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# 13
# EMBODIED COGNITION AND THE EXTENDED MIND

*Fred Adams and Ken Aizawa*

The mind has an evolutionary history; it is an adaptation for coping with the environment. Perception and action are intimately related. Thinking is grounded in and inseparable from action. Mental representations do not play the role that traditional cognitive science has posited for them. The mind is shaped by, dependent upon, and bound up with the body and its environment. Each of these general ideas has made an appearance in the growing embodied cognition and extended mind (EC-EM) literature. Each of these components of this developing perspective is open-ended, subject to refinements or interpretations that make them more or less radical. They are also shaped, refined, and developed, in part, by the research interests of a diverse array of cognitive scientists from developmental psychologists to roboticists, philosophers, and vision scientists. Developmental psychologists within the EC-EM movement focus on the way in which infants mature and emphasize the role of action and perception in their development. Roboticists and vision scientists adopting the EC-EM perspective emphasize the role of the environment in guiding perception and action, minimizing the role of intensive centralized information processing. Philosophers have concerned themselves with arguments that attempt to undermine apparent cognitive differences between brain processes and processes that take place in the body and environment.

To sample and introduce some of the leading ideas of the EC-EM perspective, we will adopt an approach often taken by the proponents of the perspective, namely, we will contrast the EC-EM approach with the more mainstream cognitivist approach.[1] As we see it, the proponents of EC-EM have often sought to distance their new perspective from a more traditional cognitivist or "old-fashioned" artificial intelligence perspective according to which cognitive processes are processes operating on mental representations. At times, however, we think that these differences are overstated. For example, a cognitivist view of the mind is perfectly compatible with the idea that the mind has an evolutionary history and that it is an adaptation for coping with the organism's environment. Such an evolutionary cognitivist view is, in fact, developed at length by Steven Pinker.[2] One consequence of the attempt to distance the EC-EM approach from more mainstream ideas is that it exaggerates some differences. At times this threatens to create differences that do not really exist and, at others, to eclipse differences that do. What we propose to do in this chapter, after a brief introduction to cognitivism, is review and explain some of the leading ideas of the EC-EM approach, drawing attention to the diversity of ways in which these ideas might be developed further.

## Cognitivism

Broadly construed, cognitivism is the view that cognitive processes consist of the manipulation of mental representations or symbols.[3] Among those interested in, and trying to develop, artificial intelligence, the cognitivist view is often associated with Alan Newell and Herbert Simon's "physical symbol system" hypothesis.[4] Among cognitive psychologists, cognitivism is perhaps closely associated with Noam Chomsky's theory of rules and representations.[5] Philosophers often attribute the view to Jerry Fodor or Zenon Pylyshyn, under the rubric of a computational theory of mind.[6] In these various guises, the common ground among cognitivists is that cognitive processes involve the manipulation of symbolic representations. Cognitivists differ among themselves in such matters as how symbolic representations get their meaning (how they are "semantically grounded"), what mental representations are to be found in cognitive economies, how symbolic representations are structured, and what kinds of manipulations are performed on these representations. We will comment on each of these points of difference.

One family of approaches to the genesis of meaning is the set of so-called "informational" approaches. These begin with the thought that a given brain state or action "X" might represent something X in virtue of some kind of causal coupling relation between "X" and X. Fred Dretske's (1988) theory of indicator functions and Jerry Fodor's (1990) theory of asymmetric causal dependencies are examples of this kind of approach. We can illustrate Dretske's theory as it might be applied to neuronal circuits. The firing of a particular neuron in Brodmann's area 17 (i.e., "X") might mean that there is an edge at roughly some particular orientation at roughly some particular place in the visual field (X) in virtue of the fact that this neuron fires when there is an edge of about that orientation at about that place in the visual field, and developmental processes in the brain have shaped the cell to have the function to indicate the presence of this kind of edge. Another kind of approach to the symbol grounding problem supposes that mental representations are like pictures, that neuronal states represent environmental states when the neuronal states mirror environmental states. We can illustrate Cummins' (1996) version of this picture theory with a neuronal circuit example. In this case, the idea is that the firing of a set of neurons in Brodmann's area 17 might represent a cube being in the environment if the pattern of firing in the set of neurons is isomorphic to the various edges of the cube and their relations. In other words, the firing neurons represents the cube, if there is a one-to-one and onto mapping between the firing neurons and the parts of the cube and between some feature of the neurons' firing and the corresponding relations among

