Psychology 354
Marks of the Classical

Reacting To Situated Cognition
Are There Marks Of The Classical?
Hybrid Possibilities

Culture Clash

- **"The social structure of science is such that individual scientists will justify the claims for a new approach by emphasizing the flaws of the old, as well as the virtues and goodness of the new. Similarly, other scientists will justify the continuation of the traditional method by minimizing its current difficulties and by discounting the powers or even the novelty of the new" (Norman, 1993, p. 3).**
- **The three different approaches to cognitive science can be seen as engaging in this kind of competitive debate**
- **One example of this debate is the exchange between classical cognitive science and situated cognition, which is a form of embodied cognitive science**

Donald Norman

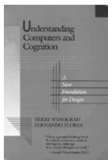
Pioneering The Embodied Approach

- **In 1972, Terry Winograd was a pioneer in programming computers to understand language. By 1987, he and Fernando Flores published a pioneering book on the embodied approach that abandoned such earlier work**
- **"Our position, in accord with the preceding chapters, is that computers cannot understand language" (Winograd & Flores, 1987b, p. 107).**

- **Rejecting the disembodied mind and the methodological solipsism of classical cognitive science, Winograd and Flores' argued instead for an embodied, radically non-rational, account of meaning: "Meaning always derives from an interpretation that is rooted in a situation" (Winograd & Flores, 1987b, p. 111).**

Situated Impact

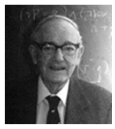
- ***Understanding Computers and Cognition* had an immediate impact**
- **According to Google Scholar it has been cited thousands of times**
- **The journal *Artificial Intelligence* published four reviews of it in the same issue, along with an editorial, because the nature of the reviews indicated that the book was controversial**
- **People took notice of the book's perspective, and classical cognitive science reacted to it**



Making Situated Action Classical

- **One reaction argued against the 'novelty of the new' of situated action**
- **Vera and Simon objected to situated action research denying "that intelligent systems are correctly characterized as physical symbol systems, and especially denies that symbolic processing lies at the heart of intelligence" (Vera & Simon, 1993, pp. 7-8)**
- **Vera and Simon then proceeded to argue that situated action could easily be incorporated into a classical theory that used production systems**
- **"We find that there is no such antithesis: SA systems are symbolic systems, and some past and present symbolic systems are SA systems" (Vera & Simon, 1993, p. 8).**

Alonso Vera



Herbert Simon

Example: Readiness-To-Hand

- **One example of dismissing SA's novelty is in Vera and Simon's treatment of readiness-to-hand, a concept inspired by Heidegger's notion of *Dasein***
- **Winograd and Flores took readiness-to-hand as evidence of direct engagement with the world; we only become aware of equipment itself when the structural coupling between world, equipment, and agent breaks down**
- **The classical reply: "Awareness has nothing to do with whether something is represented symbolically, or in some other way, or not at all" (Vera & Simon, 1993, p. 19). That is, consciousness of contents is not a defining feature of physical symbol systems**

Martin Heidegger

An Alternative Response

- An alternative classical response to embodied cognitive science is to accentuate differences, and then point out that the different characteristics of the embodied approach produce fatal flaws
- Adams and Aizawa illustrate this move in their book *The Bounds Of Cognition*
- They argue that one flaw of the extended mind hypothesis is its "insufficient attention to what makes a process cognitive. By largely ignoring what it means for something to be cognitive … one can make the hypothesis of extended cognition seem more plausible" (Adams & Aizawa, 2008, p. ix).

Fred Adams

Ken Aizawa

The Mark Of The Cognitive

- Adams and Aizawa argue that there must be some properties that distinguish 'cognition' from other entities -- the mark of the cognitive
- Adams and Aizawa's central argument against the extended mind is that it fails to provide such required features
- "If one thinks that cognitive processing is simply any sort of dynamical system process, then – so understood – cognitive processing is again likely to be found spanning the brain, body and environment. But, so understood, cognitive processing will also be found in the swinging of a pendulum of a grandfather clock or the oscillations of the atoms of a hydrogen molecule. Being a dynamical system is pretty clearly insufficient for cognition or even a cognitive system" (Adams & Aizawa, 2008, p. 23)

