Adaptive **Behavior**

Gibsonian Affordances for Roboticists

Anthony Chemero[1], Michael T. Turvey[2]
[1]*Scientific and Philosophical Studies of Mind Program, Franklin and Marshall College, Lancaster, PA, USA*
[2]*Department of Psychology, University of Connecticut and Haskins Laboratories, University of Connecticut, Storrs, CT, USA*

Using hypersets as an analytic tool, we compare traditionally Gibsonian (Chemero 2003; Turvey 1992) and representationalist (Sahin et al. this issue) understandings of the notion 'affordance'. We show that representationalist understandings are incompatible with direct perception and erect barriers between animal and environment. They are, therefore, scarcely recognizable as understandings of 'affordance'. In contrast, Gibsonian understandings are shown to treat animal-environment systems as unified complex systems and to be compatible with direct perception. We discuss the fruitful connections between Gibsonian affordances and dynamical systems explanation in the behavioral sciences and point to prior fruitful application of Gibsonian affordances in robotics. We conclude that it is unnecessary to re-imagine affordances as representations in order to make them useful for researchers in robotics.

Keywords affordances · Gibson · hypersets

1 Introduction: Gibsonians and Representationalists

James J. Gibson's ecological approach to psychology has two main components, the theory of affordances and the hypothesis of direct perception. Affordances are opportunities for behavior; they are properties of the environment, but taken relative to an animal. In Gibson's (1979, p. 127) words, "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill." Affordances are resources that the environment offers any animal that has the capabilities to perceive and use them. The hypothesis of direct perception is that perception properly construed is non-inferential. It does not involve mental representations. To quote Gibson (1979, p. 147) again, "When I assert that perception of the environment is direct, I mean that it is not mediated by retinal pictures, neural pictures, or mental pictures." Perception is direct, unmediated contact between animal and environment.

The two components, in combination, define the ecological approach to perception and action. An animal engages its environment by using the information available in the animal–environment system of which it is a part to directly perceive and act upon affordances. With the activity comes further information for directly perceiving and acting upon further affordances. Accordingly, in the ecological approach, perception–action and animal–environment each form inseparable pairs. The former pair is unified by the theory of affordances; the latter by direct perception.

Correspondence to: Anthony Chemero, Scientific and Philosophical Studies of Mind Program, Franklin and Marshall College, Lancaster, PA 17604-3003, USA.
E-mail: tony.chemero@fandm.edu
Tel.: +1 717 291 4202; *fax*: +1 717 291 4387

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Given the tight connection between perception and action forged by the ecological approach by means of the theory of affordances, it is quite natural that affordances would be attractive to roboticists, who need to build devices that behave in systematic ways relative to select aspects of their surroundings. Thus, Sahin et al. (this issue) attempt to adapt the Gibsonian concept of affordance for use in their robotics research, and seek to do so despite concerns that the concept is "elusive" and "misty". Elusiveness and vagueness are, of course, hardly unique to the notion of affordance. Commonplace notions used in the cognitive and neural sciences are similarly disputed and vexed (e.g., consider the notion of 'concept').

Gibson wrote about affordances in admirably plain English. His attempts, however, to define a new concept that straddled many traditional boundaries had to confront established binary oppositions and had to identify what would be the consequences of dissolving them. In the absence of any appropriate logical formula, expressing such consequences in plain English could not be anything other than perplexing. Thus:

> [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)

Perplexing statements of the preceding kind have invited, necessarily, attempts at clarification and resulted in some measure of disagreement over the nature of affordances, even among ecological psychologists. In particular, there have been differences over whether affordances are dispositional features of the environment that have animals among their actualizing conditions (e.g., Turvey, 1992) or relational features of animal-environment systems (e.g., Chemero, 2003; Stoffregen, 2003). This is, arguably, still an open debate. (But see Chemero & Turvey, 2007a.) There is, however, a key point of agreement among ecological psychologists who take affordances to be dispositional features of the environment and those who take them to be relational features of animal–environment systems. Both sides insist on understanding affordances so that the other main component of Gibsonian ecological psychology is respected. Affordances, both sides insist, are perceived directly. We can lump these views of affordance (and direct perception) together under the term 'Gibsonian'.

