Chapter 2

AFFORDANCES AND INFORMATION

The principles identified in the previous chapter pervade all of ecological psychology. We begin our elaboration of the ecological approach, therefore, with the theme that arguably has the most immediate consequences for psychology and how it is done. Perceiving-acting mutuality corrals a class of problems to be addressed. The problems have to do with the ways in which animals, including humans, negotiate their daily lives—problems that can be said to have “ecological relevance.” Consider a gazelle crossing the Serengeti. It must perceive surfaces of support and how to stay upright on them; perceive whether a gap in the ground is crossable and how to cross it; perceive whether a brink can be descended and how to descend it; perceive where it is going and how to get there while adjusting to the terrain where it is. These problems are not unique to wild game in Tanzania; they confront children on the playground, shoppers in the mall, and wheelchair users in the office. The bulk of what animals do in a day is perceiving the surround in terms of the actions it permits, and adjusting those actions to that surround. The bulk of what an ecological psychologist does, therefore, is trying to understand how perceiving and acting are coupled. That is the focus of this chapter.

Let’s be precise: Perceiving and acting are not, in fact, two things that somehow “get coupled.” Perception-action should be considered a single entity. History and pedagogy, however, require a starting place. We begin, therefore, with a discussion of affordances—the behavioral possibilities of an environment for an animal—and the explosion of research on them in the past decade. The research leads us naturally into a consideration of the information that allows affordances to be perceived. As used in the ecological approach, information is narrowly defined and precise. Here we will concentrate on a very few well-understood examples of invariants. We will end with a consideration of how that information is woven throughout an act, trying to make good on our promissory note of perception-action.

Environments as Settings for Behavior

The term “affordances” was coined by Gibson to name what is, perhaps, his single most important conceptual contribution to the field of perception. We have already noted that affordances are the behavioral possibilities of an environment for an animal. That definition is the proverbial tip of the iceberg because it sits atop a formidable theoretical structure of physics, philosophy, and psychology, all cast ecologically. Let’s jump right in and explore that structure.

How would you describe an environment in order to satisfy the definition? Talk of carbon or water molecules doesn’t do it because the gazelle does not behave with respect to molecules. Those molecules are collected into surfaces that have an orientation, a certain degree of rigidity, slipperiness, and so on. Those surfaces allow or prevent locomotion (as just one example). Whether or not an arrangement of surfaces in the environment allows forward locomotion is a question posed at the level of behavioral possibility—does a surface afford forward locomotion? The answer may differ, of course, if the animal in question
walks, flies, or slithers. Sheer drops, underbrush, and strong headwinds pose different kinds of problems for different styles of locomotion.

Describe the environment in terms of surfaces, then. Imagine that the gazelle confronts a ridge that is 90° relative to the ground 1 m below. That surface affords forward locomotion because the gazelle can step down from one elevation to the next. But a 1 m ridge that can be stepped down by a gazelle may not be negotiable by her foal. The foal may have success with a less steep orientation, however. A 1 m ridge may or may not afford locomotion, depending on its inclination; a 90° drop may or may not afford locomotion, depending on its height. Environmental descriptions appropriate for affordances must reflect these interdependencies. Trying to use absolute metrics—essentially units provided by our measuring instruments—will not suffice. Obviously, characteristics such as the animal’s size and style of locomotion are critical to the evaluation of an arrangement of surfaces with respect to a particular behavioral possibility. A description of the environment, therefore, must be with respect to an animal. The affordance definition thereby precludes our using descriptors inherited from other disciplines.

The paradigmatic affordance experiment—stair climbing

With these precepts in mind, we’ll begin with the study that arguably ushered in the affordance research era, a 1982 doctoral dissertation at the University of Connecticut by William H. Warren (Warren, 1982, 1984). The idea is fairly straightforward. If perception of surface layout is of behaviorally-relevant properties in animal-relevant terms, then find a layout that permits a particular behavior for some animals but not for others. And to focus on the issue of animal-environment fit, choose animals who are essentially the same—college-age humans—except for an incidental difference in size—one group has longer legs than the other. Now these animals can be presented with differing surface layouts and asked to evaluate whether a particular behavior is possible. In Warren’s experiment the surfaces were plywood boxes fashioned as steps and the people were asked whether a given step could be climbed in the usual way—with one leg on the first step, pulling the body up and over it so the other leg could do the same on the next step, without using the arms to scramble up.

