Conclusion: Where We Go From Here
Benefits of Cognitive Science

- Brings together diverse theoretical perspectives.
- Widespread influence of cognitive theory on other disciplines and in education.
- Practical applications in medicine, engineering, and robotics.
- Advances in diagnosis and treatment of disease and disorders.
People have bodies and interact with a complex world using them. This is the notion of *embodiment*.

Our perceptions influence our actions. These actions then change our environment causing us to perceive something new and act again in a cyclical process.

In the *ecological view of perception* there is no need for cognition, the relevant representations and how to compute them are given to us directly from the environment.

Brooks (1991) subsumption architecture for robotics tells a similar story.
Not everyone thinks alike. We need to understand how thinking diverges for those at both ends of the distribution: people with psychological disorders and geniuses.

There are noted differences in cognition between cultures. Nisbett (2004) argues that Asian’s think more holistically and see the “big picture” while Americans and Europeans think more analytically, seeing the “trees more than the forest”.

Individual and Cultural Differences and Cognitive Science
Cognitive science at best can solve the “easy problem” of consciousness, by explaining the neural and cognitive mechanisms that underlie our different subjective experiences. A complete NCC has yet to be developed.

Cognitive science cannot however, explain what it is like to have quale. No science can.
Cognitive Science and the Lack of a Unified Theory

- The broader sciences; physics, chemistry, and biology differ in their methodology and perspective. The same is true for the cognitive sciences. Can they ever be unified?

- Cognitive scientists still cannot agree on the exact nature of mental representation and computation. Is it symbolic, local and serial as the traditionalists would have it, or is it non-symbolic, distributed and parallel as the connectionists would have it?
A new view in cognitive science has emerged that may solve some of the problems we’ve just presented.

In the *dynamical systems approach*, phenomena are viewed as complex and multivariate, relationships are non-linear, and behavior is always in a state of flux (Friedenberg, 2009).

This approach not only conceptualizes natural processes differently, it brings with it an entirely new toolkit, or way of studying them.
Most relationships in psychology are not linear, despite what we’ve seen with regard to mental rotation, scanning of items in working memory and other simple linear effects.

Nonlinear relationships are more complex and difficult to predict. The output in these systems is not directly proportional to the input.
A Nonlinear Relationship

\[ X_{t+1} = kx_t(1-x_t) \]
Predictability and Chaos

- The brain and human behavior are not always ordered and regular. They are a mix of order and disorder. Systems like this that are neither random and completely unpredictable nor deterministic and completely predictable are called chaotic.
- Chaotic systems are deterministic but still unpredictable. We can describe the behavior of these systems, sometimes in a very precise way, but we still cannot predict their long-term behavior.
- Chaotic systems also display what is called sensitivity to initial conditions. A small change in the starting situation can produce large differences in the final outcome.
We can measure how a system changes over time by showing how it moves in a state space defined by different dimensions.

We could, for instance, plot the trajectory of mood changes in a 2-D space defined by introversion and happiness.
A State Space for Mood Change
Attractors

- Systems change in understandable ways. These changes can be plotted using attractors.
- If a system is constant it is characterized by a *point attractor*, represented as a dot in the state space.
- If a system moves around the state space in a cyclic or looping fashion it is represented as a *periodic attractor* or limit cycle.
Dynamical Representation

- Mental representations are constantly changing and are altered based on our mood, new information and other factors (Peschl, 1997).
- No two individuals will have the same representation nor will a single individual at different times.
- The purpose of a representation is not to depict the environment but to mediate an organism’s response to it.
Symbolic Dynamics

- A way to reconcile the classical and connectionist views on representations.
- Symbols can be code for as bounded regions of state space. They are attractors the system can gravitate towards.
- When the system is in these regions, the symbol is activated.
Symbolic Dynamics
The Continuity of Mind

- All mental activity is fuzzy, graded and probabilistic (Spivey, 2007).
- Thoughts are characterized as trajectories in state space that gravitate toward attractor basins.
- These basins represent percepts or concepts.
- The system stays only briefly in these states before moving on.
Modularity vs. Distribularity

- The modular approach to mind is easy to conceptualize and study.
- The brain is not exclusively modular though. Many of its functions are distributed across different brain areas and are not functionally encapsulated.
- We can use the term *distribularity* to describe partial modularity.
Component- vs. Interaction Dominance

- In the *component-dominance* view, computations are isolated and don’t share information with other processors.

- *Interaction-dominant* computation is characterized by the sharing of information between units.

- Because information is shared, modules never stop processing. They are continually updated.
Internalism vs. Externalism

- Closed systems are isolated from what is going on around them. The *internalist* view is that the brain is a closed system. If we explain what is going on inside the brain we will have figured out how it works.

- Open systems are continually sending and receiving with the world outside themselves. The *externalist* view sees the brain as part of an open system embedded in a brain that is inside a world. Only by explaining its interactions with these other systems can we fully understand mind.
An *embodied* system is one that has a physical body and experiences the world by the influence of the world on that body.

A *situated* system is one that is part of the world and participates in it by receiving inputs and sending outputs. It does not need to have a physical body.

An assembly line robot that follows a step-by-step program to spray paint cars is embodied but not situated. An airline reservation system is situated but not embodied.

In the dynamical view the brain is both.
Feed-Forward vs. Recurrence

- Information flow is *feed-forward* if it continually travels in one direction, upward through the different levels of a system.
- It is *recurrent* if it travels up and down through the levels, i.e., it can loop or cycle between levels.
- The visual system was once believed to be feed-forward. It is now known to contain recurrent processing as well.
Evaluating the Dynamical Perspective

- In this view, cognition is not only “in the head” but a cyclical process between brain, body, and world.

- It offers a more accurate account of real world relationships; they are nonlinear.

- Computations don’t need to have a beginning and an end. Processing continues and continues to change.
Evaluating the Dynamical Perspective

- It offers a unifying methodology. Any field in science can be understood as the movement of a trajectory through state space.
- State spaces are multi-dimensional and can allow us to examine the relationships between many variables, not just two or three.
- Cognitive science needs to adopt new models that take change and complexity into account. Oscillatory, cellular automata and agent-based models are a start (Friedenberg, 2009).
Integration in Cognitive Science

- Integration across levels of description. The need for theories and models that specify the implementation, algorithmic, and computational levels.
- Integration across disciplines. Need for collaborative interdisciplinary work.
- Integration across methodology. Need for synergistic use of multiple methods.
Interdisciplinary Crossroads: Multiple-Levels of Explanation

- A *phenomenal level of explanation* is symbolic. It tries to describe what a process is like using language-like terms. Favored by linguists and philosophers.

- *Mechanistic explanations* are *subsymbolic*. They operate a level below symbols. In the brain, this would be stating how neurons or neurotransmitters allow a process to happen. Favored by connectionists and neuroscientists.
Multiple-Levels of Explanation

- These two levels should complement, not replace one another (Abrahamsen & Bechtel, 2006).
- The future for cognitive science is to combine these approaches.