, no symbols, and totally decentralized computation" (Brooks, 1999, p. 170).


Rodney Brooks


Genghis

Cognitive Scaffolding

- **The world can also be used to carry out or support computations, again freeing resources**
  - **"By failing to understand the source of the computational power in our interactions with simple 'unintelligent' physical devices, we position ourselves well to squander opportunities with so-called intelligent computers" (Hutchins, 1995, p. 171).**
- **This is called *cognitive scaffolding***
  - **"Advanced cognition depends crucially on our abilities to dissipate reasoning: to diffuse knowledge and practical wisdom through complex social structures, and to reduce the loads on individual brains by locating those brains in complex webs of linguistic, social, political, and institutional constraints" (Clark, 1995).**

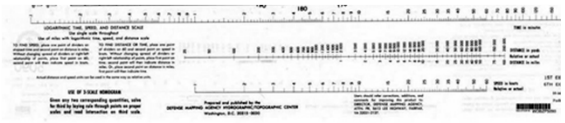
Edwin Hutchins

Andy Clark

Nomograms And Other Examples

- **A nomogram is a graphical tool that is an example of scaffolding**
  - **"It seems that much of the computation was done by the tool, or by its designer. The person somehow could succeed by doing less because the tool did more" (Hutchins, 1995, p. 151)**
- **Can you think of other scaffolding examples?**

Maneuvering board



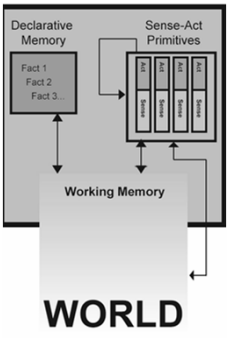
The Leaky Mind

- **Scaffolding causes incredible rethinking of the locus of an agent's intelligence**
- **It as if the mind has leaked into the world!**
  - **"It is the human brain plus these chunks of external scaffolding that finally constitutes the smart, rational inference engine we call mind" (Clark, 1995, p. 180)**
- **The world can serve as a common memory, or computing device, for groups of agents to think collectively**
  - **"Organized groups may have cognitive properties that differ from those of the individuals who constitute the group" (Hutchins, 1995)**

Robert Wilson

Porous Production System

- **As in Goodale's duplex theory, there may be a need for both sense-act and sense-think-act processing**
- **"Minds may be essentially embodied and embedded and still depend crucially on brains which compute and represent" (Clark, 1997, p. 143)**
- **Production systems could be modified to reflect traditional computation as well as processes that have leaked into the world**
- **Productions can sense, and act on, internal or external representations in this model**

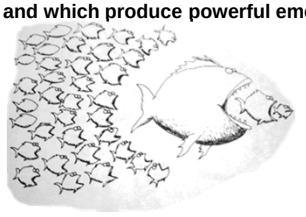


Stigmergic Thought

- **By leaking the working memory of a production system into the world, and by letting at least some sense-act processing proceed (without using internal representations), the control of a production system becomes very familiar – *stigmergy!***
- ***When working memory leaks into the world via scaffolding, cognitive control becomes as stigmergic as a wasp nest's control of its own creation***

Decentralized Control

- **Scaffolding, and sense-act processing, remove control from central cognitive processing in the classical sandwich**
- **The result is collective power – individual agents (sense-act processes) that are stigmergically controlled, and which produce powerful emergent results**



Resource Allocation Issues

- In the "leaky production system", four different resources must be allocated:
  - Productions that sense the world, and act on the world
  - Productions that sense memory, and act on memory
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  - Productions that sense memory, and act on the world
- Cognition must proceed by choosing, in some way, what kinds of productions to use to obtain some result
  - "Creatures will neither store nor process information in costly ways when they can use the structure of the environment and their operations upon it as a convenient stand-in for the information-processing operations concerned. That is, know only as much as you need to know to get the job done" (Clark's 1989 007 principle)
- The same problem might be solved with different resources at different times – mental bricolage!
  - "The 'bricoleur' is adept at performing a large number of diverse tasks; but, unlike the engineer, he does not subordinate each of them to the availability of raw materials and tools conceived and procured for the purpose of the project. His universe of instruments is closed and the rules of his game are always to make do with 'whatever is at hand'" (Lévi-Strauss, 1966)