People were shown a variety of step heights, ranging from 20 to 40 inches (50 to 100 cm), ordered randomly, with each step shown several times. As might be expected, shorter and taller participants differed with respect to how high a step could be and still be climbable. Does this mean that the affordance for climbing stairs differs for people of different heights? Well, yes and no. Whether a given stair affords climbing may, in fact, differ for people of different heights. But the highest step that can be climbed by a short person should be captured by the same metric as the highest step that can be climbed by a tall person. Height of a step is just an absolute measure of an aspect of the environment. Once scaled by leg length, an aspect of the animal, this commonality is revealed. Whereas the absolute boundary between what can be climbed and what cannot differs for short and tall people, the body-scaled boundary is the same (Figure 2-1). This boundary is indexed by a dimensionless number (the units cancel out when riser height is divided by leg length) that is called a π-number (so-called after π which is obtained by intrinsically scaling the diameter of a circle to its circumference). It is a critical π-number because it indexes a change from one behavioral category (climbable) to another (not climbable).

1In order to facilitate the running of the experiment, Warren took photographic slides of the different steps. These were projected at actual size relative to the position of the observers. An additional anchoring for the scale was provided by a chair which appeared in each photograph as well as in the room next to the projection screen.
Warren elaborated his investigation beyond perceiving the boundary of what can be climbed to include perceiving preferences for climbing. Obviously, very high steps are difficult to climb, but so are very low steps, so-called monument steps that people often take two or three at a time. Presumably, somewhere in between the extremes, is a step height that is optimal for an individual. In the experimental attack on this problem, people were shown two stairways next to each other and asked simply which they would prefer to climb. After running through the entire range of stairways (with step heights from 3 to 15 inches, each paired with every other 4 times), participants were put on a stair mill, a contraption that is like a short escalator with adjustable steps. When step height is zero, the apparatus is flat (like a treadmill); with increasing step height, the climbing angle increases. While people were climbing a stairway of a given step height, their oxygen consumption was measured. This was repeated for each height in the experiment (with an appropriate rest in between runs). Warren presumed that if there were an optimal step height for climbing, it would be the height that cost the least energetically (in this case, used the least oxygen). Indeed, this is what he found. Each group of people, the short and the tall, preferred the step that, for them, used the least oxygen. And, not forgetting our lesson about an animal-referential metric for environmental properties, this turned out to be the same step in leg-length terms (Figure 2-2). These are also $\pi$-numbers, but this time they are called optimal $\pi$-numbers (they don’t index categorical boundaries as critical $\pi$-numbers had. For stair climbing, $\pi_{\text{optimal}} = .25$. 

*Figure 2-1.* (left) Judgments of which height surfaces can be climbed differ for short and tall perceivers when the surfaces are measured on an absolute scale. (right) The difference between those two groups is eliminated when the surface is measured *intrinsically*, that is, when it is scaled to the perceiver (in this case, scaled to the perceiver’s leg length).
Figure 2-2. (left) Judgments of which height stair short and tall perceivers prefer to climb differs when the surfaces are measured on an absolute scale. (middle) The difference between those two groups is again eliminated when the surface is measured intrinsically. (right) The perceived judgment of preferred climbable height matches the energetically least costly stair, which is also the same for the two size groups when scaled intrinsically.

These pioneering experiments established a paradigm for studying affordances experimentally, permitting the evaluation of a number of Gibson’s theoretical assertions about affordances. Subsequent investigations of affordances are essentially variations on the strategies adopted by Warren. One strategy is to treat perception of affordances as a prospective act. Without actually engaging in the behavior, participants are asked to provide an indication of whether the behavior would be possible under current conditions. At first blush, this may seem a bit artificial. But this is what the gazelle does when he chooses to embark on the long grassy slope rather than the shorter rocky path. And when your mother says “please pass the salt” rather than reaching for it herself, she has perceived prospectively that to reach would be unseemly. Plainly, neither the gazelle nor your mother is consciously dwelling on what makes the behavior of the moment possible; they just perceive the possibility. Ideally, this is what is tapped by the prospective perception task.

Another strategy adopted by Warren that will undergo some modification in later affordance research is the use of two groups of participants chosen so that their action capabilities can be expected to differ. Warren’s choice was geometric—the people differed in size. The measurement of the environment is said to be body-scaled, or measured in units of leg length (or arm length or eye height). But many affordances require more than size. They require strength, flexibility, balance, and so on. Finding biodynamic scalers, though difficult, has become a goal of affordance research.

Pushing the envelope
It is fair to say that Warren’s research started something. It was as if there was a collective slapping of foreheads as ecological psychologists across the country said, “So that’s how you study affordances!” Of course, it wouldn’t suffice to show only that sitting and reaching and passing through or stepping over are heir to the same kind of analysis. Each problem that is added to the repertoire of affordance experiments should extend the analysis in theoretically meaningful ways.