In contrast to the Gibsonians, Sahin et al. wish to detach the theory of affordances from the hypothesis of direct perception. Or, to put the same thing slightly differently, they want to disrupt the connection between animal and environment, but maintain the connection between perception and action. They disrupt the animal–environment connection by making affordances into mental representations that mediate the animal–environment coupling. We will argue that this also disrupts the connection between perception and action. Sahin et al. are not the first to define affordances as mental representations: Norman (1988), Vera and Simon (1997) and Wells (2002) also understand affordances as varieties of mental representation. We can refer collectively to Sahin et al. and these others as 'representationalists'. Representationalists believe that affordances must be internalized for use by computational processes in order to make a difference in guiding action; we Gibsonians disagree.

In the rest of this paper, we will detail the differences between the Gibsonian and representationalist viewpoints. As we have done in several recent papers, we will make the comparison using hyperset diagrams, which we have shown to be useful in analyzing complex systems (Chemero & Turvey 2007a, 2007b). In particular, we will show graphically that Gibsonians, but not representationalists, model animal–environment systems as densely interconnected complex systems. We will also show that this makes Gibsonian, but not representationalist, views of affordances inconsistent with the computational theory of cognition, according to which cognition is a kind of internal computation. This, however, does not remove complex, interconnected animal–environment systems as understood by Gibsonians from the purview of computational simulation, nor does it rob Gibsonian affordances of their usefulness to roboticists.

2 Sets and Hypersets

Hyperset theory differs from standard set theory in that it allows sets to be members of themselves, directly and indirectly (Aczel, 1988; Barwise & Etchemendy, 1987). An example of the direct case is the set $\Omega = \{\Omega\}$. An example of the indirect case is $A = \{B\}$ and $B = \{A\}$, which gives us that $A = \{\{A\}\}$ and $B = \{\{B\}\}$. We will typically lump the direct and indirect kinds of self-membership under the term 'circularity'. Circularity is not allowed in standard set theory because it leads to various paradoxes, but it seems that circularity is necessary if one wishes to use sets to account for natural language (Barwise & Etchemendy, 1987) and other phenomena of natural systems (Chemero & Turvey, 2007a, 2007b). The theory of hypersets is useful for modeling the structure of complex natural systems primarily because of the graphical tools it provides.

Hyperset graphs are constructed by drawing an arrow from each set in a system of sets to each of its members. The graph of the set $P = \{a, b, c\}$ is shown in Figure 1. The most basic case of self-membership Ω is shown in Figure 2. Figure 3 shows the circular sets A and B described above. The key feature of Figures 2 and 3—the graphs of sets with themselves as members (directly or indirectly)—is the presence of loops. The graph of the standard legal set (Figure 1) has no loops. This is a general property of hyperset graphs: the sets they depict are circular if and only if the graphs have one or more loops.

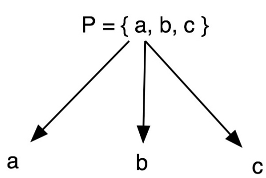


Figure 1 The graph of the set $P = \{a, b, c\}$.

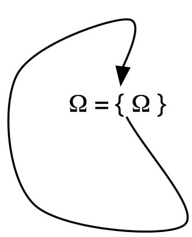


Figure 2 The most basic case of self-membership Ω.

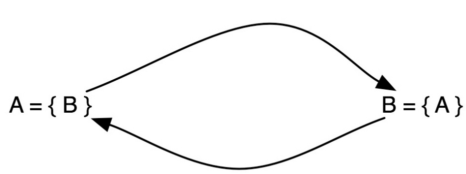


Figure 3 The circular sets A and B.

