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Radical Embodied Cognitive Science

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This paper briefly introduces radical embodied cognitive science (RECS) and places it in historical perspective. Radical embodied cognitive science is an interdisciplinary approach to psychology that combines ideas from the phenomenological tradition with ecological psychology and dynamical systems modeling. It is argued that radical embodied cognitive science has a long history; it is as a direct descendent of the Jamesian functionalist approach to psychology. This approach to psychology is contrasted with the current trend of supplementing standard cognitive psychology with occasional references to the body. In contrast with these trends, radical embodied cognitive science is skeptical of the explanatory usefulness of mental representations. The future prospects of radical embodied cognitive science and the broader functionalist framework are discussed.

Keywords: embodied cognition, ecological psychology, dynamical systems, pragmatism, functionalism

From the very beginning, there have been two ways to do psychology. At around the same time that Wilhelm Wundt founded his institute in Leipzig in 1879, William James began teaching courses in psychology at Harvard University. Despite the fact that both Wundt and James can claim to be founding fathers of psychology, their theories, their methodologies, and their views of what psychology was supposed to explain could not have been more different. Wundt's version of psychology was very much in the Cartesian tradition that Descartes laid out in his *Discourse on the Method*. The correct methodology, Descartes argued, for understanding any phenomenon was to break it down into its constituent parts, and then to attempt to recombine those parts to explain the phenomenon (note the similarity to modern neomechanism in philosophy of science; e.g., Bechtel & Richardson, 2010.) Thus, Wundt's psychology focused on simple sensations, that is, the atoms of conscious experience. Its goal was to see how these simple sensations could be combined into more complex experiences. In contrast, William James created a psychology in the broadly Darwinian tradition. Rather than focusing on the atoms of conscious experience, he said, psychology should tell us how the mind adapts us to our environment. That is, to understand, say, emotions, we needed to understand the role that emotions play in adapting an animal to its environment over behavioral, developmental, and evolutionary timescales. While Wundtian psychology was narrowly focused on the smallest bits of consciousness, Jamesian psychology was as wide as could be, taking in "such things as we call feelings, desires, cognitions, reasonings, decisions, and the like" (James, 1890, p. 1). James (1890) said, "The boundary-line of the mental is certainly vague. It is better not to be pedantic, but to let the science be as vague as its subject, and include such phenomena as these if by so doing we can throw any light on the main business in hand" (p. 6). These two very different beginnings for psychology were codified in the United States as the (Jamesian) Functionalist and (Wundtian) Structuralist schools, which engaged in theoretically fruitful, energetic, and entertaining name-calling throughout the 1890s. The name-calling continued throughout the 20th century, with the protagonist taking on different names. Skinnerian behaviorism is very much a form of functionalism, as is Gibsonian ecological psychology. The cognitive revolution was a structuralist revolution, with leading cogntivist Jerry Fodor (1987) acknowledging that "the computer metaphor" is its only major advance over Wundtian structuralism (p. 23). Indeed, since cognitivism really took hold in the 1970s and 1980s, the psychological mainstream has been solidly Wundtian.

The purpose of this article is to describe an attempt to develop a psychology in the Jamesian tradition that I have called *radical embodied cognitive science* (Chemero, 2009). I am the originator neither of the name, nor, for the most part, the psychology. The psychology, to be described below, combines nonlinear dynamical modeling with ideas about the nature of the mind from James Gibson and/or phenomenological philosophers, and is currently practiced by two tight-knit and loosely interacting groups of scientists. Those more influenced by Gibson, call themselves *ecological psychologists* (e.g., Turvey, Shaw, Reed, & Mace, 1981); those more influenced by phenomenologists call themselves *enactivists* (e.g., Varela, Thompson, & Rosch, 1991; Thompson, 2007). One of the key aims of my work has been to get ecological psychologists and enactivists to realize that they are (almost) on the same page (see Chemero, 2012.) The name is due to Andy Clark (1997). Clark coined the term *radical embodied cognitive science* as a contrast with what he took to be the more cognitivism-friendly version of embodied cognitive science. In what follows, I will explain radical embodied cognitive science, my target, in terms of what has come to be called *embodied cognitive science*.

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Embodied Cognitive Science

Nowadays, much of cognitive science claims to be embodied, but embodied is meant in a very weak sense, and one that differs from what I call radical embodied cognitive science. Typically, those writing about embodied cognition start with the early work of Rodney Brooks (1991). To give credit where it is due, I will go back further, to the work of American naturalist offspring Gibson (1979) and the collaborations between John Barwise and John Perry (1981, 1983).

