Extending the classical view of representation

Representation is a central part of models in cognitive science. But this idea has come under attack. Researchers advocating perceptual symbol systems, situated action, embodied cognition, and dynamical systems have articulated alternative assumptions of cognition. These alternative approaches must be incorporated into models of cognitive processes.

Nonetheless, representation should remain a core part of cognitive science, but that belief is not without its assumptions. We review the core assumptions of the dominant view of representation and the four suggested alternatives. We argue that representation should remain a core part of cognitive science, but that its insights must be incorporated into models of cognitive processing.

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Nonetheless, representation should remain a core part of cognitive science, but that belief is not without its assumptions. We review the core assumptions of the dominant view of representation and the four suggested alternatives. We argue that representation should remain a core part of cognitive science, but that its insights must be incorporated into models of cognitive processing.
There is a revolution in the air in cognitive science. Since the late 1950's, models of cognition have been dominated by representational approaches. These models posit some kind of internal representation to store and manipulate data. While the field of cognitive science has made great strides, the early predictions of paradigms such as autonomous robots and intelligent computers on our desktops have not yet come to pass. Each approach has been found wanting in a successive fashion, with each paradigm effort to meet the representational assumptions made by cognitive models. Instead, new approaches to cognitive modeling are examined.

This paper sketches the classical view of representation that is widely employed in cognitive models. Then, four new approaches to cognitive modeling are examined: perceptual symbol systems, situated action, embodied cognition, and dynamical systems. Each of the four alternative approaches have been put forward as a successor to the classical view. The paper ends with a discussion of ways to reconcile the classical and alternative approaches.
As an example, Tversky's contrast model of similarity assumed that objects (the represented world) are represented by sets of features (the representing world). Each feature is a symbol that stands for a particular property of the object such as the color blue (the representing relations). Pairs of sets representing two objects are compared by finding the intersection of the sets. The elements of the intersection are the commonalities of the pair, and the features that are not in the intersection are the differences of the pair.

The second assumption is that some representations are enduring states of the system. In particular, agents must use their experience as a guide. Thus, they have internal states that endure longer than the states in the represented world that gave rise to them. To continue the example of the color model, an object that is blue in the represented world can be blue even if an agent is not aware of the property of 'blue'.

The third assumption is that some representations are symbols. Symbols have two central qualities: their relationship to the represented world is arbitrary, and they are discrete packets of information. Symbols are necessary for referring to specific values or properties. In the contrast model, features are symbols in the representing world.

The fourth assumption is that representational elements exist at a variety of levels of abstraction. Some representations correspond directly to aspects of perceptual experience. Other representations are more abstract and refer to abstract concepts like truth or justice. In the contrast model, there is no necessary connection between the features that describe an object and the properties of that object. Different representations correspond directly to aspects of perceptual experience. The features in the represented world are the commonalities of the pair, and the features that are not in the intersection are the differences of the pair.

In each of the following sections, we describe one of the approaches that modifies the classical view. Each approach departs from the classical view, either by some insight or example that suggests a modification of the classical view.
argue that none of the new alternatives can replace the classical view. We conclude by discussing possible extensions to the classical view suggested by the alternatives.

Perceptual symbol systems

Cognitive processing is flexible. People are able to recognize when a new situation is like one they have experienced before, but they are also good at handling deviations from normal situations. The classical approach to representation assumes that flexibility requires abstraction. By abstracting away from the perceptual details of specific situations, the commonalities across situations can be preserved. Thus, the classical approach typically assumes that there are abstract amodal representations that play an important role in cognitive processing.

Amodal representations are not flexible as they were initially assumed to be. Current research suggests that flexibility in cognitive processing arises from the storage and use of specific episodes in memory and their perceptual content. For example, Barsalou’s perceptual symbol system approach proposes that the perceptual system is used to simulate objects and events. Representing an apple in a bowl involves simulating an apple on top of other apples using the perceptual system. This connection between perception and language is accomplished using principles derived from cognitive grammar.

Symbolic models have also struggled to account for differences in the way a property manifests itself across items. People know that the red of a fire engine is different from the red of hair, even though the same color term is used for both. Likewise, the same spatial preposition may describe many subtly different situations. For example, the English preposition “in” normally means that an object is contained inside another object, but an apple can be “in” a bowl even when it is stacked on other apples inside another bowl. The English preposition “on” normally means that an object is contiguous with another object, such that the object above the drop line of the bowl is difficult to recognize for this purpose. People often learn new features, even new perceptual features. Thus, to understand categorization, it is necessary to consider the underlying process of perceptual processing.