Hyperset graphs can be used as complexity detectors, allowing the sorting of simple systems from complex systems at a glance. Robert Rosen (1991, 2000) defines complex systems, such as the most basic living system, as systems whose models are circular. (Rosen actually uses the term 'impredicative', which more or less means 'circular' as we are using it here.) Pretend that the systems of sets Ω, $A + B$, and P are models of natural systems. Looking at the graphs, it is easy to see that the systems modeled by Ω and by $A + B$ are complex in Rosen's sense, while that modeled by P is simple. This is the case because the graphs of Ω and $A + B$ have loops, but the graph of P does not.

3 Competing Definitions of Affordance

In what follows, we present the hyperset graphs of competing definitions of affordances identified in Chemero and Turvey (2007a) along with hyperset graphs of two of Sahin et al.'s definitions. We preface the presentations with three brief notes on conventions. First, relations are represented as ordered pairs. Thus, NEARER-THAN ($Reach_{max}$, Banana) is represented as the ordered pair: <$Reach_{max}$, Banana>. Second, ordered pairs are represented as the singleton set of the first member of the pair and a set that includes both members of the pair. Thus, <$Reach_{max}$, Banana> is represented as $\{Reach_{max}\}$, $\{Reach_{max}, Banana\}$. Third, equivalence classes of entities are represented as just one individual. That is, $\{dog_1, dog_2, dog_3, \ldots\}$ is represented as $\{dog\}$.

Figures 4 and 5 depict the definitions of affordance proposed in Turvey (1992) and Chemero (2003), respectively. As part of their careful and generally fair review of the literature on affordances, Sahin et al. (this issue) describe these theories accurately. So we will not describe them here, other than to point out that we will refer to them collectively as Gibsonian definitions. Figure 6 depicts a definition of affordance proposed by Vera and Simon (1993) that Sahin et al. do not discuss. We, therefore, discuss it briefly here. Vera and Simon's (1993) definition is an attempt to incorporate the advantages of situated, embodied cognitive science into a more standard (circa 1993, at least) computational cognitive science. Thus, they

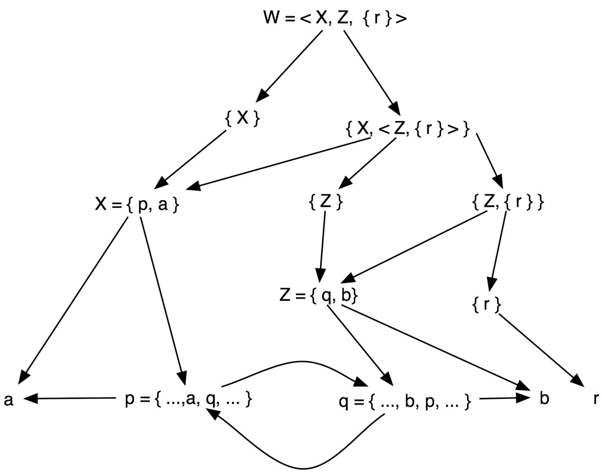


Figure 4 The definitions of affordance proposed in Turvey (1992).

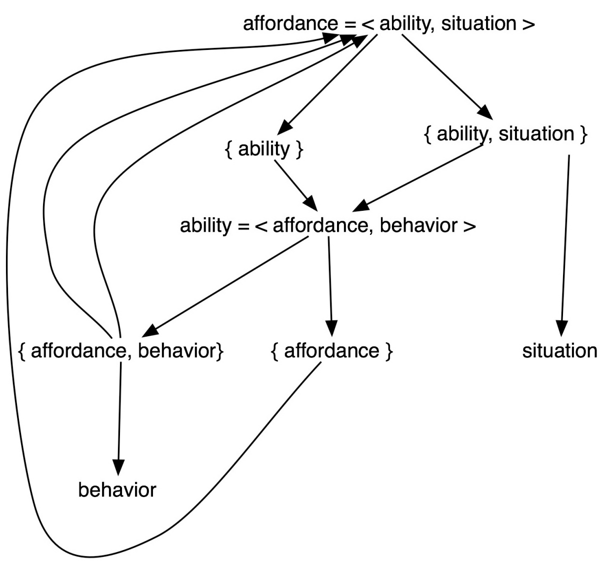


Figure 5 The definitions of affordance proposed in Chemero (2003).