Gibson's (1979) ecological theory of vision was intended as a direct response to the increasing dominance of computational theories of mind, according to which perception and thought are rule-governed manipulations of internal representations. Gibson's ecological approach to perception has three major tenets. First, perception is direct, which is to say that it does not involve computation or mental representations. That is, Gibson thought that perception was not a matter of internally adding stored information to sensations. Second, perception is primarily for the guidance of action, and not for action-neutral information-gathering. We perceive the environment in order to do things. The third tenet follows from the first two: Because perception does not involve mental addition of information to stimuli, yet is able to guide behavior adaptively, all the information necessary for guiding adaptive behavior *must* be available in the environment to be perceived. Thus, the third tenet of Gibson's ecological approach is that perception is of *affordances*, that is, directly perceivable, environmental opportunities for behavior. Affordances, as Gibson was well aware, are ontologically peculiar:

> [A]n affordance is neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective−objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behavior. It is both physical and psychical, yet neither. An affordance points both ways, to the environment and to the observer. (Gibson, 1979, p. 129)

Despite this ontological peculiarity and the controversy over how to best understand affordances (Turvey, 1992; Reed, 1996; Stoffregen, 2003; Chemero, 2003; Şahin, Çakmak, Doğar, Uğur, & Üçoluk, 2007; Chemero & Turvey, 2007), the idea of affordances—divorced of their relation to direct perception—is the one aspect of Gibson's theory that gained significant attention from the beginning, for example, from designers (see Norman, 1988). The rest of Gibson's ideas were not widely accepted by cognitive scientists on their appearance. They were, however, widely discussed (see Fodor & Pylyshyn, 1981; Turvey et al., 1981), and did attract a small, solid core of devotees. More recently, Gibson has become one of the heroes of embodied cognitive science, which has adopted these views (substantially softened) as its own.

Moving slightly closer to the present, we can trace the origins of the *situated* aspect of embodied cognitive science to situation semantics, the work in the philosophy of mind and language done in the 1980s by Barwise and Perry (1981, 1983). Taking themselves to be providing a semantics for Gibsonian psychology, Barwise and Perry argued that we cannot understand meaning or cognition without taking into account that thinkers are spatially located (i.e., situated) and so have only incomplete, locally available information at their disposal. Every thinker and speaker is someone, who is somewhere, and who is aware of only certain things. One major upshot of this is that indexicals, terms such as *I*, *you*, and *here*, whose meaning is dependent on the context of use, move from the periphery of accounts of cognition to the center. The idea is that because animals are situated in their environment and experience it from a particular point of view, indexical thoughts about *here*, *there*, *now*, and *me* are ubiquitous. This focus on indexicals, we will see, is a crucial, but almost incidental feature of embodied cognitive science. A second important feature of Barwise and Perry's was derived directly from its Gibsonian motivation. Barwise and Perry developed their situation semantics in order to account for meaning without reference to mental representations. In their nonrepresentational account, having meaningful thoughts (e.g., perceptions, utterances) has nothing to do with having mental representations, or indeed with anything that might be called epistemic. The meaning of thoughts and sentences is a matter of the relationship between thinkers/speakers and information in their environments.

It is this latter aspect of Barwise and Perry's situation semantics that Brooks (1991) picked out when he used the word *situated* to describe his robots. When Brooks said that his simple, mobile robots are situated, he meant that, because they are in the midst of a changing world, they do not need to use representations of the world to plan or guide their behavior. Instead they interact with the world itself. The idea is that there is no need to store information on-board and make predictions about how things will change during an action, when you can just act and check again. Brooks summed up this antirepresentationalism with the slogan, "The world is its own best model." This Gibson-like skepticism about mental representations is perhaps the most (in)famous aspect of Brooks's early work, but it is not his antirepresentationalism that makes Brooks the model for embodied cognitive science. Instead, it is his insistence that intelligence is necessarily embodied. Brooks argued that it is real interaction with the real world that is the mark of intelligence. In effect, Brooks sees Barwise and Perry and raises them: for Brooks, it is not just a thinker's setting, but also its physical constitution, that is essential for understanding it as intelligent, thinking, and so on. And, of course, having a physical constitution that is essential to intelligent behavior guarantees being situated in a physical (not to mention social) environment. Embodied cognition is necessarily situated.