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Table A: Perceptual symbol systems

<table>
<thead>
<tr>
<th>Cognitive Grammar</th>
<th>Semantic Grammar</th>
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<tbody>
<tr>
<td>Perceptual system</td>
<td>Abstract system</td>
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<tr>
<td>Simulate objects</td>
<td>Represent concepts</td>
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<td>Events</td>
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feature creation. In one study, Schyns and Rodet taught people perceptual categories, each consisting of unfamiliar shapes. What people considered to be the basic perceptual components of the categories depended on the order in which they were exposed to the categories. For example, they might see some items that contained the complex feature XY from Figure 1 as one of its components. To summarize, the perceptual approach offers new ways of seeing something that can be modeled.

Situated action

The classical approach often views cognition as something that can be modeled by computers. By taking seriously the role of perception in conceptual representations, it becomes difficult to separate cognitive processes from the context in which they occur.

Two important insights follow from this focus on context. First, all of the information relevant to thinking about a situation may not need to be represented, because a substantial amount of information present in the environment is distributed across the world. Second, information relevant to thinking about a situation may not need to be represented. Two important insights follow from this focus on context. First, all of the information relevant to thinking about a situation may not need to be represented. Second, information relevant to thinking about a situation may not need to be represented. The study of situated action (or situated cognition) assumes that cognitive processes become difficult to separate from the environment in which they occur.

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An attacking enemy in the game was represented as something chasing the agent. The agent used this representation for any attacking enemy, because what was relevant was the relationship between the agent and the enemy at that moment.

A second aspect of situated action is that the problem an agent must solve is determined by the environment. For example, Hutchins provides an extensive description of the way navigation teams aboard naval vessels track a ship's position. At a general level, the problem is to determine the ship's position in the environment and ensure that the ship maintains a course that keeps it from running aground. However, the problem is not simply to fix the position of the ship in the environment and ensure that the ship maintains a course that keeps it from running aground. The relative location of landmarks with respect to the ship and the ship's own position in the environment are critical factors in determining the ship's course.

In summary, because cognitive agents are embedded in environments, they need not form complete representations of their environment at all times. Instead, they can assume that the world is relatively stable, thus, lower representations in the cognitive system need to be capable of providing a very good account of the environment at all times. Instead, they can rely on partial or incomplete representations of the environment. These representations are sufficient to solve the problem at hand.

Related to the situated action approach is embodied cognition, which assumes that it is necessary to build agents that actually interact in real environments. Building real agents suggests ways that the environment can be exploited to solve difficult problems. Furthermore, the environment can be exploited to solve difficult problems.

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Sometimes building an agent can also lead to simple solutions to potentially difficult problems. For example, Pfeifer and Scheier describe a robot that is able to distinguish large cylinders from small ones. The robot has simple motor routines that allow it to follow walls and therefore to circle around objects. When the robot circles a small cylinder, the ratio of its circumference to its diameter is different from that of a large cylinder. As a result, the robot is able to perform a classification task without an elaborate visual system.

Finally, Glenberg suggests that memory research must focus on the function of memory within an organism. Many forms of memory require little effort, such as perceptual priming observed following the presentation of a word that is related to another word. However, more effortful forms of memory require suppression of current input, which is what makes them different from simple memory. Glenberg argues that these forms of memory are what permit organisms to carry out actions in the world. Where do traditional forms of memory require suppression of current space? Glenberg identifies these forms of memory with the planning of an action in the environment. When an organism is navigating through its environment, planning requires the organism to perform an action that will achieve a goal. This goal is determined by the organism's current location in the environment and the current state of the environment.