argue (contra Gibson and Gibsonians) that affordances are a kind of mental representation. "A functional description of the world (i.e., a description in terms of something like affordances) is one that allows simple mappings between our functional models of what is out there (e.g., road curves to the left) and our functional actions (e.g., turn to left)" (Vera & Simon, 1993, p. 21). For them, an affordance is an internal representation that allows relatively fast mapping between two other representations, one of what the

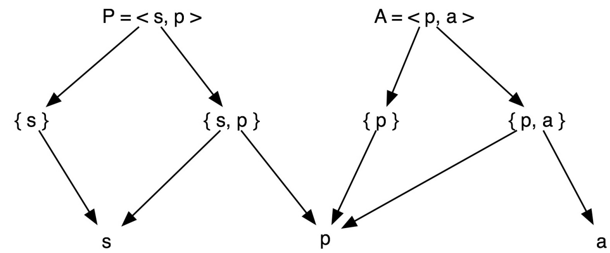


Figure 6 A definition of affordance proposed by Vera and Simon (1993).

world is like and another of what one might do in respect to it. More formally, the idea is that perception is a function from sensory states to perceptual representations, $P = \{<s_1, p_1,>, <s_2, p_2,>, \ldots, <s_n, p_n,>\}$. Affordances, on Vera and Simon's view, are mappings from perceptual representations to action representations, $A = \{<p_1, a_1,>, <p_2, a_2,>, \ldots, <p_n, a_n,>\}$. Following the convention described above, s_1 s_n are collectively depicted as simply 's'; similarly, for a_1 a_n and p_1 p_n. Sahin et al.'s own definitions of affordance from the perspectives of observer and agent are depicted in Figures 7 and 8, respectively.

The most important feature of Figures 4–8 is that the hyperset graphs of the affordance definitions proposed by Turvey (1992) and Chemero (2003) contain loops, whereas those for the affordance definitions proposed by Vera and Simon and Sahin et al. do not. This means that the Gibsonian, but not the representationalist, definitions understand animal–environment systems as complex systems. On both Gibsonian views, the animal's abilities (or effectivities) and the behavior-relevant environment are defined (circularly) in terms of one another, and are therefore unintelligible separately. That is, on the Gibsonian definitions the animal and environment form a unified system. This is not the case for the representationalist definitions.

Taking the animal and environment to form a unified, complex system has two important consequences. First, it makes dynamical systems theory the most natural explanation of action. Indeed, the current attraction to dynamical systems theory in the cognitive sciences has been inspired in large part by the efforts within ecological psychology to develop a non-representational account of perception–action (Kugler, Kelso & Turvey 1980; Kugler & Turvey 1987; Kelso 1995; Kelso & Engstrom 2006; Warren 2006). Taking animal-environment systems to be unified complex sys-