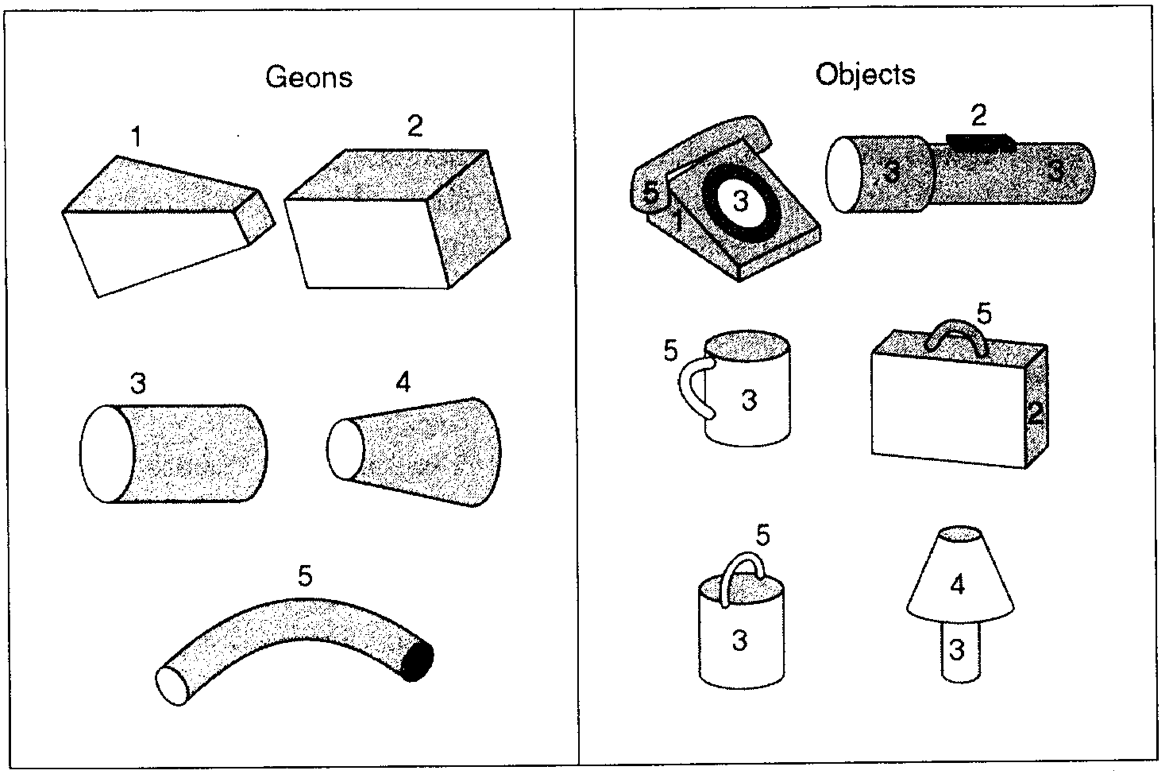


*Figure 13.1* Geons and some constructions of geons (from Biedermann 1990).

parts of the cube.[7] Still other naturalized semantic theories begin with the idea that it is not relations between brain or neuronal state and the world that make a brain or neuronal state a representational state; it is relations among the brain/neuronal states that matter. A version of conceptual role semantics, such as that in Block (1986) and perhaps part of Newell and Simon's (1972) physical symbol system hypothesis, would exemplify this kind of approach. Applying these theories to brain circuits, one would maintain that it is relations among the firings of neurons that lead them to have their meanings.[8] Stich and Warfield (1994) contains an excellent collection of philosophy papers on the subject of the origins of mental representation.

Cognitivists can also differ among themselves about what is represented in this hypothetical system of mental representation; for example, they can differ over whether objects, Gibsonian affordances, or actions are represented.[9] As a more detailed illustration of one difference, we can note two theories of what is involved in object recognition. One theory, advanced by Irving Biedermann, hypothesizes that object recognition involves the assembly of a few, simple three-dimensional objects called geons (a contraction for **geo**metrical icon**s**) (see Figure 13.1).[10] There are two important features of these atomic mental representations for object recognition. First, they can typically be discriminated from one another from almost any viewing angle. Second, they can be fairly readily discriminated even when partially occluded. Another theory, advanced by Bülthoff, Tarr, and their colleagues, however, postulates that object recognition involves matching a perspectival representation, or perspective-relative representation, to the object being viewed.[11] For most objects, these perspectival representations have a natural or canonical perspective. So, for example, the natural perspectival view of a car would be from the front, somewhat off to one side, and somewhat higher than the hood. This approach is meant to explain, among other things, findings in which it is easier to recognize a given object from some orientations than it is to recognize it from others. More familiar perspectives are supposed to facilitate recognition over less familiar perspectives (Palmer et al. 1981). Biedermann, on the one hand, and Tarr, Bülthoff et al., on the other, have in common a commitment to the existence of mental representations and operations on those representations. Where they differ is in the content of those mental representations.

One of the leading issues concerning the structure of mental representations begins with a concern about how one is to account for perception and mental imagery.[12] Think of a person looking at a warm sunny, sandy beach. Pre-theoretically, one might suppose that this person is having a perceptual experience and that this experience involves the formation of a mental picture in one's brain. Or, let this person *imagine* looking at a warm sunny beach. Again, one might suppose that this person is having an experience that includes the creation of an internal picture. Here the issue is not whether there are mental representations or what content they might have. It concerns the form or medium of the representations thought to underlie these experiences. Two kinds of hypotheses have been entertained here. One is that perception and imagination involve the creation of pictorial, or quasi-pictorial, analog mental representations, where the other involves sentential representations. The more theoretical or philosophical dimension of the debate concerns articulating the putative difference between these two forms of mental representations, while the more empirical dimension concerns what phenomena require an appeal to one format or the other. One of the phenomena most frequently cited in support of mental pictures is the following. Subjects are asked to memorize a map of an island with various landmarks on it. Subjects are asked to focus their attention on one of the landmarks, and then report when they "see" a second landmark. The central finding is that there is a linear relationship between the distance between the landmarks and the reaction times. This suggests to some that subjects possess a mental picture of the island which they scan across. Although psychological discussions of the existence of mental pictures date to at least the early part of the twentieth century, seminal experimental work by Kosslyn (1980, 1994) sparked renewed interest in the debate within the cognitivist tradition. Twenty years of vigorous debate and pronouncements to the contrary notwithstanding, the debate appears to be far from over.[13]

The issue of the format of mental representations is directly connected to the issue of the way in which cognitivists can think about the manipulation of mental representations. The most common cognitivist view of symbol manipulation is that it is carried out by some form of Turing-equivalent digital computation. Put very simply, cognitive processes are digital computations. It is quite common, for many purposes, to propose that cognitivism is defined by the hypothesis of digital computation. Such an approach is based on a circumscribed understanding of what is meant by "computation," i.e., that it means something like Turing-equivalent digital computation.

A broader understanding, however, would count analog computation as a type of computation. Thus, manipulation of analog images, such as images of islands, could count as a form of analog computation, hence those theories that postulate analog imagistic representations would count as *bona fide* cognitivist theories.

In the foregoing introductory comments on cognitivism, we have devoted more space to the topic of representation than to the topic of their manipulation. We have said more about representation than about rules.[14] This is because the topic of representation is so much more significant to our understanding of the multifarious relations between cognitivism, on the one hand, and the various components of the EC-EM perspective on the other.

## Cognition and evolution

The mind has an evolutionary history; it is an adaptation for coping with the environment. As we said at the outset of the paper, this kind of claim is subject to multiple interpretations and there are various morals one might draw from it. Anderson (2005) claims that the embodied cognition approach foregrounds six ideas about cognition and evolution. To paraphrase, these ideas are that cognition has an evolutionary history, that cognition is an adaptation to specific environments in conjunction with specific organismal and environmental features, and that it builds on preexisting behaviors, instincts, needs, and purposes. Each of these claims, however, is perfectly consistent with a broadly construed cognitivist approach. Indeed, as we have noted, such claims are combined in detailed ways with cognitivism in Steven Pinker's book, *How the Mind Works*. This suggests that the combination of evolution and cognition is orthogonal to the issues separating the cognitivist and EC-EM approaches to mind.