Dynamical systems, another approach to understanding cognition, have been successful in building simple machines that navigate through environments and avoid obstacles. These agents are able to perform simple tasks like picking up cans or classifying simple objects. The claim these researchers make is that all of cognition, including higher cognition, can be understood in terms of dynamical systems. In a dynamical system, the current state consists of the values of some set of control variables. There is also a set of equations that govern how the state changes over time. Thus, the two key aspects of dynamical systems are the current state and the dynamics that govern how the state changes over time. Dynamical systems are also useful for understanding how the brain works, as they can model the interaction between the brain and the environment.
synchrony regardless of the speed of the movement. In contrast, it is difficult to flex the index finger of one hand while extending the index finger of the other at high speeds, and if they try, they ultimately end up flexing and extending both fingers in synchrony. Kelso can describe this movement, as well as many more complex kinds of motor coordination using dynamical systems. In contrast, current theories of cognitive processing do not lend themselves to the description of these types of movements. Some researchers have argued that this success in describing motor behavior can be extended to all of cognitive processing. They suggest that dynamical systems have two advantages over other approaches to cognition. First, by focusing on processes that evolve continuously, they are able to account for the plasticity of cognition. Second, it is assumed that continuous processes allow dynamical systems to account for the fine details of processing, which in turn allows them to account for individual differences. This focus on individual differences contrasts with much research in cognitive science, which focuses primarily on correspondence. The four alternative approaches to representation have failed primarily on how.

Semantics and representation

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Each of the alternative approaches highlights particular properties that must be added to mediating states in order to account for cognitive processing. Thus, the remaining assumptions of the classical view all require some change in light of the issues raised by alternative approaches. The assumption that some representations are amodal is the one that requires the most future scrutiny. The studies supporting perceptual symbol systems suggest that tying representations to specific perceptual actions is necessary for capturing low-level processes. This criticism seems less problematic for classical models, as there are many cases where an enduring symbol does not represent the past in order to be able to reason about the current state of the environment.

The dynamical systems view also qualifies the importance of discrete symbols. Symbols are not all amodal, and not all are independent of the sensory and motor systems. The assumption that symbols are enduring is not consistent with the idea that many cognitive processes require discrete symbols to represent spatial relations in language. For example, people's ability to represent spatial relations in language involves enduring symbols that endure beyond particular sensory stimulation. The dynamical systems approach captures the importance of enduring symbols as an important source of information that is used in cognitive processing.

The other three assumptions of the classical view are likely to survive intact for most aspects of higher cognitive processing. The assumption that cognitive systems have enduring states was challenged by the idea that many aspects of the world remain stable and thus do not need to be incorporated into enduring representations. The embodied cognition approach suggests that the world is an open system, and that the environment is a source of information that must be added to basic concepts of a mediating state in order to capture cognitive processing.
Despite the clear importance of perception in cognitive processing, cognitive science must continue to develop models of higher cognitive processes. Perception is not a purely bottom-up process. Expertise in a domain changes the way people perceive the basic features of that domain. Thus, without models of how complex reasoning and expertise develop, we will not be able to understand how perceptual representations and mental models influence cognitive processing. In particular, cognitive models must be more sensitive to perceptual representation in approaches to representation. However, to capture significant changes in the brain view, approaches to cognitive science must remain intact. The core insights of the framework approach to cognitive science remain intact. Therefore, these assumptions can be retained. The basic intuition of the mind's representational view of mind, whereby these assumptions can be retained, but not replaced. The fundamental assumption that there are internal mediating states and that these states are amodal and external, is retained. In summary, the classical approach to representation must be extended, but not replaced by a purely bottom-up approach. While cognitive science was understood ultimately to have explanations that emerge from perception, the problem of how perceptual representations are encoded in the brain has not been addressed. Thus, without models of how complex reasoning and expertise develop, we will not be able to understand how perceptual representations are encoded in the brain. Despite the clear importance of perception in cognitive processing, cognitive science
Acknowledgements

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References


Figure 1. Example of a perceptual feature like the ones used by Schyns and Rodet (1997).
Cognitive grammar attempts to account for grammatical phenomena using representations and processes that are continuous with those used by other cognitive processes A1. On this view, the construction of representations involves both perceptual and attentional processes. For example, the representation of the prepositions "above" and "below" can be expressed by a series of steps: (1) setting up locations in a semantic space, (2) focusing attention on one of the objects (the top object in the case of "above" and the bottom object in the case of "below"), and (3) binding a symbol for the lamp in the role of the top object to the symbol for "above" and a symbol for the table in the role of the bottom object to the symbol for "below". In this way, the productivity of grammar is accomplished by allowing representations of the arguments of the prepositions to be freely bound to the circles in the representation. Temporal events can be represented by extending the representations in time. For example, the concept "arrive" can be represented by a situation in which one argument gradually gets closer to a second fixed argument over time. These processes are continuous with those used by other cognitive phenomena, such as perception and attention.