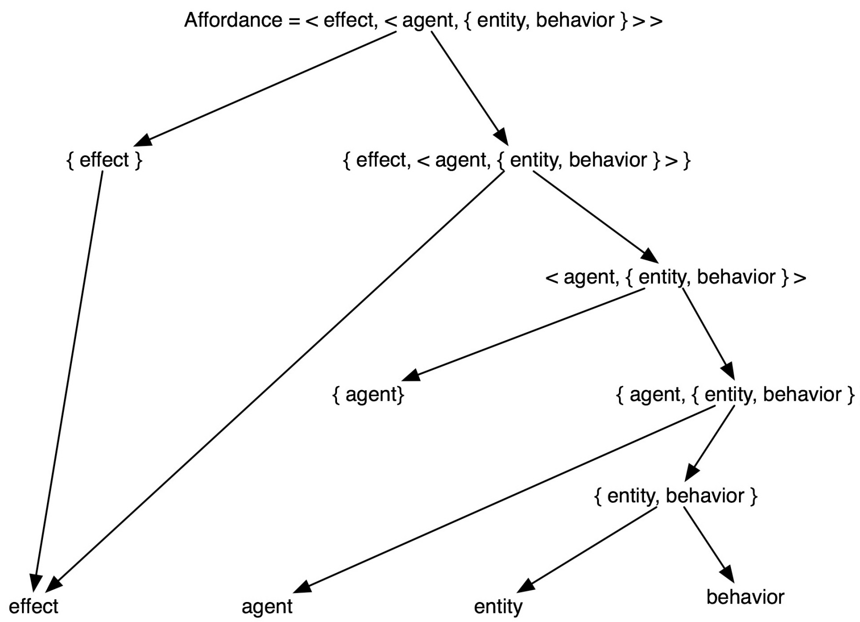


Figure 7 Sahin et al.'s own definitions of affordance from the perspectives of observer.

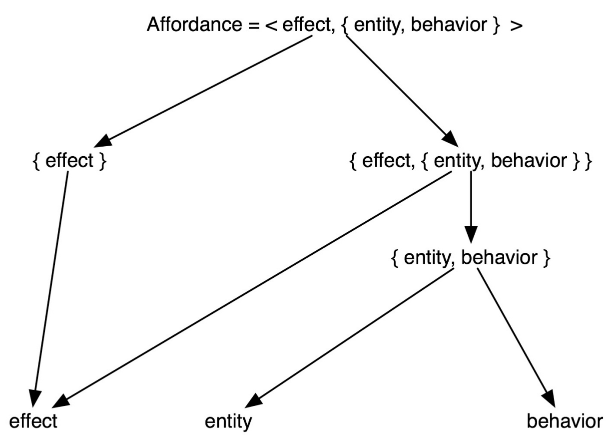


Figure 8 Sahin et al.'s own definitions of affordance from the perspectives of agent.

tems all but necessitates explaining their behavior using non-linearly coupled dynamical equations. Second, and more to the point here, is that taking the animal and environment to form a unified system gives license to the claim that perception is direct. If the animal and the behavioral-relevant environment are just one system, then perception can be direct because there is no need for the animal to represent the environment. In contrast, on the representationalist view, the animal must gather data about an entity (out there), combine that mentally represented data (in here) with mentally represented actions (in here), and with the mentally represented effects of those actions (in here), in order to mentally select (in here) an action (out there). Representationalists such as Sahin et al. take animals and environments to be separate, and represented affordances to be necessary mediators, storing data in the animal about what actions can be taken in specific environmental circumstances. That is, they make the two main components of Gibsonian ecological psychology incompatible. In spite of Sahin et al.'s claims to the contrary, if affordances are mental representations, perception of them cannot be direct.

Furthermore, as implied in the "in here–out there" scenario above, representationalist affordances also mediate between perception and action. By definition, representationalist affordances are percepts of the environment suitable for action; they are what Clark (1997) calls action-oriented representations. They are the result of internal perceptual processes that are especially useful for internal action-guiding processes, but they still mediate between perceiving and acting. Animals perceive first; then act, guided by the represented affordances. In contrast, Gibson (and Gibsonians) take perception (of affordances) and action (using affordances) to be co-constitutive: perception is always, in part, action; action is always, in part, perception. Representationalist understandings of affordance thus also disrupt the Gibsonian connection between perception and action.