The evolutionary history of cognition can, however, lead one to draw different conclusions. For example, one might conclude that the way to study cognition is to begin with the study of simpler minds, the minds of nonhuman animals.[15] Daniel Dennett (1978) proposed such a thing, and Dan Lloyd (1989) pursued it more extensively. It is also a theme in Rodney Brooks (1991a, b, 1997), works more closely allied with the EC-EM approach. Although a shift in methodological approach to the study of cognition, this idea need not constitute a break with cognitivism. Simpler minds might have fewer mental representations, mental representations with less structure, or simpler operations on those mental representations. Then again, a study of simpler minds could lead one to break ranks from cognitivism. It could lead one to a different research focus, a focus on adaptive behavior or behavior that enables an organism to cope with its environment. This can lead to a divergence in research interests between cognitivists and advocates of EC-EM – which is not necessarily the same as a theoretical difference – insofar as adaptive or coping behavior does not necessarily require intelligence or cognition. In other words, we should be prepared to find that the best way for an organism to adapt to its environment or cope with its environment is not to think.[16]

As a possible case in point, works by Brooks (1991a, b, 1997) are often cited as a source of inspiration or illustration of the embodied cognition approach. Consider

Brooks's interest in Creatures. He writes, "I wish to build completely autonomous mobile agents that co-exist in the world with humans, and are seen by those humans as intelligent beings in their own right. I will call such agents *Creatures*. This is my intellectual motivation. I have no particular interest in demonstrating how human beings work, although humans, like other animals, are interesting objects of study in this endeavor as they are successful autonomous agents" (Brooks 1991b: 86). By a "Creature" Brooks means the following:

- A Creature must cope appropriately and in a timely fashion with changes in its dynamic environment.
- A Creature should be robust with respect to its environment. Minor changes in the properties of the world should not lead to total collapse of the Creature's behavior; rather one should expect only a gradual change in capabilities of the Creature as the environment changes more and more.
- A Creature should be able to maintain multiple goals and, depending on the circumstances it finds itself in, change which particular goals it is actively pursuing; thus it can both adapt to surrounding and capitalize on fortuitous circumstances.
- A Creature should do *something* in the world; it should have some purpose in being (Brooks 1997: 402).

Brooks apparently expects that anything that meets these conditions will be a cognitive agent, that they will be "seen by those humans as intelligent beings in their own right." But, unless one takes care to interpret the conditions with this aim in mind, one should be prepared to discover that some organisms, such as plants or slime molds, that are normally construed as non-cognitive meet these conditions. Plants cope appropriately with their environments insofar as they can survive, reproduce, and even flourish. They often respond to their environments by sending out roots in appropriate directions and orienting their leaves and shoots toward the sun. Many can thrive in a wide range of climates or environments, at least as wide as some thinking animals. They can have multiple goals, if one counts producing leaves, roots, stems, taking in carbon dioxide, collecting water, and so forth. They also do something in the world and have some purpose in essentially the same sense in which cognitive animals do. What Brooks is proposing to study, while a legitimate enterprise in its own right, is evidently a departure from the subject of traditional artificial intelligence and cognitivism.

Notice that Brooks might simply insist that his conditions define or specify what he means by something's being intelligent/cognitive, so that he simply stipulates that plants and jellyfish are, in his sense, intelligent/cognitive. Perhaps the conditions on Creatures are supposed to provide an operational definition of intelligence/cognition. Even on this interpretation of what Brooks is up to there is an evident change in research. Where traditional cognitivism has supposed that plants are not organized in such a way as to have cognitive lives at all, Brooks does not share this presupposition. Thus, what Brooks proposes to study is apparently not what cognitivists propose to study. This is not to say that there is a conflict between cognitivism and EC-EM, only a parting of the ways.

## Cognition and mental representations

In light of the prominent role of mental representations in the mainstream cognitivist view of cognition, it is not surprising that alternative theories of cognition or approaches to cognition will have something to say about mental representations. EC-EM, however, does not have a univocal position on the role of mental representations in the life of the mind. There are a number of different things that advocates of EC-EM mean when they claim that mental representations do not play the role that traditional cognitive science has posited for them.

At the more conservative end of the spectrum are theories that propose distinct contents and structures for mental representations. Lakoff and Johnson's (1999) theory of primary metaphor is a case in point. Lakoff and Johnson draw attention to what they believe are some underappreciated causal influences on cognition. They claim that the human mind is inherently embodied and that reason is shaped by the body. By this, they mean two principal things. In the first place, they mean *neural embodiment*. This is the claim that the structure of the neural networks making up the brain shapes the concepts and categories we use. As an example, they cite the fact that the human retina has about 100 million photoreceptors, but only about one million retinal ganglion cells leading out of the eye. This, they maintain, forces the nervous system to impose categories on the light information impinging on the retina. Further, what happens in the earliest stages of visual processing is characteristic of the brain as a whole. As another example of neural embodiment, they cite the role of our neural apparatus in the creation of color concepts. Without the particular combination of cones and other neural apparatus for processing electromagnetic radiation of specific frequencies, humans would not have color concepts or not the color concepts they do. In addition to neural embodiment, Lakoff and Johnson draw attention to *phenomenological embodiment*. This is the idea that the concepts we have are acquired and shaped through contingent features of our bodies. As an example of this, they cite the concepts of *front-of* and *back-of*. These are concepts we have and use as a result of the fact that our human bodies are asymmetrical, having a front and a back that mediate our interactions with the world. In our normal daily lives, we move in the direction our front faces and interact with others via our front side. We then project these concepts derived from our bodies on to other objects. Cars have a front in virtue of the direction they move. Televisions and stoves have a front because of the way in which one normally interacts with them. Following these principles, we can see that trees and rocks do not have fronts or backs. Shaun Gallagher (2005) presents another study of the ways in which cognitive processes (and conscious experience) are causally influenced by, or as he says shaped by, being embodied in the way they are. In Gallagher's account, the notions of *body image* and *body schema* are the principal theoretical posits. A *body image* consists of a set of perceptions, attitudes, and beliefs pertaining to one's own body. A *body schema* is a system of sensory motor capacities that function without perceptual monitoring or awareness.