Warren had mentioned in passing that the information of relevance to the fit between a climber-stair system was probably reflected in the structuring of the optic array by the observer’s eye height. This conjecture is rooted in Gibson’s observation that the horizon is
a fundamental feature of the optic array that is informative about the sizes of things relative to me. The horizon is at my eye height; my size is part and parcel of the structured optic array. Where the horizon cuts things specifies their height in units of my eye height (see also Sedgwick, 1973, 1980, 1983). The importance of eye height was examined explicitly in parallel investigations of stair climbing and sitting.

Mark (1987) chose these two behaviors because leg length is a relevant scaler for both of them. In most respects, his manipulations mirrored those of Warren. The surface was on a hydraulic lift (a fancy car jack) so that its height could be adjusted easily and in infinitely small increments right in front of the observer. The basic details of Warren (1984) were replicated: The boundary between what could be climbed and what could not differed for short and tall participants in absolute terms but was the same when scaled by leg length. \( \pi_{\text{critical}} \) turned out to be .89, just as in Warren’s study. The same was true for sitting, and \( \pi_{\text{critical}} \) was remarkably similar, .87 (probably revealing a biomechanical similarity between the two tasks). Anticipating the relevance of eye height, Mark also scaled the boundary in terms of the fundamental partitioner of the optic array, yielding \( \pi_{\text{critical}} = .40 \). He then introduced a manipulation of eye height. For a second block of trials, participants strapped 10 cm blocks to their feet. Obviously, this raised their eye heights. Less obviously, because the additional height was all in the lower limb, the effect on the acts of climbing stairs and sitting on ledges was different. In particular, the additional blocks do not change the height of a stair that can be climbed—the supporting foot raises the hips by 10 cm, but the 10 cm sole on the stepping foot needs just that additional height to clear the step. For sitting, in contrast, the longer legs increase the height of surface that can be sat upon (Figure 2-3).

![Figure 2-3](image)

**Figure 2-3.** (left) The maximum surface height for climbing is approximately the same as the maximum surface height for sitting. (right) Adding 10 cm blocks to the feet has different consequences for these behaviors. Namely, whereas the maximum surface height for climbing is not changed, the maximum surface height for sitting is increased.

What should the consequence of these new legs be for perceiving the affordances of horizontal surfaces? Well, if their judgments with their new legs are based on their old \( \pi_{\text{critical}} \), they should overestimate what is climbable. Say that a person whose eye height is at 200 cm can climb an 80 cm step. When that person’s eye height is 210 cm, he or she can still climb an 80 cm step. But if the optical structure that specifies climbable is anchored in \( \pi_{\text{critical}} = .40 \), that would specify an 84 cm step as climbable. For sitting, perceivers should overestimate: A person whose eye height is at 200 cm can sit on a 40 cm surface. Extending the legs by 10 cm raises maximum sit-on-able surface to 90 cm as well as raising the eye height to 210 cm. Again, if the optical structure that specifies sit-on-able is anchored in \( \pi_{\text{critical}} = .40 \), that would specify that a surface of 84 cm would be the maximum that could be sat on.

This is essentially what was found. In their first judgments standing on their new legs, perceivers overestimated what heights could be climbed and underestimated what heights
could be sat on. But you have to expect that this couldn’t last. Our eye height changes for a variety of reasons—dramatically, during growth, and less dramatically (usually) through our choice of footwear. Postural shifts from, say, standing to sitting, can also produce large albeit temporary alterations in eye height. Yet we don’t experience even short-lived collapses in our awareness of how the surrounds fit our capabilities. Mark showed that fairly minimal experience with the optical consequences of their new proportions allowed his subjects to adapt (Figure 2-4, left). He never let them practice climbing or sitting while wearing the blocks; he simply let them walk around the room in between trials. They, in essence, discovered $\pi_{\text{critical}}$ for the effectors they now had. It is important to note that the change in their affordance evaluations was not a simple consequence of experience making this kind of judgment—there was no change in the affordance evaluation over trials in which they were not wearing blocks (Figure 2-4, middle). And even though walking around was the best experience, even simply standing and experiencing the optical consequences of ordinary postural sway was also beneficial. Most dramatically, perhaps, preventing that very subtle sway by having people lean up against a wall not only eliminates improvement but distorts ordinary no-blocks judgments, too (Figure 2-4, right).

\begin{figure}[h]
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\caption{(left) With minimal experience wearing 10 cm thick blocks on their feet, perceivers eliminate their initial distortions of what is climable or sit-on-able. (middle) Focusing just on sitting, simply having experience making the judgment does not affect responses—without wearing blocks, affordance judgments are stable over trials. (right) Whether wearing blocks or not, perceivers who are prevented from making postural adjustments produce distorted—but stable—judgments of what is sit-on-able.}
\end{figure}