Another important difference is that Gibsonian views are inconsistent with the idea that cognition is computation. As Fodor (1981, p. 180) has famously put it, "[t]here is no computation without representation." Thus only representationalist views, like those of Sahin et al., are consistent with computationalism. Indeed, Vera and Simon (1993) define affordances as internal representations to ensure that affordances can be part of a computational cognitive system. This inconsistency between Gibsonian views and computationalism can encourage the dismissal of Gibsonian understandings of affordance virtually out of hand. For many mainstream cognitive scientists the non-computationalist stance is reason enough to reject Gibson's views, and motivation to develop an understanding of affordances that is computation-friendly. Gibson and his followers, however, purposely reject computationalism and representationalism. They take their theoretical views on affordances, direct perception, and information, along with the methods and concepts of dynamical systems theory, to comprise a genuine alternative to the still-dominant computational theory of cognition.

4 Gibsonian Affordances in ALife and Robotics

In our view, the aforementioned differences between representationalist and Gibsonian affordances are reasons to favor Gibsonian approaches, at the very least in virtue of being faithful to Gibson's own thinking. We also believe that properly Gibsonian views provide a superior set of concepts and explanatory tools for the cognitive sciences, ALife, and robotics. This is, of course, not the place to argue for this claim. (Indeed, no largely conceptual argument for the superiority of Gibsonian approaches would be convincing.) This *is* the place, though, to set aside two consequences that do not follow from Gibsonian views on affordances. First, the complexity of animal–environment systems does not take them out of the realm of computational modeling and simulation. Second, the incompatibility of Gibsonian affordances and computationalism by Gibsonians does not make Gibsonian affordances irrelevant to roboticists. We address these in order.

4.1 Complexity and Computation

If understanding animal–environment systems as unified complex systems puts them beyond the reach of computational modeling, Gibsonian views on affordances would be very unattractive to researchers in ALife—and, in fact, many researchers have taken complex systems to be non-computable. This is one of the central claims made by Robert Rosen (1991, 2000) whose understanding of complexity we are using here. It is easy to see why one would take complex systems to be non-computable. Complex systems, like animal–environment systems in the Gibsonian definition of affordances, are circular: affordances are defined in terms of abilities and abilities are defined in terms of affordances. Every experienced computer programmer knows that you get compile-time errors when you write code with circularities, and if the compiler does not catch them, the running program will get caught in an infinite loop. So it would seem that complex systems, including animal–environment systems on the Gibsonian understanding, are not computable. ALife researchers, who spend their time modeling things on computers, will therefore prefer representationalist understandings of affordances.

It turns out, however, that complex systems are computable. There is no necessary connection between circularity and non-computability. Hyperset membership has been shown to be Turing-computable in polynomial time (Lisitsa & Sazonov, 1999; Sazonov, 2006), a result anticipated in the pioneering work of Barwise and Moss (1996). Deciding on hyperset membership therefore does not necessarily involve infinite loops. This runs counter to many intuitions, including our own (see Chemero & Turvey, 2007a; Turvey, 2004). One can develop a competing intuition by considering web-search algorithms of the kind used in the Google search engine, which must terminate and produce a page of results even when confronted with multiply interlinked web pages. A typical professor's main web page, for example, will have a link to a page of published papers, and the page of published papers will have a link back to the main web page. Every Google search result page comes from software that navigates circularly linked web pages without getting caught in infinite loops. The fact that Gibsonians define 'affordance' circularly, then, is not a barrier to computational modeling of animal–environment systems. Gibsonians do not take cognition to be computation, but this does not mean that the unified animal–environment systems Gibsonians study are not computable.

4.2 Gibsonian Affordances and Robotics

Gibsonian affordances are not compatible with the idea that cognition is computation. Computation requires representations, and Gibsonians understand affordances as perceived directly (i.e., non-representationally). It might seem that this makes Gibsonian affordances unhelpful to roboticists, who build robots using, among other things, micro-processors. To be useful to the roboticist, one might believe, affordances must be taken to be representations. This, perhaps, is the motivation behind Sahin et al.'s representationalist definition.