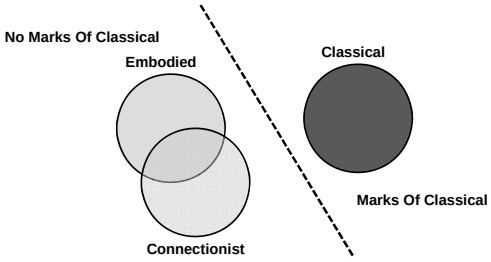
Marks Of The Classical

- Embodied (and connectionist) researchers would disagree with claims that characteristics of their approach are fatally flawed
- They would agree, though, that their theories are qualitatively different than classical approaches. Only if such differences exist could they make claims of 'paradigm shift', etc.
  - "During my earlier years as a postdoc at MIT, and as a junior faculty member at Stanford, I had developed a heuristic in carrying out research. I would look at how everyone else was tackling a certain problem and find the core central thing that they all agreed on so much that they never even talked about it. I would negate the central implicit belief and see where it led. This often turned out to be quite useful" (Brooks, 2002, p. 37)
- Are there key features – marks of the classical – that can be used to distinguish a classical theory from a connectionist theory, or from an embodied theory?

Rodney Brooks

If Classical Marks Exist…

- … then classical theories are qualitatively different than alternatives, which may or may not share features that distinguish them from one another



Control

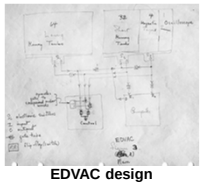
- Control is required to determine "what to do next" – to choose which primitive operation is to be applied at any given moment.
- "Beyond the capability to execute the basic operations singly, a computing machine must be able to perform them according to the sequence – or rather, the logical pattern – in which they generate the solution of the mathematical problem that is the actual purpose of the calculation in hand" (von Neumann, 1958, p. 11)

John von Neumann

Centralized Control

- One potential mark of the classical is centralized control
- One of the innovations of EDVAC's design was the inclusion of a central controller
- The central controller had the task of fetching, interpreting and executing an instruction from memory, and then repeating this process after proceeding to the next instruction in the sequence
- Von Neumann called the central controller "the central control organ"

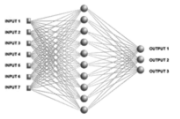
Von Neumann with the EDVAC



EDVAC design

Decentralized Control

- Reactions to classical theories would claim that their theories abandoned centralized control
- "There is one final aspect of our models which is vaguely derived from our understanding of brain functioning. This is the notion that there is *no central executive* overseeing the general flow of processing" (Rumelhart & McClelland, 1986 p. 134)
- "The realization was that the so-called central systems of intelligence – or core AI as it has been referred to more recently – was perhaps an unnecessary illusion, and that all the power of intelligence arose from the coupling of perception and actuation systems" (Brooks, 1999)



Brooks' Genghis

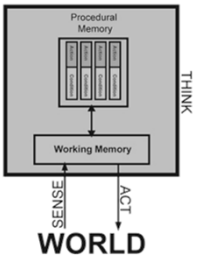
Myth of Decentralized Control

- The claim that artificial neural networks invoke decentralized control is largely a myth
- Dawson and Schopflocher argued that even the most basic PDP networks are not autonomous, because they are externally controlled by a programmer, a teacher, or a learning rule that is not part of the network itself
- In this sense, the control of network learning is essentially classical in nature

Don Schopflocher

Myth of Centralized Control

- Centralized control may not be true of all classical systems
- In a prototypical classical model, the production system, control is broadcast by the working memory
- This makes control stigmergic in nature
- Stigmergic control is more typical of embodied theories!
- If central control is not true of such an architecture, and decentralized control is not true of PDP networks, then centralized control is not a mark of the classical!



Serial Processing

- One key criticism that connectionist researchers leveled at classical cognitive science was that they were too slow
- The 'hundred step constraint' criticism of Feldman and Ballard is an example of this criticism
- Why are classical models thought to be slow?
- Because they are serial in nature – Turing machines, production systems, modern digital computers execute only one rule at a time
- Connectionists argued that serial processing is a mark of the classical!

