The Ecological Approach to Perception
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Perception refers to how animals, including humans, can be aware of their surroundings. The ecological approach to perception refers to a particular idea of how perception works and how it should be studied. The label “ecological” reflects two main themes that distinguish this approach from the establishment view. First, perception is an achievement of *animal-environment systems*, not simply animals (or their brains). What makes up the environment of a particular animal—cliffs or caves or crowds—is part of this theory of perception. Second, perception’s main purpose is *guiding activity*, so a theory of perception cannot ignore what animals do. The kinds of activities that a particular animal does—how it eats and moves and mates—are part of this theory of perception.

Including the environment and behavior as important parts of perceptual theory, rather than as afterthoughts, is clearly different from theories that start inside the eye (or the ear or the skin), but it is not necessarily controversial. Nonetheless, the ecological approach is considered controversial because of one central claim: Perception is direct. To understand the claim, and why some might consider it troubling, we have to contrast it with the more traditional view. Most scientists believe that perception begins with faulty input. For example, when objects in the world reflect light, the pattern of light that reaches the back of the eye (the part called the *retina*) has lost and distorted a lot of detail. The job of perception, then, becomes one of fixing the input and adding meaningful interpretations to it so that the brain can make an inference (or educated guess) about what caused that input in the first place. This traditional view is called indirect perception because the animal’s awareness of the world is a result of these intermediary steps. A theory of direct perception, in contrast, argues that the intermediary steps are only needed if the
scientist has described the input incorrectly. Including the environment and activity into the theory of perception allows a better description of the input, a description that shows the input to be richly structured by the environment and the animal’s own activities. This means that the intermediary steps are not needed and perception is direct.

_Gibson’s Contribution_

The ecological approach to perception originated in the work of the American psychologist James J. Gibson (1904-1979). Two biographical facts were important to shaping what became a radical theory. As the young son of a railroad man in America’s Midwest, he had spent many hours on trains watching the world flow by. He noticed that from a vantage point in the locomotive looking forward the flow was outward but from the caboose looking rearward the flow was inward. Here was the seed of his notion that the light that comes to our eyes is reliably structured by activity—structured light can be rich and meaningful. Many years later, after he had established a career as a perceptual psychologist, Gibson took time away from his college teaching position to spend four years as a scientist with the Aviation Psychology Program during World War II. There he realized that the practical problems of takeoffs and landings and pursuit and evasion, which could not only be mastered by 18-year old pilot trainees but also performed routinely by birds and bees, had little to do with the physiology of the eyeball. Here was the seed of his notion that perceptual theory should try to explain real-world behaviors (and not simply human behaviors).

Upon resuming his job as a college professor, Gibson set about challenging the assumptions that he thought sat unexamined in most laboratory work, including his own. His first book, published in 1950, argued that perceivers are aware of the world not their own sensations and perception theory should respect that. Gibson’s reformulation of the problem of distance
perception illustrates the essence of what developed into his ecological approach. For centuries, scientists believed that “distance is not perceivable by eye alone.” Indeed, if the objects are treated as isolated points in otherwise empty space, then their distances on a line projecting to the eye are indistinct: Each stimulates the same retinal location. Gibson dubbed this formulation Air Theory (A in Fig. 1) and argued that it was inappropriate for addressing how we see. His alternative was Ground Theory, which emphasized the contribution of a continuous background surface to providing rich visual structure (G in Fig. 1). The simple step of acknowledging that points do not float in the air but are attached to a surface such as the ground introduces what might be considered a higher-order property, the gradient. For Gibson, this realization opened up the new possibility that perception might be veridical, that is, about facts of the world.

Gibson began to emphasize the enriching role of movement in perception at this time as well. Once more, an ecological solution to an old problem is instructive. This problem concerned how a perceiver could distinguish object motion from his or her own motion. The puzzle arises due to the traditional assumption that the cue to perceived motion is the stimulation of successive retinal locations. An object moving from left to right fixated by a stationary eye will stimulate retinal receptors A, B, C, then D. That same object fixated by an eye moving from right to left will also stimulate retinal receptors A, B, C, then D. Since the retinal input is ambiguous, it must be compared with other input having to do with whether any muscle commands had been issued to move the eyes or the head or the legs. In the absence of counter-acting motor commands, object motion can be concluded; in the presence of such commands, the retinal signals would be

![Fig. 1. (A) The distances of four points in the air are indistinct because their projections are onto the same retinal location. (G) As texture elements on the ground, the gradient of their projections distinguishes their relative depth.](image-url)
counteracted, allowing the alternative conclusion of self-motion. Of course, sometimes the observer is moved passively under somebody else’s power (as in a train) so that other input and even knowledge must be taken into account. Gibson suggested an elegant alternative solution: Overall, or *global*, change in the pattern of light is specific to self-motion; *local* change against a stationary background is specific to object motion. This simple insight (echoing the experience of the young Gibson riding the rails) opened a new field of research devoted to uncovering the structure in changing patterns of light: *optic flow*.