Both Lakoff and Johnson (1999) and Gallagher (2005) offer new theories of the content of mental representations. They are theories of content that provide an articulation of the EC-EM idea that the mind is shaped by, dependent upon, and bound up with the body and its environment. These theories offer accounts of what the mind represents. Such theories, however, are perfectly consistent with the cognitivist view that cognitive processes are computational processes over mental representations. They count as distinct cognitivist theories of what the mind represents in just the way in which Biedermann's theory of geons and Tarr, Bülthoff et al.'s theory of perspectival representations constitute distinct cognitivist theories of what the mind represents.

Another EC-EM take on representations is to suppose that organisms need fewer of them than cognitivism has previously supposed. This theme plays out in various ways as well. Brooks's research again illustrates this theme. Although one might take the provocative title of Brooks's paper, "Intelligence without Representation," literally, what Brooks himself apparently means is that cognitive processing does not rely on representations as heavily or in the kinds of ways that cognitivism has traditionally presupposed.[17] Simple activities, such as navigating about some types of spaces, can be achieved without the construction of complex representations, or maps, of the environment. Navigation does not have to involve anything like a cycle of sensing the location of objects in the environment, constructing a map or model of the environment, then planning a route through the environment, then initiating the plan. Instead, navigation can be highly stimulus driven.

Two of Brooks's robots, Allen and Herbert, illustrate these ideas. Oversimplifying somewhat, Allen has a ring of twelve ultrasonic sonars that give it measures of distances to a dozen objects around it. Allen uses a "level-0" set of skills to compute the distances to objects around it, then moves in such a way as to avoid the objects. By using an additional "level-1" set of skills, Allen can pick random directions in which to move, then modify this choice of direction somewhat by gathering input from the level-0 apparatus that avoids collisions. By using a still further "level-2" set of skills, Allen can find distant walls and move down corridors without colliding with objects that might be in the way or that might move into it. Allen performs these tasks without creating an internal map of objects in its environment. Herbert, a successor to Allen, uses much the same reactive, stimulus driven approach in a more complex task. Herbert moves about the laboratory at MIT collecting soda cans. Herbert maintains no internal state for more than three seconds. Further, there is no communication between many of its distinct components. Herbert has, for example, several lower level modules that enable it to move about without running into objects. There are also several modules that guide the mechanical arm that actually grasps the soda cans. Yet, the movement modules and the grasping modules do not communicate with each other directly. The movement modules do not send a signal to the arm modules informing the arm that Herbert has arrived at a can. Instead, when Herbert's body is positioned appropriately by the stimulus driven moving modules, the grasping modules of the stimulus driven arm take over. When the arm detects a can, the arm in turn moves the hand into place. The arm does not signal to the hand that it has detected a can; rather, the hand simply closes when any object breaks a beam running between the fingers of the hand. The whole idea of the approach is to chain together environmentally reactive procedures in such a way as to have complex behaviors thereby emerge.

A modest construal of this behavior-based robotics is that it is an attempt to see what kinds of tasks might be accomplished without the more traditional approach of sensing, modeling, planning, and acting. As such, it can be seen as completely complementary to the traditional robotics approaches. Brooks, at least at times, seems to be satisfied with this kind of characterization. He sometimes describes it as modeling "insect-level intelligence." Perhaps insect-level intelligence is one thing and human intelligence quite another. Perhaps insect intelligence can be purely stimulus driven and lack complex mental representations, where human intelligence is not purely stimulus driven and does make use of complex mental representations. So conceived behavior-based robotics can exist happily alongside cognitivism. One might also maintain that many of the tasks humans perform in their normal daily routines are the product of environmentally cued responses of the sort found in Allen and Herbert. This, too, however, is consistent with cognitivism. Cognitivists might well concede that much of what humans do is thoughtless in the sense that it does not involve the kinds of information processing that cognitivists maintain constitute thought.

Then there are more radical conclusions one might draw from behavior-based robotics. One might propose that all of human behavior is entirely as reactive and stimulus driven as is Allen's method of moving around or Herbert's method of collecting soda cans. All of human behavior is produced without the mediation of complex mental representations in just the way that Allen's movement down a hallway or Herbert's soda can collecting is produced without the mediation of complex representations. One can, indeed, go farther and claim that cognition does not involve representations at all, complex or otherwise. Here there are two distinguishable ideas, that cognition is stimulus driven and that cognition does not involve complex representations, or even any representations at all. Each merits separate comment.

Clearly there are tasks that can be accomplished in the way suggested by the example of Herbert. But, there appear to be many other tasks that humans perform that cannot. If one proposes that behavior is purely stimulus driven, one needs some account of what is involved in the multifarious effects of what appear to be learning and memory. Surely no normal human being does anything like resetting its cognitive state every three seconds in the way Herbert does. Surely any moderately sophisticated conversation involves remembering information gathered outside the last three seconds. Surely reading with comprehension any moderately complicated paragraph in a book or newspaper article involves remembering what was read prior to the last three seconds. Surely humans going to the grocery without a shopping list remember more than Herbert does. Herbert need only wander about randomly waiting for the appropriate stimuli to guide it to soda cans and then guide it to their drop off point. No normal human going to the grocery wanders about until she finds the car keys, then wanders about the house until she finds the garage, then drives around randomly until finding a grocery, and so forth. Normal humans going to the grocery do seem to have short-term goals that are strung together to bring about complex, coordinated actions. To suppose that cognitive processing is mere stimulus driven processing is more apt to describe the sad condition of H.M., the subject of a bilateral hippocampectomy, who was largely unable to form long-term memories. H.M. had memories of numerous past events, but could form next to no new memories. So, for example, he could not recall from one day to the next the names of the members of the hospital staff who cared for him. He could not recall where the bathroom was or what he had eaten for lunch a half-hour after he had finished (Scoville and Milner 1957). How can EC-EM account for the apparent effects of learning and memory, without representations?