Claude Levi-Strauss

The Power of Bricolage

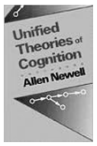
- Levi-Strauss introduced the notion of bricolage, but did so in a way that disparaged it in comparison to "classical" thought
  - "The 'bricoleur' is still someone who works with his hands and uses devious means compared to those of a craftsman"
- Modern researchers view bricolage as a distinct, powerful style of thinking – because of its nonlinearity
- This style of thinking is modern, and is consistent with decentralized theories
  - Turkle describes bricolage as a sort of intuitive tinkering, a dialogue mediated by a virtual interface. "As the computer culture's center of gravity has shifted from programming to dealing with screen simulations, the intellectual values of bricolage have become far more important. […] Playing with simulation encourages people to develop the skills of the more informal soft mastery because it is so easy to run 'What if?' scenarios and tinker with the outcome" (1995, p. 52)

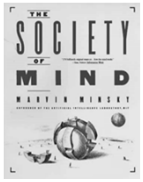
Claude Levi-Strauss

Sherry Turkle

Unified Theories vs Societies of Mind

- Production systems seek unified theories of mind
  - "All the higher cognitive processes, such as memory, language, problem solving, imagery, deduction and induction, are different manifestations of the same underlying system" (Anderson, 1983
- Collections of agents of diverse types, which somehow produce emergent phenomena, are theories of mind that are not unified
  - "The operations of our minds do not depend on similarly few and simple laws, because our brains have accumulated many different mechanisms over aeons of evolution. This means the psychology can never be as simple as physics, and any simple theory of mind would be bound to miss most of the 'big picture'. The science of psychology will be handicapped until we develop an overview with room for a great many smaller theories" (Minsky, 1985)





Make Room For Smaller Theories

- How do we make room for smaller theories?
- We can adopt forward engineering, or what Braitenberg calls the synthetic approach
- Put a system together from interesting components – as bricoleurs must – and see what surprises emerge from simple theories or models
  - "Only about 1 in 20 'gets it' -- that is, the idea of thinking about psychological problems by inventing mechanisms for them and then trying to see what they can and cannot do" (Minsky, 1995, personal communication)
  - "Analysis is more difficult than invention in the sense in which, generally, induction takes more time to perform than deduction: in induction one has to search for the way, whereas in deduction one follows a straightforward path" (Braitenberg, 1984)
- In other words, to model societies of mind, cognitive scientists must practice bricolage

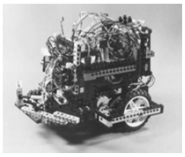
Marvin Minsky

Valentino Braitenberg

Synthetic Example

- One example of the synthetic approach is Webb's use of robots to study cricket phonotaxis
- The original cricket robot was built from LEGO
- The model of phonotaxis uses two auditory neurons, which drive two motor neurons
- The behavior of the robot makes it appear as if it is doing signal processing – which it is not!
  - "Thus it is clear from our results that much of the evidence for the standard 'recognize and localize' model of phonotaxis in crickets is insufficient to rule out an alternative, simpler model" (Webb & Scutt, 2000, pp. 265-266)

Barbara Webb



Verum-Factum

- Classical cognitive science is rooted in the philosophy of Rene Descartes
- Connectionist cognitive science appeals to British empiricists like John Locke
- The synthetic approach of embodied cognitive science is rooted in the philosophy of Giambattista Vico (1668-1744), who critiqued both Descartes and Locke
- Vico's philosophy is based on the central assumption that the Latin term for truth, *verum*, was identical to the Latin term *factum:*
  - "It is reasonable to assume that the ancient sages of Italy entertained the following beliefs about the true: 'the true is precisely what is made'"
  - "To know (*scire*) is to put together the elements of things"

Giambattista Vico

Mind and Method

- **If intelligence is the product of an embodied society of mind, if cognizing systems are bricoleurs, then how should cognitive science proceed? One promising approach is for researchers to think like the systems that they study – to become bricoleurs themselves. The synthetic approach, which assembles available elements into embodied agents whose surprising behavior exceeds what might be expected of their simple components, is an example of a cognitive science that depends upon 'tinkering'**

Building Bricoleurs

- **The embodied view of mind seems very difficult for practicing cognitive scientists to fully embrace**
- **So how should we build the bricoleurs who may be the future of cognitive science?**
  - **"We cannot understand what is special and distinctively powerful about human thought and reason by simply paying lip service to the importance of the web of surrounding structure. Instead, we need to understand in detail how brains like ours dovetail their problem-solving activities to these additional resources, and how the larger systems thus created operate, change, and evolve" (Clark, 2003)**
- **One approach to such detailed understanding – to be explored in this course – is to provide hands-on experience with LEGO robots**