**Optic Flow and the Visual Guidance of Locomotion**

Optic flow refers to the patterns of light, structured by particular animal-environment settings, available to a point of observation. The goal of optic flow research is to discover particular reliable patterns of optical structure, called *invariants*, relevant to guiding activity. Outflow and inflow are distinct forms of optic flow—distinct *flow morphologies*—that tell me whether I’m moving forward or backward. As scientists consider how that flow is structured by the variety of clutter that we encounter as we move around—doorways and hillsides and the like—they discover invariants specific to those facts as well (Fig. 2).

![Fig. 2](image-url)
In order to effectively guide their activities, animals need to know more than what they’re approaching. They also need to know how they’re approaching (are they moving too fast?) and whether they need to adjust that approach (should they slow down? Turn?). As a busy waiter rushes towards the swinging door of the restaurant kitchen, he makes subtle adjustments to his behavior in order to control his collision. He needs to maintain enough speed to push through the door but not so much that he crashes into it. Effective behavior requires that he know when a collision will happen (so he doesn’t slow down too early) and how hard the collision will be (so that he slows down enough). Optical structure relevant to these facts has been identified and provides examples of quantitative invariants. The optical quantity called $\tau$ is specific to when a point of observation will contact an upcoming surface. Consider the rectangular contour in Fig. 2a. As the waiter approaches it, its optical projection magnifies. The speed of approach affects the rate of expansion, that is, the change in optical area per some unit time. The quantity $\tau$ is given by the inverse of the relative rate of this expansion—how long will it take until there are no units of time left. As he slows down (or speeds up), the rate at which $\tau$ approaches zero changes. The rate of this change (that is, the derivative of $\tau$) is specific to how severe the collision will be. It essentially quantifies whether the observer’s on-board kinetic energy is being dissipated (e.g., by braking) at a rate sufficient to stop movement before contact occurs.

The preceding descriptions of global optical structure refer to situations in which the observer is approaching a surface. But they are also relevant to a surface, such as a projectile, approaching the point of observation. Local disturbances of optical structure relevant to the guidance of interceptive behavior can also be described in terms of $\tau$ and its derivative, specific to when and how hard a collision will be. Other quantities are relevant to getting the perceiver
(or the hand or the bat) into position to intercept (or avoid) the projectile. Moreover, the same invariants are available to the family dog catching a ball, a chickadee landing on a bird feeder, and a bumblebee searching for pollen. Although these creatures have obviously different visual systems and brains, the information relevant to guiding their behaviors is the same. Of course, while all creatures need to perceive things like openings and obstacles to locomotion, what counts as an opening necessarily differs. How perception is “personalized” is addressed next.

**Affordances**

In highlighting the relevance of optical structure to whether an activity is possible (“Is the ball catch-able?”) the preceding examples introduce what might be the most radical contribution of Gibson’s theory, the notion of *affordance*. Affordances are the possibilities for action of a particular animal-environment setting; they are what an arrangement of surfaces means to an animal. Affordances are usually described as “-ables” as in catch-able, pass-through-able, climb-able, and so on. Whether a ledge, for example, is a stepping down place or a falling off place is not determined by its absolute size or shape but how it relates to a particular animal, including that animal’s size and agility and style of locomotion (Fig. 3, left). Such activity-relevant animal-environment relations are specified in the optics (Fig. 3, right) where the rate of flow above a horizontal is greater than the rate below with the discontinuity proportional to an animal’s eye height. The variety of affordances constitute ecological reformulations of the traditional problems of size, distance, and shape perception.
The Ecological Approach to Perception—a theoretical perspective on how animals, including humans, can be aware of their surroundings. It emphasizes the relevance of activity to defining the environment to be perceived.

Glossary

affordance—A description of environmental properties that highlights their behavioral relevance for an animal.

Air Theory —Gibson’s characterization of the traditional formulation of distance perception that treats the problem as one of abstract geometric points suspended in empty space.

ambiguous input—In theories of indirect perception, the stimulation of a sense organ is thought to be an inadequate indicator of its cause in the environment.

animal-environment system—Within the ecological approach, perception is considered to be an achievement of a unit of analysis larger than the brain.

direct perception—A theory of how animals know their surroundings that assumes input is rich and reliable and not in need of mediating processes.

flow morphologies—Distinct patterns of light (described by velocity vector fields) structured by the variety of animal-environment circumstances (e.g., forward locomotion generates optical expansion).

Ground Theory —Gibson’s characterization of a reformulation of distance perception that emphasizes the rich structure available in a natural, cluttered surround.

invariants—Aspects of structured energy distributions that persist despite variation in incidental aspects of those energy distributions.
**optic flow**—The pattern of light generated by a particular animal-environment circumstance, described in terms of a velocity vector field.

**specific**—A unique and lawful relationship between a structured energy distribution and the animal-environment circumstance that gave rise to it.

τ—An optical invariant specific to the timing of an impending collision.

**texture elements**—A face or facet of a surface delineated by a homogeneous level of contrast within its borders. Texture elements anchor velocity vectors in an optic flow field.

**velocity vector field**—A mathematical description used to capture the form of optic flow.