The current work in embodied cognitive science that arose from these sources (among others, of course) is a broad-based movement, incorporating work in robotics, simulated evolution, developmental psychology, perception, motor control, cognitive artifacts, and phenomenology that attempts to combine the ideas of Gibson, Barwise and Perry, and Brooks with ideas from computational cognitive science. That is, embodied cognitive scientists do not reject mental representations. Yet, although embodied cognitive scientists do call on representations to explain behavior, they call on them in such a way that the need for internal computation is reduced. The representations they call on are indexical−functional (Agre & Chapman, 1987), pushmi−pullyu (Millikan, 1995), action-oriented (Clark, 1997), or emulator representations (Grush, 2004). In what follows, I will refer to these collectively with Clark's term *action-oriented representations*. Action-oriented representations differ from representations in earlier computationalist theories of mind in that they represent things in a nonneutral way, as geared to an animal's actions, as affordances. Action-oriented representations are more primitive than other representations in that they can lead to effective behavior without requiring separate representations of the state of the world and the cognitive system's goals. That is, the perceptual systems of agents need not build an action-neutral representation of the world, which can then be used by the action-producing parts of the agent to guide behavior; instead, the agent produces representations that are geared toward the actions it performs from the beginning.

In fact, despite the influence of Gibson, embodied cognitive science is a form of cognitivism. For all its breaks with traditional cognitive science, embodied cognitive science is still a *computational* theory of mind. This much can be seen from the way Kirsh and Maglio (1994) described the zoid-rotations of their Tetris players: they said that zoid-rotation is a matter of off-loading computational complexity onto the environment, so that the rotation is *part of the computation*. This position, often referred to as the *extended mind* or *extended cognition* (Clark, 1997), seems like a radical break with tradition, implying that the machinery of the mind can extend beyond the biological body, until you realize that it is still a form of computationalism. Wilson (2004) called it *wide computationalism* in which we explain cognition in terms of representations in computational systems that span brain, body, and environment. Embodied cognitive science, thus, is in an ambiguous position. It is highly influenced by the Jamesian functionalist worldview, but it is also a form of the Cartesian computational theory of mind.

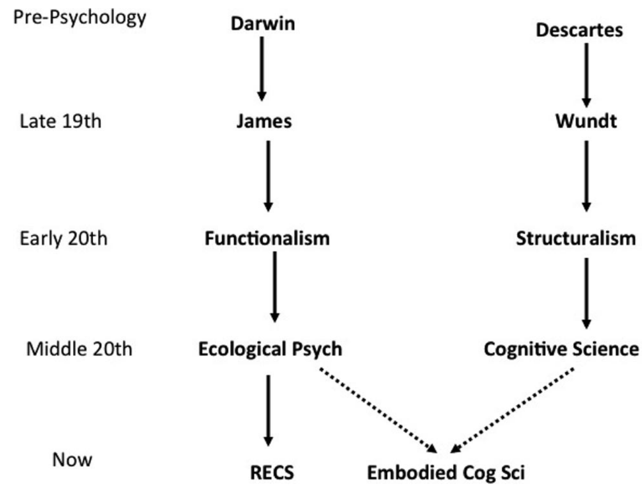

Figure 1. Intellectual lineage of modern psychological traditions. Note that radical embodied cognitive science is the continuation of a well-established set of psychological traditions. Nonradical embodied cognition, in contrast, tries to incorporate a small number of principles from the ecological tradition into an otherwise unchanged cognitive approach. RECS = radical embodied cognitive science; cog sci = cognitive science.

Radical Embodied Cognitive Science

The best way to understand the relation between the more common embodied cognitive science and *radical* embodied cognitive science is to look back again at the historical forbears of embodied cognitive science. As noted above, the more common form arose from embracing some of the ideas of Gibson, Barwise and Perry, and Brooks, but backpedaling on the strongest claims these authors made. In particular, they embraced the necessity of embodiment and the value of dynamical explanation, but combined those principles with the computational theory of mind. That is, embodied cognitive scientists were unwilling to embrace the most interesting tenets of those who inspired them. The *antirepresentationalism* of Gibson, Barwise and Perry, and Brooks, which implies anticomputationalism, was simply too much for most embodied cognitive scientists. Radical embodied cognitive science, in contrast, is a form of Jamesian functionalism that rejects representationalism fully. (Gibsonian ecological psychology, remember, is a direct descendent of the work of James.) I would suggest, then, that radical embodied cognitive science is not a radicalization of embodied cognitive science. Instead, what commonly passes as embodied cognitive science should be seen as a watering down of radical embodied cognitive science, and an attempt to combine a theory that is ultimately Jamesian in origin with the computational theory of mind (see Figure 1).

