Adaptive Behavior

# Perception, Categories, and Possibilities for Action

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Beer's approach to addressing questions about embodiment, situatedness, and dynamics is to investigate an evolved model agent capable of exhibiting the most basic form of behavior that one might call "cognitive." One "minimally cognitive behavior" performed by Beer's agent is the discrimination between circles to catch and diamonds to avoid. Indeed, it is often assumed that the ability to perceive the categories to which objects in the world belong is a basic form of cognition. We wholeheartedly agree that the perception of boundaries separating categories plays a fundamental role in adaptive behavior, and that this topic provides an appropriate focal point for fruitful investigations of minimally cognitive behavior. But we argue that the entities composing the most important categories are *possibilities for action* rather than objects, and that perception detects these boundaries rather than creates them (Michaels, Prindle, & Turvey, 1985).

From an ecological perspective (Gibson, 1979), successful behavior depends on the ability to perceive which actions are possible and which actions are not possible (Turvey, 1992). The Outfielder Problem (Oudejans, Michaels, Bakker, & Dolné, 1996)—that is, the problem of how an outfielder runs to catch a fly ball—provides a convenient example to illustrate this point, and is not unlike the behavior performed by Beer's agent when it moves to catch a falling circle. When an outfielder runs to catch a fly ball, she must know whether or not it is possible to run quickly enough to reach the landing location before the ball does. If the ball is hit too hard or the fielder is too slow, she may slow down and catch it on a bounce rather than on the fly. The other behavior performed by Beer's agent (i.e., moving to avoid a falling diamond) is akin to avoiding traffic when crossing the street. When a pedestrian crosses the street, he must know whether or not it is possible to walk quickly enough to pass in front of an approaching car. If the car is approaching too quickly or the pedestrian is too slow, he may wait for the car to pass.

In both cases, the situation invites a qualitatively different kind of behavior depending on whether or not the action is possible. This is the sense in which actions are categorical—we either catch the ball on a fly or let it bounce; we either cross in front of the car or wait for it to pass. But the boundaries separating categories are not invented by the organism and imposed on continuous stimuli. Rather, they are defined by the fit of organism and environment such that possibilities for action are real and out there to be discovered. If behavior is to be appropriate for the situation (e.g., if the outfielder is to know whether to catch the ball on the fly or let it bounce), the behavioral possibilities of the environment must be perceived.

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Possibilities for action are defined in part by the organism's action capabilities. Whether or not a fly ball is catchable depends on the fielder's maximum running speed. To perceive whether or not the ball is catchable, information about how fast the fielder needs to run to catch the ball must be scaled to maximum running speed. We prefer to think of scaling in terms of the organization of a "smart" perceptual instrument (Runeson, 1977) for detecting information about the required action in the correct intrinsic units. When an outfielder detects information about the running speed required to catch the ball in units of maximum running speed, then 1.0 separates possible from impossible catches. The correct intrinsic units are not fixed because an organism's action capabilities are constantly changing due to factors such as fatigue, injury, load, and external forces (e.g. wind, surface friction, surface slope). A street may be safely crossable by a pedestrian now, but not when he's carrying a heavy backpack. This means that organisms must recalibrate to changing action capabilities by adjusting the size of the intrinsic units until 1.0 reliably separates possible from impossible actions. Without the ability to calibrate information to action, the agent would be unable to adapt to changing conditions.

The significance of perceiving possibilities for action follows from one of the core assumptions of the ecological approach—namely, that the environment is perceived in terms of what the organism can and cannot do within it. In other words, to see something is to see what to do with it. Gibson (1979) introduced the term *affordance* as a way of describing the environment in action-relevant terms. Chairs afford sitting, stairs afford climbing, and doorways afford passage. Affordances are properties of the environment taken with reference to the animal. Thus, a narrow opening may afford passage by a small child, but not by a large adult; a narrower opening may afford passage by a cat but not by a small child. Affordances can be "body-scaled," as are the examples listed earlier, or "action-scaled," as are catching a fly ball and crossing the street. Whether or not a ball is catchable depends not on the fielder's leg length or eye height, but on her running speed. Thus, the boundary that separates possible from impossible catches is defined by one's action capabilities rather than one's body dimensions. The empirical research on both body-scaled affordances, such as stair-climbing (Warren, 1984), sitting (Mark, 1987; Mark, Bailliet, Craver, Douglas, & Fox, 1990), passing through apertures (Warren & Whang, 1987), and reaching (Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989) and action-scaled affordances, such as catching (Oudejans, Michaels, Bakker, & Dolné, 1996), has demonstrated that people are attuned to the boundaries of their actions, lending support to the notion that successful behavior is a matter of perceiving affordances.

Of course, organisms and artificial agents must do more than just perceive whether or not an action is possible. They must also control their actions to achieve some goal, which often means using continuously available information to guide action in an ongoing manner. How could the perception of affordances allow an agent such as the one in Beer's model to guide its actions on the basis of information? If the speed required to catch a falling circle is less than the agent's maximum speed (i.e., $< 1.0$ in intrinsic units), then it is still possible to catch the circle by changing speed. On the other hand, if the required speed is greater than the agent's maximum speed (i.e., $> 1.0$ in intrinsic units), then it is no longer possible to catch the circle. This suggests a simple rule for catching circles: move so as to keep the required speed $< 1.0$ (in intrinsic units). As long as the required speed is greater than or equal to zero and less than the maximum speed, the agent can still change speeds within its capabilities to catch the circle. Thus, an agent capable of perceiving when circles are catchable can simply act so as to make sure that it is always still possible to catch the circle. In general, successful performance in visually guided action is a matter of perceiving possibilities for action, and behaving so as to keep the desired action within the range of possible actions.

The agent in Beer's (this issue) model does not perform the circle-catching and diamond-avoiding tasks by perceiving possibilities for action. So what? Overall performance is quite good and the dynamical systems analysis revealed many interesting properties of the brain/body/environment system. Nevertheless, we must be cautious because there is no consideration of the agent's action capabilities. In the real environments of organisms and artificial agents, action capabilities are not infinite—there is a limit to how fast one can move, turn, stop, etc. To underscore the significance of this point, one might compare the behavior of an outfielder running to catch a fly ball that is well out of reach with the behavior of Beer's agent moving to catch a falling circle that is well out of reach. Whereas the outfielder will slow down to catch the ball on the bounce, the agent in Beer's model will pursue the uncatchable circle with the same zest that it pursues catchable circles because it doesn't know the difference. Nor would it know the difference if its maximum running speed suddenly changed. In contrast, humans and many animals exhibit a surprising ability to rediscover their capabilities anew each time they perform an action (Oudejans et al., 1996; Mark, 1987; Mark et al., 1990).

Beer's approach in this target article was to address questions about situatedness and embodiment by investigating minimally cognitive behavior in an evolved model agent. The agent provides a concrete example of how basic locomotory actions can emerge from the interaction of simple components with the environment, and his unique methodology suggests one way in which dynamical systems theory can be applied to understand the brain/body/environment interaction. Although Beer's strategy will certainly appeal to many ecological psychologists, there are aspects of visually guided behavior that are essential to successful action, but which are not reflected in Beer's agent. We believe that the theory of affordances provides a powerful framework within which to guide research aimed at understanding visually guided behavior in humans, non-human animals, and even artificial agents. The affordance theory asserts that successful action is a matter of perceiving which actions are possible and which actions are not possible. This is the sense in which actions are categorical, and perceptual systems must learn (or evolve) to discover these categories. Perhaps a future generation of Beer's model agent will someday be evolved to perceive affordances and control its actions on their basis.

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