Psychology 354
The Cognitive Dialectic

Thesis And Antithesis In Cognitive Science
Synthesis In Cognitive Science?
Natural Computation And Synthesis
Synthetic Psychology And A Cognitive Synthesis

Dialectic

- **Hegel's dialectic logic viewed ideas as evolving towards truth and unity in the following progression**
- **Develop a position (Thesis)**
- **Develop an antagonistic position (Antithesis)**
- **Develop a combination of thesis and antithesis that leads towards truth (Synthesis)**
  - **"The bud disappears when the blossom breaks through, and we might say that the former is refuted by the latter; in the same way when the fruit comes, the blossom may be explained to be a false form of the plant's existence, for the fruit appears as its true nature in place of the blossom. The ceaseless activity of their own inherent nature makes these stages moments of an organic unity, where they not merely do not contradict one another, but where one is as necessary as the other; and constitutes thereby the life of the whole" (Hegel, preface to *The Phenomenology of Spirit*, 1807)**

Georg Hegel

A Cognitive Dialectic

- **"Dialectical progression depends upon having a critical tradition that allows current beliefs (theses) to be challenged by alternative, contrasting, and sometimes even radically divergent views (antitheses), which may then lead to the origination of new ideas based on the old (syntheses)" (Sternberg, 1999, p. 52)**
- **Robert Sternberg has argued that cognitivism can be characterized as such a dialectical progression**
  - **What is the thesis?**
  - **What are the antitheses?**
  - **Has there been a synthesis of these opposing ideas?**

Robert Sternberg

A Classical Thesis

- **In cognitive science, the classical approach represents the thesis**

Word cloud created from Chapter 3

Classical Characteristics

	Classical Cognitive Science
Core Ideas	• Mind as a physical symbol system • Mind as digital computer • Mind as planner • Mind as creator and manipulator of models of the world • Mind as sense-think-act processing
Preferred Formalism	Symbolic logic
Tacit Assumption	Nativism, naïve realism
Type of Processing	Symbol manipulation
Prototypical Architecture	Production system (Newell, 1973)
Prototypical Domain	• Language • Problem solving
Philosophical Roots	• Hobbes • Descartes • Leibniz • Craik
Some Key Modern Theorists	• Chomsky • Dennett • Fodor • Pylyshyn
Some Pioneering Works	• *Plans And The Structure Of Behavior* (Miller, Galanter, & Pribram, 1960) • *Aspects Of The Theory Of Syntax* (Chomsky, 1965) • *Human Problem Solving* (Newell & Simon, 1972)

A Connectionist Antithesis

- **Connectionism is one key antithesis in cognitive science**

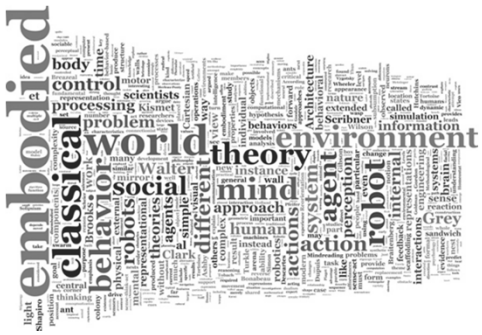
Word cloud created from Chapter 4

Connectionist Characteristics

	Connectionist Cognitive Science
Core Ideas	• Mind as information processor, but not as a digital computer • Mind as a parallel computer • Mind as pattern recognizer • Mind as a statistical engine • Mind as biologically plausible mechanism
Preferred Formalism	Nonlinear optimization
Tacit Assumption	Empiricism
Type of Processing	Pattern recognition
Prototypical Architecture	Multi-layer perceptron (Rumelhart, Hinton, & Williams, 1986)
Prototypical Domain	• Discrimination learning • Perceptual categorization
Philosophical Roots	• Aristotle • Locke • Hume • James
Some Key Modern Theorists	• J.A. Anderson • Hinton • Kohonen • McClelland
Some Pioneering Works	• *Principles Of Neurodynamics* (Rosenblatt, 1962) • *Parallel Models Of Associative Memory* (Hinton & Anderson, 1981) • *Parallel Distributed Processing* (McClelland & Rumelhart, 1986; Rumelhart & McClelland, 1986b)