This point is important for two reasons. First, it needs to be clear that radical embodied cognitive science is part of a venerable scientific tradition, one that begins with the birth of American psychology, and so is in no sense radicalism for its own sake. Second, understanding weak-embodied cognitive science as a watered-down version of radical embodied cognitive science blunts one common criticism. Clark has argued several times (Clark, 1997, 2008; Clark & Grush, 1999) that the antirepresentationalism of radical embodied cognitive science is misplaced. Really, he thinks, radical embodied cognitive scientists are mistakenly extending their disagreement with traditional cognitive science to a disagreement with all of computationalism. What radical embodied cognitive scientists are "really" opposed to, he has suggested, are objective, sentence-like representations. Thus, Clark thinks that radical embodied cognitive scientists are pushing for too severe a break with the good-old fashioned artificial intelligence of the cognitivist revolution; they should be satisfied with the less severe break he offers. This line of argument loses a good deal of its force, though, once one realizes that radical embodied cognitive science is not a recent breakaway from computationalism, is not Clark's system plus antirepresentationalism, but is antirepresentationalist root and branch. The onus, I would argue, is instead on more mainstream view, which must show that its attempts to incorporate Jamesian ideas into computationalism are truly stable. It might be that this combination of functionalist and structuralist thinking ends up being no more fruitful than that other recent attempt to combine a Darwinian worldview with computational psychology, that is, modern "evolutionary psychology," a field whose day in the sun seems to have passed without much in the way of lasting scientific value having been generated (see Richardson, 2007, for a trenchant critique).

To see how radical embodied cognitive science works, consider a theory of the relationship between mind and world as general as those by Gibson (1966, 1979) and phenomenologists such as Heidegger (1927/1962) or Merleau-Ponty (1962). In each case, the theory begins with a critique of an understanding of cognition like that depicted in Figure 2a. Here, we have the world causally impinging on the thinker, and causing the thinker to form internal representations of the world. These representations are the thinker's only access to the world. This, of course, is a very old and very common way to understand our place in the world, and motivates the entire structuralist tradition, from

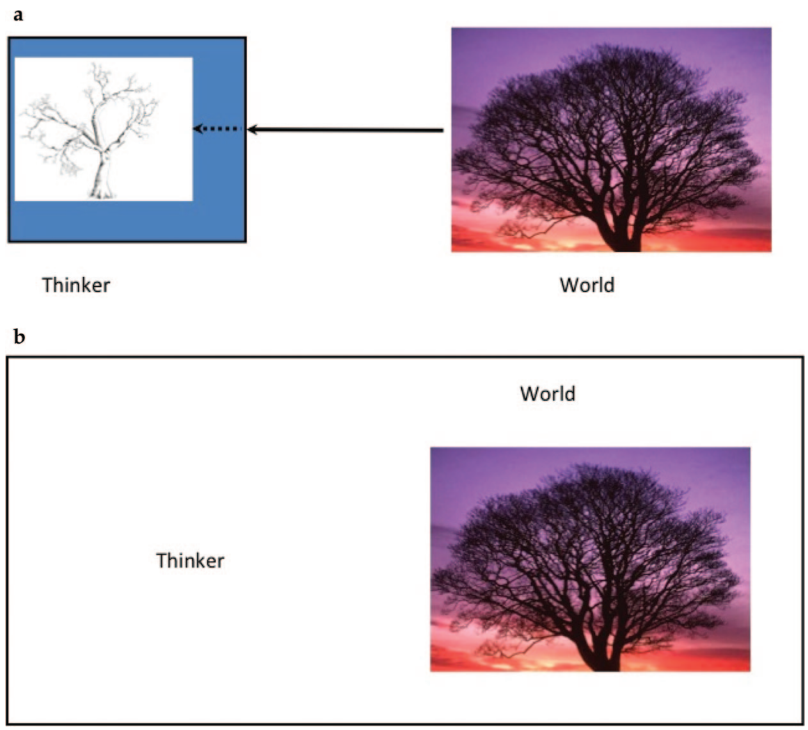

Figure 2. The contrast between approaches that see the world as causally impinging on the thinker (a) and those approaches that see the thinker as dynamically interacting with the world (b).