Beer (2003) apparently rejects the hypothesis that human behavior is entirely stimulus driven and proposes to explain the effects of learning and memory by appeal to nonrepresentational internal states. In other words, systems may take on different internal states as a function of experience and thereby modify their behavior as a result of experience, but we need not construe these different states as representational states. Beer backs up this proposal by appeal to the mathematical framework of dynamical systems theory, which allows one to have behaviors change in response to experience, without appeal to a change in representations. One might say that changes in the weights in a connectionist network, for example, are nonrepresentational changes of state that can enable a system to change its behavior as a result of experience.

Van Gelder (1995) supports much the same view and provides a simpler illustration of nonrepresentational processing than we find in Beer (2003). Van Gelder claims that there are two ways in which one might adjust a throttle valve from a steam engine to maintain a flywheel at constant speed. One is through one or another algorithm that measures the speed of the flywheel, compares that speed to a target speed, and then adjusts the throttle valve, if necessary. Another way is to link the flywheel to a vertical spindle. On this spindle, one can add rotating arms holding metal balls at their ends. The rotating mechanism of the arms can then be linked to the adjustable throttle. If the flywheel rotates too quickly, the centrifugal force on the rotating arms increases, extending the arms outward, thereby slowing the throttle. If the flywheel rotates too slowly, the centrifugal force on the rotating arms decreases, lowering the arms inward, thereby speeding up the throttle. In other words, one can attach a Watt governor to the engine. Van Gelder claims that the first method involves a computational method using representations, the kind of explanatory apparatus that a cognitivist might invoke to explain some human behavior, where the second is a non-computational method in a dynamical system that does not involve representations and that these are genuinely different methods.[18] The suggestion, then, is that if cognitive processing consists of changes in the state space of a dynamical system that does not use representations, then cognitive processing does not require representations.

Perhaps Beer and van Gelder are correct, that one can accomplish many tasks that are thought to be cognitive without appealing to representational states. Does this show that cognition does not involve representation? That is not so clear. Beer and van Gelder observe that there are two ways of completing or performing a task, such as regulating the flow of steam from a steam engine. Suppose this is so. Now compare the task of regulating the steam engine with a task such as obtaining food. One way to perform this task might be to deploy processing mechanisms of the sort proposed by cognitivists, namely, mechanisms for visual recognition, evaluating individual objects for edibility, planning a course through the environment, and so forth. But, another way to obtain food apparently involves no cognition at all. The Venus flytrap is not a cognitive agent, but it obtains food. This plant secretes a sweet mucus that attracts insects. When an insect appropriately triggers one of the hair structures in the trap, the trap snaps shut. The Venus flytrap can then proceed to digest the insect over the course of the next few days. Does the way that a Venus flytrap obtains food show that cognition does not require representation? No. A perfectly reasonable thing to say is that the task of obtaining food simply does not require cognition. The point, therefore, is that showing that some task is accomplished by some dynamical system that does not use representations does not show that cognition need not involve representations. Instead, it may show only that, prior expectations notwithstanding, the task does not need to be performed using cognitive processing at all, hence does not need to be performed using representations.

What Beer and van Gelder need is some theory of what a cognitive process is. What do they propose separates a cognitive process from a non-cognitive process? In virtue of what is it the case that an organism or machine, such as Allen or Herbert, is supposed to be cognizing? Cognitivists maintain that the use of representations is part of what sets cognitive processes apart from non-cognitive processes, but Beer and van Gelder have foresworn this theory. It does not suffice to say that cognitive processes are changes of state in some dynamical system. After all, even if one accepts this view, there presumably remains a need to discriminate between dynamical systems, such as coupled pendulums, that are non-cognitive from dynamical systems, such as human cognitive systems, that are cognitive. It might well be that in order to separate cognitive dynamical systems from non-cognitive dynamical systems, one has to say that the former involve representations. That, however, would undercut Beer and van Gelder's anti-representationalism. Nor will it do to say, as does van Gelder, that "the question here is not what makes something cognitive, but how cognitive agents *work*" (van Gelder 1998: 619). This only pushes the question of what processes are cognitive back on to the question of what a cognitive agent is. How can we determine how cognitive agents work, unless we have some sort of theory of what a cognitive agent is? The cognitivist answer is that, among other things, a cognitive agent uses representations. This, however, is precisely the answer that Beer and van Gelder reject.

## Perception and action

As we saw in the last section, there is a strain of EC-EM thought that challenges the cognitivist view that a thinking robot would be one that senses, models, plans, and acts, by challenging the need for complex representations, or for any representations whatsoever.[19] Another EC-EM way of challenging this picture, however, is by challenging the apparently great separation between sensing and perceiving, on the one hand, and action, on the other. The EC-EM slogan here is that perception and action are intimately related. There are numerous very simple and thoroughly uncontroversial illustrations of ways in which actions generate important perceptual cues. In human audition, there are two primary cues for the localization of sounds, interaural time differences and interaural intensity differences. In humans, the ears are separated in space which will in many cases lead to differences in the times at which sound waves reach one ear versus the other and will lead to differences in the intensities of the sounds arriving at one ear versus the other. Sounds will arrive sooner and be more intense in the ear that is closer to the source of the sound. This gives humans important cues to the direction from which a sound is coming. These cues work well, except when the source of a sound falls near the plane of bilateral symmetry of the human head. When this happens, incoming sounds arrive at roughly the same time and with roughly the same intensity at both ears. In these cases, it is hard for people to localize the source of a sound. To address this problem, people often simply turn their heads. If the source of the sound is directly in front of or behind someone, this will enable localization. If, however, the sound is more or less directly above the person's head, the sound will still be difficult to localize. In olfaction, when smells are faint, humans, like other animals, will often sniff in an attempt to bring in more odorant. In vision, it is sometimes difficult to judge the distance of various objects in the visual field. Moving the head, however, induces motion parallax in which objects move differently relative to the fixation point. These motions provide depth cues that can be useful.