An Embodied Antithesis

- **Embodied cognitive science is a second antithesis**



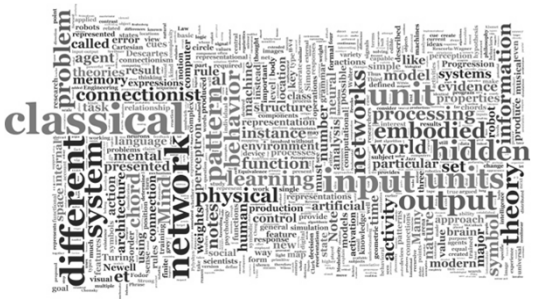
Word cloud created from Chapter 5

Embodied Characteristics

	Embodied Cognitive Science
Core Ideas	•Mind as controller of action •Mind emerging from situation and embodiment, or being-in-the-world •Mind as extending beyond skull into world •Mind as sense-act processing
Preferred Formalism	Dynamical systems theory
Tacit Assumption	Embodied interaction
Type of Processing	Acting on the world
Prototypical Architecture	Behavior-based robot (Brooks, 1989)
Prototypical Domain	• Locomotion • Social interaction
Philosophical Roots	• Vico • Dewey • Heidegger • Merleau-Ponty
Some Key Modern Theorists	• Brooks • Clark • Noë • Wilson
Some Pioneering Works	• *Cognition And Reality* (Neisser, 1976) • *The Ecological Approach To Visual Perception* (Gibson, 1979) • *Understanding Computers And Cognition* (Winograd & Flores, 1987)

A Cognitive Synthesis?

- **Is synthesis possible in cognitive science? It seems easier to find key differences amongst the three approaches**



Word cloud created from Chapters 3, 4 and 5 combined

Comparing Cognitive Sciences

	Classical Cognitive Science	Connectionist Cognitive Science	Embodied Cognitive Science
Core Ideas	•Mind as a physical symbol system •Mind as digital computer •Mind as planner •Mind as creator and manipulator of models of the world •Mind as sense-think-act processing	•Mind as information processor, but not as a digital computer •Mind as a parallel computer •Mind as pattern recognizer •Mind as a statistical engine •Mind as biologically plausible mechanism	•Mind as controller of action •Mind emerging from situation and embodiment, or being-in-the-world •Mind as extending beyond skull into world •Mind as sense-act processing
Preferred Formalism	Symbolic logic	Nonlinear optimization	Dynamical systems theory
Tacit Assumption	Nativism, naïve realism	Empiricism	Embodied interaction
Type of Processing	Symbol manipulation	Pattern recognition	Acting on the world
Prototypical Architecture	Production system (Newell, 1973)	Multi-layer perceptron (Rumelhart, Hinton, & Williams, 1986)	Behavior-based robot (Brooks, 1989)
Prototypical Domain	• LProblem solving • anguage	• Discrimination learning • Perceptual categorization	• Locomotion • Social interaction
Philosophical Roots	• Hobbes • Descartes • Leibniz • Craik	• Aristotle • Locke • Hume • James	• Vico • Dewey • Heidegger • Merleau-Ponty
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Potential For Synthesis

- **There is potential for synthesis in cognitive science**
- **No defining 'marks of the classical' to clearly distinguish classical theories from others**
- **Existence of hybrid theories that exploit ideas from all three approaches**
  - **Seeing and visualizing**
  - **Cognitive science of music**
  - **Art of memory**
- **Structural similarities between the three approaches**
  - **Four levels of investigation**
  - **Cognition as some kind of information processing**
  - **Differing emphasis on three contributors (mind, body, environment)**
- **Calls for studies of "whole cognition" or cybernetic inspiration (though often ignored!)**
  - **Plans and the Structure of Behavior**
  - **Neisser**
  - **Norman**

Ulric Neisser

Donald Norman

Resisting Synthesis

- **Classical researchers acknowledge that they have neglected aspects of cognition that are critical to antitheses**
- **One reason for this, which prevents synthesis, is that the classical approach arose as a stark rebuttal to behaviorism, rejecting environment and rejecting associationism**
  - **"We were not out to 'reform' behaviorism, but to replace it" (Bruner, 1990, p. 3)**
  - **The cognitive revolution "was not one of finding new positives to support the important role of cognition, many of which were already long evident. Rather, the story is one of discovering an alternative logic by which to refute the seemingly incontestable reasoning that heretofore required science to ostracize mind and consciousness" (Sperry, 1993, p. 881)**

Jerome Bruner

Roger Sperry

Breaking Down The Resistance

- **How can the classical approach's resistance to synthesis be broken down?**
- **One approach may be to consider more carefully the theoretical perspectives that guided its pioneers:**
  - **"A man, viewed as a behaving system, is quite simple. The apparent complexity of his behavior over time is largely a reflection of the complexity of the environment in which he finds himself" (Simon, 1969, p. 25)**
- **Another approach may be to consider the advantages of abandoning ideology and of taking a more pragmatic approach to understanding human information processing**
  - **Marr's natural computation approach**