In Mark’s study, participants were aware of their new height. A surreptitious manipulation of eye height would permit an evaluation of the informativeness of a given optic array, untainted by participants’ trying to figure out what should be true with their new effectors. This time the investigation was of whether or not a doorway could be walked through straight on, with the shoulders perpendicular to the path of locomotion. As a rule, the taller the person, the wider the shoulders so that eye height specification of body size is still relevant. Participants viewed an adjustable doorway through a large peep hole that masked the ceiling and walls. The doorway was sitting on a floor that was either even with the floor on which the observers were standing or that was 22 cm higher. Because of the peep hole, observers were not aware of the manipulation of their height. With the raised floor, observers’ eye heights were less, their eye height-specified size should have been less, and therefore, the minimum aperture that would permit forward locomotion should have been smaller. This was, in fact, what was found (Warren & Whang, 1987). And once again the category boundary was the same when body-scaled by eye height (actual or surreptitious, as appropriate). A second experiment on the passability of apertures revealed the equivalence between an on-line behavioral measure and a prospective verbal report. With an overhead camera recording the door width at which participants
initiated shoulder rotation in order to pass though the aperture, Warren and Whang found that the boundary coincided with the one obtained verbally.

In the examples considered thus far, the affordance style of inquiry was an ecological reformulation of the old problem of size perception. But notice that nowhere did we consider the more classic variable-triple of retinal size, physical, size, and distance. That is because the affordance story is not one in which a standard property is perceived and then compared with body size so that the affordance can be deduced. Rather, it is the affordance that is perceived. This point provided the theoretical context for an experimental investigation of perceiving what is reachable, an investigation that focused on the implications of an ecological reformulation of distance perception, as well as on potential complexities of body scaling (Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989).

In a simple parallel of stair climbing and sitting experiments, participants were selected on the basis of height so as to produce a group with short arms and a group with long arms. In evaluating reach to an object on a surface at shoulder height, using only the arm, the standard results were obtained: The category boundary was farther for taller than shorter participants and the difference disappeared when body-scaled, this time by arm length. Given that reachers do not typically limit themselves to using only the arm in reaching, a second condition considered the “effective reacher” to be the arm + torso. This so-called two degree of freedom task also replicated the basic finding, with the body-scaler provided by the arm + torso length.

Subsequent experiments examined these effectors—either the single arm or the arm + torso—when the surface layout affected whether their whole length could be exploited in reaching. For example, the amount of extension provided by the torso is limited if the object to be reached is on a table that is in front of the reacher. The front edge of the table limits how far the reacher can bend from the hip. If the table is right up against one’s chest, the second degree of freedom cannot be brought into play at all; the farther away the table, the more extension can be provided by the torso. As it turns out, perceivers are sensitive to the degree of constraint exercised on the effectors by the surface layout. Similarly, if limited to the one degree of freedom of the arm, its extension can be affected by the height of the surface to which one is reaching. Reaching to a surface at shoulder height takes advantage of the full forward extension of the arm. Reaching to lower or higher surfaces loses forward extension. This is because the arm is always the hypotenuse of a triangle whose sides are composed of the vertical distance to the surface as well as the horizontal distance to the object (Figure 2-5). Again, perceivers are sensitive to the limitations placed on the effectors by the surface layout.

![Figure 2-5. Change in reach](image)

Figure 2-5. When a person reaches to surfaces of ever-lower heights, the effective forward reach is reduced. And the change is nonlinear: A fixed drop from the highest depicted surface to the middle has a small effect on forward extension of the arm. The same size drop from the middle surface to the lowest produces a much larger effect on forward extension. This nonlinear difference in effective arm length is reflected in perceivers’ judgments of what is reachable at different surface heights.

This is impressive enough but it gets more so. Although the “effective reacher” would seem to be a fairly straightforward consequence of geometry, it is not. In all of the
aforementioned conditions, actual reaching distances were obtained. The scientists equipped with rulers to measure the limbs and torso, and trigonometry to calculate angles of reach and how much forward extension should be lost with particular surface layouts were not close to predicting how far the participants should have been able to reach (Carello et al., 1989). In contrast, the perceivers were quite good at perceiving the consequences of varied surface layouts. Obviously, treating the arm as a rigid piece was inappropriate, given the flexibility and complexity of the shoulder joint. Nonetheless, knowing these vagaries did not lead to any biomechanically motivated body-scaler that worked as well as the perceivers (and the structured optic array) did.