Descartes to today's cognitive science, including (nonradical) embodied cognitive science. Heidegger, Merleau-Ponty, and Gibson explicitly criticized this picture. As Heidegger (1927/1962) put it, "[T]he perceiving of what is known is not a process of returning with one's booty to the cabinet" of consciousness after one has gone out and grasped it" (p. 89). In contrast, Gibson and the phenomenologists depicted a situation more like that in Figure 2b, according to which a thinker is surrounded by and interacting with the world itself, and need not form representations of it to do so. Figure 2b is the general understanding of the relationship between the mind and world that inspires radical embodied cognitive science. Very general theories of the relationship between thinking and the world are instructive and inspiring, but can be difficult to put into contact with data gathered in the lab. To put this very general picture into contact with data you can gather in the lab, to make it into an empirical science, something more is needed. In the case of radical embodied cognitive science, that something else is dynamical systems modeling.

And, indeed, the recent resurgence of interest in dynamical modeling in psychology begins with work by Kugler, Kelso, and Turvey (1980), in their attempt to try to answer a question raised by Gibson (1979). In trying to explain action in a way that did not demand an inner agent using sensory representations to develop motor representations, Gibson (1979) said that, "The rules that govern behavior are not like laws enforced by an authority or decisions made by a commander: behavior is regular without being regulated. The question is how this can be." Kugler et al.'s (1980) answer was that human behavior is self-organizing, and therefore subject to the same kind of mathematical modeling that one applies to self-organizing systems in other sciences. The use of dynamical systems theory as a modeling tool plays several crucial roles in radical embodied cognitive science. First, and perhaps most important, it does what modeling does throughout the sciences: it bridges the gaps between abstract theorizing and concrete data that can be gathered in the lab. Second, radical embodied cognitive science requires an explanatory tool that can span the agent−environment border. A dynamical system is a set of quantitative variables changing continually, concurrently, and interdependently over time in accordance with dynamical laws that can, in principle, be described by some set of equations. To say that cognition is best described using dynamical systems theory is to say that cognitive scientists ought to try to understand cognition as intelligent behavior and to model intelligent behavior using a particular sort of mathematics, most often sets of differential equations. Dynamical systems theory is especially appropriate for radical embodied cognitive science because single dynamical systems can have parameters on each side of the skin.[1] It is only for convenience (and from habit) that we think of the organism and environment as separate; in fact, they are best thought of as forming just one nondecomposable system. Rather than describing the way external (and internal) factors cause

[1] That is, we might explain the behavior of the agent in its environment over time as coupled dynamical systems, using something like the following equations, from Beer (1995):

$$\dot{X}_A = A(X_A; S(X_E))$$
$$\dot{X}_E = E(X_E; M(X_A))$$

where A and E are continuous-time dynamical systems, modeling the organism and its environment, respectively, and $S(x_E)$ and $M(x_A)$ are coupling functions from environmental variables to organismic parameters and from organismic variables to environmental parameters, respectively.

changes in the organism's behavior, such a model would explain the way the system as a whole unfolds over time.

What I am calling radical embodied cognitive science, then, is the use of dynamical modeling to put the theoretical positions of Gibson, Heidegger, and Merleau-Ponty in touch with data about perception, action, and cognition that can be gathered in the lab. As mentioned above, people have been doing radical embodied cognitive science, under different names, for decades now. Pioneers in this endeavor include (alphabetically) Walter Freeman, J. A. S. Kelso, David Lee, Robert Shaw, Linda Smith, Esther Thelen, Evan Thompson, Michael Turvey, Francisco Varela, and William Warren, among others.

Because I presume that the work of those just listed is familiar to most readers of this article, I will close this section with an example of radical embodied cognitive research from my own lab. Dobromir Dotov, Lin Nie, and I wanted to empirically test a claim that can be derived from Heidegger's (1927/1962) phenomenological philosophy (see Dotov, Nie, & Chemero, 2010). In particular, we wanted to see whether we could gather evidence supporting the transition Heidegger proposed between "ready-to-hand" and "unready-to-hand" interactions with tools. Heidegger argued that most of our experience of tools is unreflective, smooth coping with them. When we ride a bicycle competently, for example, we are not aware of the bicycle but of the street, the traffic conditions, and our route home. The bicycle itself recedes in our experience, and becomes the thing through which we experience the road. In Heidegger's language, the bicycle is ready-to-hand, meaning that we experience it as a part of us, no different than our shoulders or knees. Sometimes, however, the brakes grab more forcefully than usual or the chain slips, and the bicycle becomes temporarily prominent in our experience. We notice the bicycle. Heidegger would say that the bicycle has become unready-to-hand, in that our smooth use of it has been interrupted temporarily and it has become, for a short time, the object of our experience.