Herbert Simon

David Marr

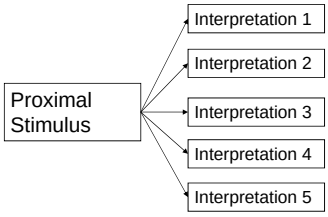
Pragmatic Natural Computation

- **Vision scientist David Marr's (1945-1980) work on natural computation in vision provides an excellent example of a synthesis of the different approaches to cognitive science**
- **This synthesis resulted from a pragmatic view of what is needed to make viable theories of vision**
- **Excluding an approach for ideological reasons, or calling some aspects 'cognitive' and others not, was foreign to Marr's natural computational view**

David Marr

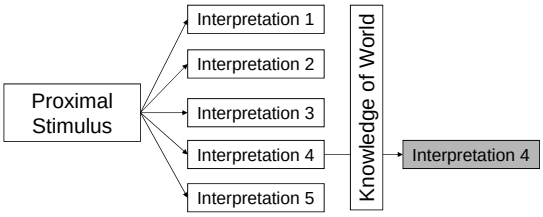
Why Is Vision Hard?

- **Vision is hard for computers because the proximal stimulus underdetermines the kinds of visual interpretations that we can make**
- **Why is it underdetermined?**
  - **3D to 2D projection loses information**
  - **Local measurements underdetermine global properties**



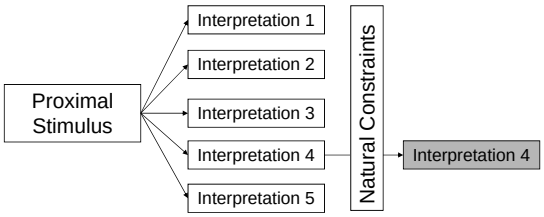
The New Look

- **Theories in vision have to solve the problem of underdetermination**
- **How do you add missing information to overcome the poverty of the proximal stimulus?**
- **A classical solution to this problem – the New Look – argued that general knowledge of the world was added**



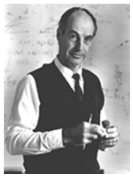
Natural Computation

- **Marr's natural computation approach reacted against the New Look**
- **Built-in natural constraints were presumed to be used to solve the problem of underdetermination**
- **But Marr's approach was still representational**
  - **"Vision is a process that produces from images of the external world a description that is useful to the viewer" (Marr, 1982, p. 31)**



What Are Natural Constraints?

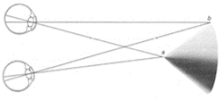
- **A physical, not psychological, property that is almost always true of the world**
- **Can be used to generate unique, correct solutions to problems of underdetermination**
- **Constraints are exploited as follows:**
- **Choose the interpretation that is**
  - **consistent with the proximal stimulus**
  - **consistent with the natural constraints being exploited**
- **The trick is to find the right natural constraints to make this approach work**



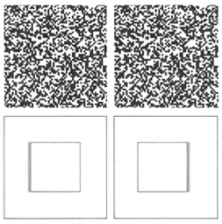
Whitman Richards

Case Study: Stereopsis

- **Binocular vision provides a power source of information about depth, stereopsis**
- **However, computing depth from stereopsis requires solving problems of underdetermination**
- **Stereo correspondence problem: how do we match a point in the left eye image to the corresponding point in the right eye image?**



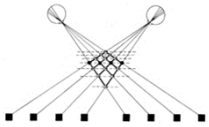
Depth from stereo disparity



Random-dot stereograms

Constraining Stereo Correspondence

- Matching points between stereo images is intrinsically underdetermined
- Marr and Poggio (1976) proposed three natural constraints to deal with this problem
  - Compatibility constraint:
    - only match elements that could only be associated with the same element
  - Uniqueness constraint:
    - only make one-to-one matches between images
  - Continuity constraint:
    - assign matches such that disparity varies smoothly across the image
- Note that these constraints are all natural in the sense that they are argued to be the result of general properties of the visual world

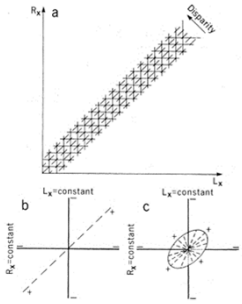


Underdetermination of stereo correspondence

Tomaso Poggio

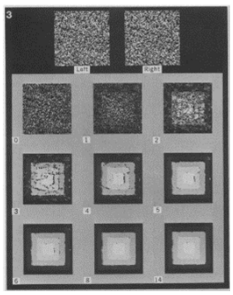
Correspondence Algorithm

- How do you use these natural constraints to compute stereo matches?
- For each possible match, place a processor
- Let connections amongst the processors enforce the natural constraints
- Signals between processors causes the network to relax into a low energy state that only turns on the processors for correct matches
- Note that this exploits the properties of artificial neural networks



Performance Of Algorithm

- Marr and Poggio (1976) presented several examples of the excellent performance of this algorithm
- In the example to the right, the numbered images show the disparity maps provided by the processors at different iterations of network processing
- Later versions of the algorithm were proposed to enhance its biological plausibility

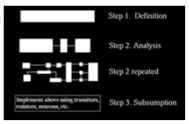


Implications For Synthesis

- Marr's need to develop pragmatic accounts of vision produced natural computation theories that represent a true cognitive synthesis
  - The theory is classical, in the sense that it is representational
  - The theory is embodied, in the sense that natural constraints are properties of the external world
  - The theory is connectionist, in the sense that it exploits natural constraints using biologically plausible networks
- Natural computation can teach cognitive science important lessons!