It is true that the Gibsonian understanding of affordances places constraints on the practice of robotics. One cannot, as a Gibsonian roboticist, build robots that construct internal models of the environment. Furthermore, one must commit to constructing robot–environment systems, rather than just robots, that satisfy the circular nature of Gibsonian definitions of affordances. The robot and the environment must be built for one another. Although it requires a way of thinking that may be foreign to many roboticists, this hardly makes Gibsonian robotics impossible. Indeed, the Gibsonian concepts of affordances as aspects of unified animal–environment systems and direct perception, and the explanatory tools of dynamical systems theory have been and will no doubt continue to be very valuable to robotics. To make this case, we simply point to the following papers that exemplify the use of non-representationalist, Gibsonian affordances: Duchon and Warren (1994), Duchon, Warren and Kaelbling (1995), Slocum, Downey and Beer (2000), and Lewis and Simo (2001). Furthermore, we make note of research prefatory to a thoroughgoing Gibsonian robotics exemplified, for example, by Kuniyoshi, et al. (2004) and Bird, Layzell, Webster and Husbands (2003).

5 Conclusion

Sahin et al. try to re-define Gibson's concept of affordance so that it is useful for their own research in robotics. We commend them for doing so, despite the fact that we do not approve of their formulation. By making affordances into a variety of representation, Sahin et al. join the line of researchers who try to co-opt the insights of Gibsonian ecological psychology for use in more standard computational approaches (Norman, 1988; Vera & Simon, 1993; Clark, 1997; Wells, 2002). We believe that this can lead to a somewhat improved version of computational cognitive science, ALife and robotics—we would take Andy Clark's embodied computationalism over Jerry Fodor's Cartesian materialism any day of the week. Unfortunately, though, making affordances into representations distorts the concept so that it is barely recognizable, most importantly by making affordances incompatible with direct perception, the other main pillar of Gibsonian ecological psychology. This is unfortunate mostly because it is so unnecessary. Un-co-opted Gibsonian affordances, along with direct perception and dynamical modeling, have been and continue to be very useful conceptual tools for researchers ALife and robotics. Part of the reason for their usefulness, we believe, is that they accurately describe the nature of perception, action and cognition in the wild.

References

Aczel, P. 1988. *Non-well-founded Sets*. Stanford: CSLI.

Barwise, J., & Etchemendy, J. (1987). *The liar: an essay on truth and circularity*. New York: Oxford University Press.

Barwise, J., & Moss, L. (1996). *Vicious circles*. Stanford: CSLI.

Bird, J., Layzell, P., Webb, A., & Husbands, P. (2003). Towards epistemically autonomous robots: Exploiting the potential of physical systems. *Leonardo*, *56*, 109–114.

Chemero, A. (2003). An outline of a theory of affordances. *Ecological Psychology, 15*, 181–195.

Chemero, A., & Turvey, M. (2007a). Hypersets, complexity, and the ecological approach to perception-action. *Biological Theory*, *2*, 23–36.

Chemero, A., & Turvey, M. (2007b). Autonomy and hypersets. *BioSystems*, published online doi:10.1016/j.biosystems.2007.05.010.

Clark, A. (1997). *Being there*. Cambridge: MIT Press.

Duchon, M., & Warren, W. (1994). Robot navigation from a Gibsonian viewpoint. In *IEEE Conference on Systems, Man and Cybernetics*, pp. 2272–2277. Piscataway, NJ: IEEE.

Duchon, M., Warren, W., & Kaelbling, L. (1995). Ecological robotics: Controlling behavior with optical flow. In J. D. Moore & J. F. Lehman (Eds.), *Proceedings of the 17th Annual Conference of the Cognitive Science Society*, (pp. 164–169). Mahwah, NJ: Lawrence Erlbaum Associates.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin

Kelso, J. (1995). *Dynamic patterns*. Cambridge: MIT Press.

Kelso, J., & Engstrom, D. (2006). *The complementary nature*. Cambridge: MIT Press.