Jerome Feldman

Dana Ballard

Parallel Processing

- Connectionist networks were a response to the hundred step constraint
- They were intended to overcome this problem in virtue of their parallel processing – the ability for more than one process to be executed at the same time
- Embodied architectures are also largely parallel
- For instance, Brooks' subsumption architecture has parallel streams of input and output information flows, and all levels in his architecture are active at the same time

Jets/Sharks
PDP Network

Subsumption
Architecture

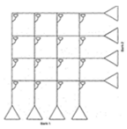
Classical But Parallel

- Serial processing is a possible, but not necessary design decision for a classical computing device. Computers that were the ancestors to the EDVAC did not use vacuum tubes, and therefore took different approaches to speeding up performance. They 'telescoped' processes – ran different parts of the machine in parallel. For instance, Zuse computers used parallel operations to compute arithmetic
- Parallel processing is also common in modern machines (e.g. video card operating in parallel with the CPU)
- It would appear, then, that serial processing is not a mark of the classical, because classical machines can be parallel!

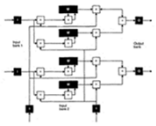
Zuse with the Z1

PDP But Serial

- A similar argument can be made in the opposite direction: PDP networks invoke large amounts of serial processing
- For example, Dawson and Schopflocher demonstrated that the standard pattern associator could not simultaneously learn and recall unless its architecture was radically elaborated
- It would appear, then, that serial processing is not a mark of the classical, because PDP networks can be serial!



Standard pattern associator



Elaborated standard pattern associator

Local vs. Distributed Representations

- Classical and connectionist researchers agree on the need for theories that exploit internal representations
- They may disagree, however, on the nature of these internal representations
- Classical representations are typically viewed as being local
  - In a classical local representation "individual words, objects, simple concepts, and the like are coded distinctly, with their own dedicated representation" (Bowers, 2009, p. 220)
- Connectionist representations are typically viewed as being nonlocal or distributed
  - "Knowledge is coded as a pattern of activation across many processing units, with each unit contributing to multiple, different representations. As a consequence, there is no one unit devoted to coding a given word, object, or person" (Bowers, 2009, p. 220)

Jeff Bowers

Distributed As Extended

- The definition of 'distributed representation' is difficult to pin down, and this in turn blurs the distinction between classical and connectionist representations
- For instance, one view of 'distributed' is extended
  - Van Gelder (1991) notes, for instance, that one common sense of 'distributed representation' is that it is extended: a distributed representation uses many units to represent each item, while local representations do not.
- By this definition, though, many classical representations would seem to be distributed because they are extended over resources
  - Mental image

Tim van Gelder

Distributed As Coarsely Coded

- Van Gelder (1991) also observes that one could define 'distributed representation' as a coarse code
- Again, however, classical representations like Venn diagrams or Johnson-Laird's mental models operate exactly in the same way as a coarse code
- So this notion of 'distributed' does not distinguish classical theories from its alternatives

Philip Johnson-Laird

More than half of the people at this conference speak French.
More than half of the people at this conference speak English.
Does it follow that more than half of the people at this conference speak both French and English?
reasoners spontaneously drew diagrams of counterexamples to the putative conclusion[18] (Fig. 2).

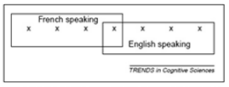


Fig. 2. A typical diagram of a counterexample to a problem (see text) drawn by a subject. In a group of 7 people (each x represents an individual), more than half of them speak French, more than half of them speak English, but it is not the case that more than half speak both languages.

Distributed As Superposition

- Van Gelder (1991) argues for a strong definition of 'distributed' involving superposition – the same resources represent different content at the same time
  - "Thus in connectionist networks we can have different items stored as patterns of activity over the same set of units, or multiple different associations encoded in one set of weights" (van Gelder, 1991, p. 43)
- But this doesn't rule out classical representations where the same features are used, via combination, to define different concepts
- Local representations do not appear to be a mark of the classical

Tim van Gelder

Internal Representations

- Theories in classical cognitive science invariably exploit internal representations
- "My hypothesis then is that thought models, or parallels, reality -- that its essential feature is not 'the mind', 'the self', 'sense data' nor 'propositions', but is symbolism, and that this symbolism is largely of the same kind which is familiar to us in mechanical devices which aid thought and calculation" (Craik, 1943)
- The classical sandwich was due to classical cognitive science being inspired by von Neumann's stored program computer architecture