Classical Analysis

- **Classical cognitive science has been successful, and is comfortable with an analytic approach to mind**
- **Reverse engineering**
  Collect data first
  Build model from data
- **Cummins' functional analysis**
  "Perhaps the most extensive use of the analytical strategy in science occurs in psychology, for a large part of the psychologist's job is to explain how the complex behavioral capacities of organisms are acquired and how they are exercised. Both goals are greatly facilitated by analysis of the capacities in question"



Robert Cummins

Embodied Synthesis

- **Synthetic methods seem to be the province of embodied cognitive science**
- **Forward engineering**
  - **Build model first**
  - **Collect data from model**
- **Braitenberg's synthetic psychology**
  - **"We have to distinguish between the perspective of an observer looking at an agent and the perspective of the agent itself. In particular, descriptions of behaviour from an observer's perspective must not be taken as the internal mechanisms underlying the described behaviour" (Pfeiffer & Scheier, 1999)**

Christian Scheier

Rolf Pfeiffer

Bricolage And Forward Engineering

- **Forward engineering is an alternative to classical analysis**
- **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)**
- **Forward engineering focuses on using materials 'at hand', and therefore is strongly related to a concept called bricolage**

Marvin Minsky

Valentino Braitenberg

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 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)**
  - **"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 powerful style of thinking**
  - **"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" (Turkle, 1995, p. 52)**

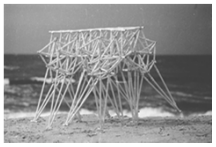
Claude Levi-Strauss

Sherry Turkle

The Great Pretender

- For one example of synthetic psychology as bricolage, consider the work of Dutch sculptor Theo Jansen
- The synthetic approach can be used to create multi-legged walkers without extant analysis
- Rather than analyzing what makes a gait "lifelike", Jansen explored, from the ground up, configurations of tubing that resulted in amazingly lifelike, many-legged, walking sculptures
  - "I want to make everything out of plastic tubing. Just as nature as we know it consists largely of protein, I want to make my own life-forms from a single material" (Jansen, 2007, p. 35).

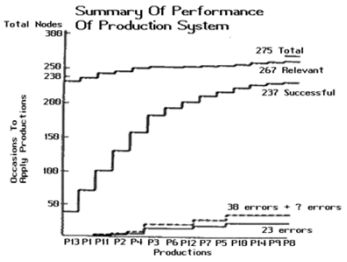
Theo Jansen



Strandbeest

Classical Synthesis

- Synthesis and bricolage are not foreign to the classical approach
- Newell and Simon used materials 'at hand' – available productions – to see what happened with production systems of different sizes
- As they added productions, fit to verbal protocol data improved



Synthetic Strandbeest

- Jansen's approach to Strandbeest construction reflects many of the fundamental properties of the synthetic approach, and its relation to bricolage
  - "Remarkably, chance is more likely to play a role when there are restrictions. Financial restrictions, for example, may mean that drawers in the workplace stay closed. This necessitates looking for other possibilities elsewhere. During this search new ideas automatically emerge, ideas that are often better than the ones you first had. Again, the restrictions of the plastic tubing oblige you to look for technical solutions that are less than obvious" (p. 37)
- Finding such restrictions may be why forward engineering is apt for a cognitive dialectic

Synthesis By Synthesis

- Dawson argues that the synthetic approach might induce a cognitive synthesis because it will lead to 'roadblocks' that can only be overcome by exploiting ideas from other schools of thought
- "The synthetic approach provides a route that takes a cognitive scientist to the limits of their theoretical perspective. This in turn will produce a theoretical tension that will likely only be resolved when core elements of alternative perspectives are seriously considered" (Dawson, 2011, Chap. 9)

Learning More About Synthesis

- **If you are interested in learning more about synthetic approaches in cognitive science, then you might be interested in the following courses:**
- **PSYCO 452 (Winter, 2012) "Minds and Machines"**
  - **Hands-on training with PDP networks**
  - **Connectionism as synthetic psychology**
- **PSYCO 457 (Fall, 2012) "Embodied Cognitive Science"**
  - **Hands-on training with LEGO robots**
  - **Behavior-based robotics and embodied cognitive science**