To test Heidegger's theory, we had participants play a simple video game, in which they used a mouse to control a cursor on a monitor. Their task was to move the cursor so to "herd" moving objects to a circle on the center of the monitor. At some point during the trial, the connection between the mouse and cursor was temporarily disrupted, so that movements of the cursor did not correspond to movements of the mouse. Later, control would return. We measured their hand movements to determine whether they showed 1/f scaling, a property of physiological systems that would indicate the mouse was being treated as part of a single system along with the rest of their body (Riley & Holden, 2012; West, 2006). As predicted, the hand-mouse movements of the participants exhibited 1/f scaling while the video game was working correctly. The 1/f scaling decreased, almost to the point of exhibiting pure white noise, during the mouse perturbation, then returned to 1/f scaling when they regained control. So, while participants were smoothly playing the video game, they were part of a human−computer system that had the same pattern of variability as a well-functioning physiological system; when we temporarily disrupted performance, that pattern of variability temporarily disappeared. This is evidence that the mouse was experienced as ready-to-hand while it was working correctly, and became unready-to-hand during the perturbation (see Dotov et al., 2010, for more details).

It is important to note the role of dynamical modeling. The dynamical model was used to put Heidegger's claims about phenomenology into touch with potentially gatherable data. In effect, the models made Heidegger's claims empirically accessible, and allowed us to gather evidence for them. Moreover, the results from prior dynamical modeling acted as a *guide to discovery*, a source of new hypotheses for further experimental testing (Chemero, 2000, 2009, in press). In this case, the findings concerning 1/f scaling and physiology and the knowledge of the way 1/f scaling could be detected inspired the experimental task. This makes clear that the dynamical models are not acting as mere descriptions of data, but play a significant role in hypothesis generation. The models are in no way secondary to the theory, and are an integral part of radical embodied cognitive science.

Is Radical Embodied Cognitive Science the Right Way to Do Psychology?

Typically, partisans will try to convince you that theirs is the one true way. I do not believe that radical embodied cognitive science is the one true psychology of the future. It has had many successes, especially in explaining what Brooks called "the bulkiest parts of intelligence": perception, action, motor control, and coordination. There have been few attempts to see how it fares with less bulky parts of intelligence, such as planning and decision-making, and it seems not particularly well suited to explaining abilities that require stepping back from interacting with the world and thinking carefully (but see Stephen & Dixon, 2009; van Rooij, Favela, Malone, & Richardson, in press). It seems prudent to adopt a pluralistic stance toward theorizing in psychology. To borrow a metaphor from Rick Dale, we would be puzzled if someone told us that they had an explanation of the Mississippi River (Dale, 2008; Dale, Dietrich, & Chemero, 2009). Because the Mississippi River is such a complex entity, we would want to know what aspect of the river he or she was explaining: The sedimentation patterns? The economic impact? The representation in American literature? Surely these disparate aspects of the Mississippi could not have just one explanation, or even just one kind of explanation. The mind, I submit, is just as complicated as the Mississippi River, and it would be shocking if just one style of explanation could account for all of it. For this reason, it is wise to adopt explanatory pluralism in psychology.

That said, we should not be too pessimistic about how much radical embodied cognitive science can draw into its fold. I have already discussed how ecological psychologists, dynamical systems theorists, and enactivists are radical embodied cognitive scientists. This is already sizable crowd. We could also, of course, add many behaviorists (e.g., Schoneberger, 2000; Laird, 2007) and radical empiricists (e.g., Charles, 2009). Moreover, radical embodied cognitive scientists have moved beyond the traditional borders of cognitive science to study personality (e.g., Jayawickreme & Chemero, 2008; Jayawickreme & Di Stefano, 2012) and social psychology (e.g., Schmidt, Carello, & Turvey, 1990; Harrison & Richardson, 2009). Radical embodied cognitive science may not be the one true psychology, but its prospects for the next few decades are pretty good. After that, changing times and changing methodologies will no doubt cause it to be left behind. I have no doubt, however, that the Jamesian Functionalist tradition will continue.

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