Kenneth Craik

Connectionist Sandwich

- The sandwich analogy does not distinguish classical cognitive science from connectionist cognitive science, because both appeal to internal representations
- "A feed forward connectionist network conforms equally to the sandwich metaphor. The input layer is identified with a perception module, the output layer with an action one, and hidden space serves to identify metrically, in terms of the distance relations among patterns of activation, the structural relations that obtain among concepts. The hidden layer this time contains the meat of the connectionist sandwich" (Calvo & Gomila, 2008, p. 5)

Classical Scaffolding

- Embodied cognitive science, particularly its radical forms, distinguishes itself from the other approaches by abandoning internal representations
- However, prototypical classical devices like the Turing machine are completely scaffolded; the stored program computer was a practical innovation; older devices used external memories as scaffolds
- Other embodied theorists admit a role for internal representations in their theory:
  - A successful cognitive science, I shall argue, will thus study both the larger dynamics of agent/environment systems and the computational and representational microdynamics of real neural circuitry (Clark, 1997)
- Internal representations are not a good candidate to mark the classical

Andy Clark

Explicit Rules

- Connectionists have argued that postulating explicit rules is a mark of the classical
  - For example, it has been claimed that all classical work on knowledge acquisition "shares the assumption that the goal of learning is to formulate explicit rules (proposition, productions, etc.) which capture powerful generalizations in a succinct way" (McClelland, Rumelhart, & Hinton, 1986, p. 32)
- Connectionists try to differentiate themselves from classical theories by arguing that explicit rules are <u>not</u> part of a connectionist theory
  - "The model learns to behave in accordance with the rule, not by explicitly noting that most words take ed in the past tense in English and storing this rule away explicitly, but simply by building up a set of connections in a pattern associator through a long series of simple learning experiences" (p. 40)

James McClelland

David Rumelhart

Connectionism Uses Explicit Rules

- However, the absence of explicit rules cannot be used to distinguish connectionist theories from classical ones
- Connectionist learning rules are explicit rules that manipulate a particular data structure – the connectionist network itself
- Interpretation of PDP networks trained on classical tasks can reveal internal structures that map onto explicit rules
- Hadley has argued that much of human learning involves learning explicit rules
  - "The foregoing conclusions present the connectionist with a formidable scientific challenge, which is, to show how general purpose rule following mechanisms may be implemented in a connectionist architecture" (Hadley, 1993, p. 199)

Robert Hadley

The Cognitive Vocabulary

- The cognitive vocabulary is used to capture regularities at the cognitive level that cannot be captured at the physical or the symbol level – an appeal to the content of mental representations
- "But what sort of regularities can these be? The answer has already been given: precisely the regularities that tie goals, beliefs, and actions together in a rational manner" (Pylyshyn, 1984, p. 132)
- Classical theorists like Pylyshyn argue that theories like connectionism are not classical because they do not use the cognitive vocabulary
- Is the cognitive vocabulary a mark of the classical?

Zenon Pylyshyn

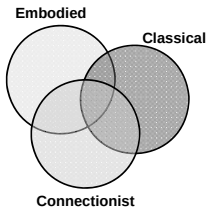
Against The Cognitive Vocabulary

- The cognitive vocabulary limits the scope of classical cognitive science – removing, for instance, vision from its study
- Simulation methods used by classical cognitive science also seem to abandon the cognitive vocabulary
- This is seen in Haugeland's formalists' motto:
- "If the formal (syntactical) rules specify the relevant texts and if the (semantic) interpretation must make sense of all those texts, then simply playing by the rules is itself a surefire way to make sense. Obey the formal rules of arithmetic, for instance, and your answers are sure to be true" (Haugeland, 1985, p. 106)
- The cognitive vocabulary is not a useful mark of the classical

John Haugeland

If Classical Marks Do Not Exist…

- **… then classical theories share characteristics with other cognitive theories, raising the possibility of theories with hybrid characteristics**



Example: Seeing And Visualizing

- **One such hybrid theory is Pylyshyn's own account of seeing and visualizing**
- **This theory combines elements of classical, connectionist, and embodied cognitive science**
- **How and why does Pylyshyn combine these approaches**
- **After combining them, how does Pylyshyn salvage his own approach – classical?**
- **This will be the topic of our next lecture**