In the area of mobile robotics, or artificial intelligence, increased attention to the role of action in perception may well constitute a new approach to the design and construction of robots for interacting with the world.[20] Yet, it remains perfectly consistent with a cognitivist view insofar as the mechanisms of action and perception might still be held to be the manipulation of representations of objects, actions, their effects, etc. Within the field of sensation and perception, however, the foregoing kind of role of action in perception is relatively well studied. The various ways in which actions can be used to influence perception, or to collect additional perceptual cues, are familiar from textbooks on sensation and perception. In the study of vision, for example, Findlay and Gilchrist (2003), wish to draw attention to the role of eye movements in visual perception. Yet, it is clear as one works through the text and its many references that this approach draws heavily on an existing literature devoted to such things as the saccade and visual orienting. What we apparently have in this case is not so much a change in perspective or emphasis as a shift of attention. In Findlay and Gilchrist's "active vision," we are to pay greater attention to the role of eye motions in visual perception.

It is, however, possible to develop a more radical version of EC-EM that proposes an even tighter connection between action and perception. One might propose that the two are literally inseparable. It is not merely that there is a causal loop in which actions influence perceptions which in turn influence actions. Instead, actions might be said to be constitutive of perceptions. There is no perception without action. This is at the heart of Kevin O'Regan and Alva Noë's sensorimotor contingency theory of perception.[21] On this view, perception is the exercise of an individual's mastery of particular sensorimotor contingencies. Perceiving is acting, a kind of acting that involves the whole of the organism, an exercise of capacities of the entire agent. Different perceptual modalities, such as vision and touch, involve mastery of distinct sensorimotor contingencies. Vision involves mastery of the ways in which the motion of one's head and eyes will give rise to changes in the visual stimulus. Vision involves practical knowledge of such things as that turning one's head to the right will lead to a leftward motion of objects in the visual field, that the retinal projection of an object depends on its distance from the observer, that only the front face of an object is visible, and that the color and brightness of an object change in certain lawful ways as the object or the light source or the observer move around. Tactile perception by contrast does not depend on distance, it allows the whole of some objects to be embraced, and the feel of an object does not vary with illumination. The sensorimotor theory of perception suggests that cognition is embodied, not just in the brain, but in the whole of the organism, because it is the whole of the organism that is apparently needed to exercise the mastery of sensorimotor contingencies.

A fundamental problem for the sensorimotor theory, however, arises from observations of perception in spite of complete neuromuscular blockade.[22] There are any number of drugs, such as curare, that compete with acetyl choline for binding sites in the neuromuscular junction. If a subject is completely paralyzed by a sufficiently large dose of curare, then that subject cannot move a muscle. That subject cannot exercise mastery of most sensorimotor contingencies. Nevertheless, a subject's perceptual capacities are largely undisturbed. In one very clear study, Topulos et al. (1993) administered the muscle relaxer vecuronium to four subjects with tourniquets applied to one arm. The tourniquet prevented the vecuronium from reaching the neuromuscular junctions in the hand, hence allowed the subjects to continue to use their fingers to signal investigators. Subjects who were immobilized with vecuronium were capable of hearing and answering the investigators' questions, tasting a topical anesthetic, and feeling discomfort. As Topulos et al. report,

> Complete neuromuscular block caused no observable impairment of consciousness, sensation, memory, or the ability to think and make decisions. Objective evidence supported this assertion, as subjects responded promptly to questions. When the experimenter misunderstood their answers, subjects recognized this and made a correction. Subjects successfully used a questionnaire with many branching points to communicate their needs. Subjects also accurately recalled specific events that occurred in the room while they were paralyzed. This unimpaired mental function is consistent with the reports of previous investigators. (Topulos et al. 1993: 373).

So, the sensorimotor contingency theory of perception does represent a kind of break with traditional cognitivism in advancing a more intimate connection between perception and action than is standard. The problem with it, however, is that it founders on some rather simple and compelling experiments involving neuromuscular blockade.

### *Complementary processes in brain, body, and environment*

Advocates of EC-EM often claim that cognition is shaped by, dependent upon, and bound up with the body and its environment. We have already seen one way of interpreting these claims in terms of the manner in which the content of one's concepts is derived in one way or another by reference to the body. Lakoff and Johnson (1999) and Gallagher (2005) each provide an example of this way of articulating these general claims. O'Regan and Noë's sensorimotor theory of perceptual experience provides another way of interpreting these claims. Yet another way of developing this general theme, however, is through what is sometimes described as the complementary relations between cognitive processes and environmental processes.[23]

The most familiar illustration of this kind of complementarity is found in the use of pencil and paper for the computation of large sums such as 736 + 877. The use of pencil and paper enables a normal human being to work around certain limitations on human cognitive processing, most particularly limits on short-term memory. Simply by writing the numbers down, one does not have to commit them to memory before starting to solve the problem. By writing "736" over "877" in the standard way, one can use relatively easy visual inspection to make sure that the numeral in the ones column in one expression is properly related to the numeral in the ones column in the other expression, that the numeral in the tens column in one expression is properly related to the numeral in the tens column in the other expression, and so forth. Again, this reduces the demands on short-term memory. In addition, as one proceeds in a step by step manner from the ones column to the tens column to the hundreds column, writing down each intermediate sum, one does not have to remember the results of past computations. This is yet another reduction in the demands on short-term memory.

Kirsh (1995) provides a classification of ways in which humans arrange objects and features of their environment in ways that help them compensate for the limitations of their relatively fixed cognitive resources. In Kirsh's scheme, we use the spatial arrangements of objects in order to regulate certain task choices, to simplify perception, and to simplify internal computation. By initially gathering all the ingredients one wants to put in a salad near the sink, one thereby simplifies subsequent task choices. This provides a visual cue concerning what items are to be used and what is to be done with them. Moving the washed items over to the knife and cutting board indicates what is to be done next. In stacking spare pieces of wood appropriately, a carpenter can facilitate the later choice of pieces for use in protecting the work piece when clamping and hammering. In working around a sink with a garbage disposal unit, it is often convenient to block the drain opening to prevent something from falling into the unit. This spares the user having to choose a safe place to put an object that might fall into the unit. These are cases in which the use of space facilitates certain task choices.