Kugler, P., & Turvey, M. (1987). *Information, natural law, and the self-assembly of rhythmic movement*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Kugler, P. N., Kelso, J. A. S., & Turvey, M. T. (1980). Coordinative structures as dissipative structures I. Theoretical lines of convergence. In G. E. Stelmach & J. Requin (Eds.), *Tutorials in motor behavior.* Amsterdam: North Holland, pp. 3–47.

Kuniyoshi, Y., Yorozu, Y., Ohmura, Y., Terada, K., Otani, T., Nagakubo, A., & Yamamoto, T. (2004). From humanoid embodiment to theory of mind. In F. Lida, P. Pfeiffer, L. Steels, & Y. Kuniyoshi (Eds.), *Embodied artificial intelligence*. Springer: New York.

Lewis, M., & Simo, L. (2001). Certain principles of biomorphic robotics. *Autonomous Robotics, 11*, 221–226.

Lisitsa, A. P., & Sazonov, V. Yu. (1999). Linear ordering on graphs, anti-founded sets and polynomial time computability. *Theoretical Computer Science, 224*, 173–213.

Norman, D. (1988). *The psychology of everyday things.* New York: Basic Books.

Rosen, R. (1991). *Life itself.* New York: Columbia University Press.

Rosen, R. (2000). *Essays on life itself.* New York: Columbia University Press.

Sazonov, V. Y. (2006). Querying hyperset/web-like databases. *Logic Journal*, *IGPL14*, 785–814.

Slocum, A., Downey, D., & Beer, R. (2000). Further experiments in the evolution of minimally cognitive behavior: from perceiving affordances to selective attention. In J. Meyer, A. Berthoz, D. Floreano, W. Roitblat and S. Wilson (Eds.), From Animals to Animats 6: *Proceedings of the Sixth International Conference on the Simulation of Adaptive Behavior* pp. 430–439.

Stoffregen, T. (2003). Affordances as properties of the animal-environment system. *Ecological Psychology, 15*, 115–134.

Turvey, M. (1992). Affordances and Prospective Control: An outline of the ontology. *Ecological Psychology*, *4*, 173–187.

Turvey, M. T. (2004). Impredicativity, dynamics, and the perception-action divide. In V. K. Jirsa, & J. A. S. Kelso (Eds.), *Coordination dynamics: issues and trends. Vol.1 applied complex systems*, pp. 1–20. New York: Springer Verlag.

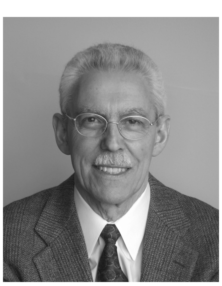
Vera, A. H., & Simon, H. A. (1993). Situated action: A symbolic interpretation. *Cognitive Science*, *17*, 7–48.

Warren, W. (2006). The dynamics of perception and action. *Psychological Review*, *113*, 359–389.

Wells, A. J. (2002). Gibson's affordances and Turing's theory of computation. *Ecological Psychology*, *14*, 141–180.

About the Authors

Anthony Chemero is Associate Professor in the Scientific and Philosophical Studies of Mind Program and the Psychology Department at Franklin and Marshall College. He is a cognitive scientist and philosopher of science whose work focuses on perception–action, dynamical systems modeling and complex systems. His first book, *Radical Embodied Cognitive Science*, is soon to be published by MIT Press. Everyone calls him 'Tony'.



Michael T. Turvey received his PhD from Ohio State University in 1967. He joined the University of Connecticut in 1967 and the Haskins Laboratories in 1970. His awards include a Guggenheim Fellow, the American Psychological Association (APA) Early Career Award, Fellow at the Center for Advanced Study in the Behavioral Sciences, Cattell Fellow, Honorary Doctorate Free University of Amsterdam, APA Distinguished Scientist Lecturer, Board of Trustees Distinguished Professor (University of Connecticut), Fellow of the Society of Experimental Psychologists, and American Psychological Foundation F. J. McGuigan Lecturer. His research on perception and action and their interrelation follows James Gibson and Nicolai Bernstein in emphasizing the search for general principles.