Spatial arrangements facilitate perception when like items are grouped together. Thus, when cooking, it is easier to distinguish the washed vegetables from the unwashed vegetables if they are kept in spatially separated clusters. When bagging groceries, the heavy items must go in the bottom of the bag, the intermediate items in the middle, and the light, fragile items on top. But, items do not reach the bagger prearranged for easy bagging. Not every item will immediately go into a bag, so the bagger must often sort the items by size and weight, prior to actually putting them in bags. It, therefore, makes sense to put the heavy items in one cluster, the medium sized items in another, and the light, fragile items in still another. This facilitates subsequent recognition of the weights of objects when they are finally to be bagged. The example of using pencil and paper to compute large sums illustrates this idea as well. By arranging the two numerals to be added one above another, rather than in a continuous line, it is easier to be sure to add ones to ones, tens to tens, etc. The long-range scanning that would be involved in the addition of the linearly arranged numerals is thereby avoided.

To illustrate how spatial arrangements simplify internal computation Kirsh refers to his work on playing the game Tetris. In this game, "tetrazoid" blocks of various shapes descend from the top of a computer screen and must be fitted into slots at the bottom of the screen. In order to assess the fit, experienced players do not imagine the blocks then mentally rotate them to check the fit. Instead, experienced players push a button on the game panel in order to rotate the block on the screen. Subjects, thus, spare themselves the effort of mentally rotating the objects by actually rotating the object on the screen. In another game context, playing Scrabble, subjects arrange the lettered tiles on their trays in an effort to cue possible uses of the tiles in words.

In describing his work, Kirsh generally offers a relatively conservative estimate of his research strategy. He takes it to be a shift in emphasis: "How we manage the space around us, then, is not an afterthought; it is an integral part of the way we think, plan, and behave, a central element in the way we shape the very world that constrains and guides our behavior" (Kirsh 1995: 31–2). Andy Clark (2002) and John Sutton (forthcoming) adopt a potentially more radical interpretation of Kirsh's work. Cognitive processes do not occur only within the brain. They can also, under some circumstances, spread across physical and social environments. Both Clark and Sutton very deliberately rely upon the complementary relations between what goes on within the brain and what takes place in the environment in support of this view of the locus of mental processes.

What is potentially radical about Clark's and Sutton's proposal is not that cognitive processes *might* extend from the brain into the body and environment. This possibility stems from the cognitivist commitment to the idea that it is the functional organization of a process that determines whether or not that process is cognitive. That organization, whatever it may be, could, in principle, be realized in any number of material substrates. So, it could be realized only in the brain, or in combination with the brain and body, or in combination with the brain, body, and elements of the environment. What is radical in Clark and Chalmers's and Sutton's view, where it departs from cognitivist orthodoxy, is in the supposition that the complementary relations between brain processes and environmental processes are reason to think that the brain-body-environmental system would be cognitively equivalent to a cognitive process. The radical view maintains the whole assembly of complementary objects and processes constitutes a single thinking being, a single cognitive process. Although cognitivism allows for many sorts of things to realize a cognitive economy, mere complementarity with an environmental process does not enable a cognitive process to extend into the environment. While there is some value in noting the many types of complementary relationships between cognitive processes and environmental processes, it is a bold move to suppose that this gives us reason to suppose that cognitive processes extend from the brain into the body and environment.

To better appreciate the challenge to this radical EC-EM reasoning, consider other cases outside of cognitive science. A standard no. 2 pencil and a pencil sharpener work together to enable a person to write clearly. Writing wears down the point of the pencil, where the sharpener puts a finer point on it. Together the pencil and the sharpener enable a writer to write more and write more clearly and perhaps more attractively. Nevertheless, the pencil and sharpener remain distinct objects in which distinct processes take place. We do not suppose that writing takes place in, or with, both the pencil and the sharpener. In an air conditioner, the evaporator coil and the condenser serve complementary functions. In the evaporator coil a refrigerant evaporates causing a drop in temperature which cools the air. In the condenser, the refrigerant is pressurized which causes it to liquefy and heat up. These are complementary processes, each limited to a distinct portion of the air conditioner. We do not suppose that the cooling takes place in the whole of the system. In a vacuum cleaner, a fan generates a vacuum and a bag filters the air that passes through it. The appropriate arrangement of the vacuum generating device and the filtration device produces an object with capabilities not had by the individual parts. Nonetheless, suction generation takes place in one region of the vacuum cleaner; it does not pervade the whole of the device. All of which suggests that it is one thing to note the complementary relations between cognitive, bodily, and environmental processes, but quite another to suppose that, in virtue of these complementary relations, cognitive processes pervade brain, body, and environment.

## The coupling between brain, body, and environmental processes

We have just seen that one way to interpret Kirsh's work is in terms of the complementary relations between brain, body, and environment. The interactions among brain, body, and environment open up possibilities that could not be realized by the brain acting in isolation. This is, however, still one more way to articulate the idea that the mind is shaped by, dependent upon, and bound up with the body and its environment. One can also think about Kirsh's work in terms of some sort of coupling between what takes place in the brain, the body, and the environment. Kirsh himself has this to say, "In many high speed interactions, the agent and environment can be so tightly coupled that it may be plausible to view the two as forming a single computational system. In that case, some elements of the computation are outside the agent, some are inside, and the computation itself consists in the dynamic interaction between the two" (Kirsh 1995: 63–4). This again invites the radical view according to which cognitive processes extend beyond the brain and span the brain, body, and environment.

Clark and Chalmers (1998), among others, pick up on the notion of coupling as one reason to think that cognitive processes are not to be found entirely within the head.[24] They claim that, "In these cases, the human organism is linked with an external entity in a two-way interaction, creating a *coupled system* that can be seen as a cognitive system in its own right. All the components in the system play an active causal role, and they jointly govern the behavior in the same sort of way that cognition usually does. If we remove the external component the system's behavioral competence will drop, just as it would drop if we removed part of its brain. Our thesis is that this sort of coupled process counts equally well as a cognitive process, whether or not it is wholly in the head" (Clark and Chalmers 1998: 8–9).[25] Here we have a familiar way of stating that cognitive processes extend into the body and environment.

This view is perhaps the boldest claim in the EC-EM literature, but it need not conflict with cognitivism. It could, in principle, be that processes that span the brain, body, and environment constitute a kind of computation on symbolic representations of just the sort found inside brains. In principle, a transcorporeal process could be cognitively equivalent to a cognitive process, hence be a cognitive process. Were there to be such an equivalence, we would have an instance of extended cognition.[26] Where Clark and Chalmers threaten to run afoul of cognitivism, however, is in thinking that creating a kind of coupling between a cognitive process and an environmental process is sufficient for bringing the environmental processes into a cognitive economy. Coupling relations appear to be insufficient to bring about a continuity of a process type. This is clear from some simple examples. Consider how Clark and Chalmers's reasoning might apply to a heating system. In these systems, a thermostat is linked with an external entity, the furnace, in a two-way interaction, creating a coupled system that constitutes the heating system. All the components in the system play an active causal role and they jointly govern the behavior. If we remove the furnace the system's behavioral competence will drop, just as it would drop if we removed part of the thermostat. Yet, contrary to what Clark and Chalmers would infer, the process of expansion of a bimetallic strip is limited to the thermostat and the process of generating heat by the combustion of a gas is limited to the furnace. As we noted above, in general, a coupling between two processes does not influence the typing of the process.[27]

## Conclusion

The EC-EM approach to cognitive science is a work in progress, a work admitting of more conservative and more radical forms. Exactly what form the approach takes depends on how various slogans are developed in detail. Part of what makes the approach plausible is the ability to take on the milder versions of its slogans. The mind has an evolutionary history. Who but creationists deny this? Perception and action are intimately related. Of course, they can be integrated into a single cognitive economy. No one should doubt that. Mental representations do not play the role that traditional cognitive science has posited for them. There are many ways in which one can take exception to certain hypotheses concerning extant theories of mental representation. The mind is shaped by, dependent upon, and bound up with the body and its environment. Of course the mind causally interacts with the body and its environment. If the milder forms of these hypotheses make the EC-EM perspective seem plausible, it is the more radical forms that make it seem exciting. It is bracing to think that cognitive processes are to be found, not just in the brain, but in the body and environment as well. It is revolutionary to think that cognitive processes involve no representations at all. If the EC-EM approach is to stand as an alternative to cognitivism, however, it will need a way of articulating its slogans in ways that are both plausible and interesting.

## Notes

1. For this mode of exposition of embodied cognition and extended mind, see, for example, Anderson (2003), Beer (1995), Brooks (1991a, b, 1997), Haugeland (1998), and Thelen (1995). For an exposition of cognitivism, see Garnham (this volume).
2. See, e.g., Pinker (1997).
3. For further exposition of cognitivism, see Garnham (this volume).
4. Newell and Simon (1972, 1976), Newell (1980, 1990).
5. See Chomsky (1980).
6. See Pylyshyn (1984) and Fodor (1987).
7. A one-to-one mapping between set A and set B is such that for each element of A, there is a distinct member of B. An onto mapping between set A and set B is such that for each member of B, there is a member of A mapped onto it.
8. There is a *prima facie* tension between the neuroscientific tendency to use single-cell-recording techniques to assign meaning to individual neurons on the basis of what environmental stimuli trigger them and the philosophical proposal that items in the mind get their semantic content in virtue of their interrelations.
9. Anderson and Perlis (2002) and Vera and Simon (1993), for example, review these options.
10. Biedermann (1987, 1990).
11. Blanz, V., Tarr, M. J., and Bülthoff, H. H. (1999), Bülthoff, H. H., Edelmann, S. Y., and Tarr, M. J. (1995), Tarr (1995).
12. Another issue concerns whether or not mental representations are compositional in the way that formulas in first-order logic are compositional, or whether they are in some sense "distributed" or "superposed." See, for example, Haugeland (1991) and van Gelder (1991).
13. See, for example, Kosslyn (1994), Kosslyn et al. (2003), Pylyshyn (2003a, b).
14. For still further discussion of representation, see Ryder, pts 1 and 2 (this volume).
15. Turing (1950) himself suggested studying and trying to implement a child's mind before trying to build an adult mind.
16. Chiel and Beer (1997), for example, focus on adaptive behavior, with ramifications much like those following from Brooks's work.
17. In truth, Brooks seems to us to take an equivocal attitude towards representations. On the one hand, he writes, "I must admit that the title is a little inflammatory – a careful reading shows that I mean intelligence without *conventional* representation, rather than without any representation at all" (Brooks 1999b: 79), and there are points in his text where this idea comes out clearly. There are, however, also points at which Brooks seems to want to claim that there are no representations at all: "we believe representations are not necessary and appear only in the eye or mind of the observer" (*ibid.*: 96).
18. Chemero (2000) challenges van Gelder's anti-representationalist interpretation of the Watt governor, where Glymour (n.d.) challenges van Gelder's anti-computationalist interpretation of the Watt governor. See also Bechtel (1998).

19. Within the EC-EM approach to vision, there is Ballard's (1991) proposal that, "[visual] behaviors may not require categorical representations of the 3-D world" (58). Churchland et al. (1994) also challenge what one might call "rich" representations of the environment. Noë (2004) argues that perception does not involve the formation of a mental image, photograph, or snapshot. Adopting these views is, of course, perfectly consistent with cognitivism. Merely challenging the need for complex representations of the environment in vision does not automatically put one beyond the pale of cognitivism. Pylyshyn (2003a, b), for example, provides an extended, cognitivist critique of the pictorial theory of vision. All of this can readily be construed as an in-house cognitivist debate over what representations are needed to explain vision, an in-house debate comparable to what is found in the imagery debate.
20. See Ballard (1991).
21. O'Regan and Noë (2001a, b) and Noë (2004).
22. For further discussion of this and other cases, see Adams and Aizawa (forthcoming).
23. See Clark and Chalmers (1998).
24. The appeal to a coupling between environmental processes and brain processes is also at the heart of Haugeland's (1998) and van Gelder's (1995) version of the view that cognitive processes should be viewed as brain-body-world processes.
25. Not to oversimplify Clark and Chalmers's view, there are overtones of a commitment to the idea that the kinds of processing that take place in the environment are, in some sense, cognitively equivalent to the kind of processing that takes place within the brain.
26. For challenges to some putative examples of a cognitive equivalence between an internal cognitive process and the processes involving the use of a pencil and paper, see Adams and Aizawa (2001) and Rupert (2004).
27. For a much more extensive discussion of "coupling arguments" for extended cognition, see Adams and Aizawa (2001, 2008).

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