APPROACHES TO COGNITION:
Contrasts and Controversies

Edited by

TERRY J. KNAPP
University of Nevada, Las Vegas

LYNN C. ROBERTSON
Veterans Administration Medical Center, Martinez, California
and
University of California, Davis, School of Medicine

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7 J. J. Gibson's Ecological Theory of Information Pickup: Cognition from the Ground Up

William M. Mace
Trinity College

INTRODUCTION

The ecological approach presented in this chapter is that developed by James Gibson. It is not the only ecological approach to issues in psychology. Of the other ecological psychologists, Barker (1965) is best known *as* an ecological psychologist. Brunswik (1943, 1956) and Lewin (1943) used the term in commenting on one another as early as 1941. Brunswik (1943) gave Lewin credit for suggesting that he use the term *ecology* when discussing "the statistics of organism and environment" (p. 267).[1] Because Barker worked closely with Lewin, and Gibson took Lewin quite seriously (Gibson & Crooks, 1938/1982), Lewin, as well as Brunswik, undoubtedly deserves a good share of the credit for ecological concerns in psychology. Urie Bronfenbrenner (1979), a long-time colleague of Gibson's at Cornell, is yet another prominent psychologist who calls his work ecological psychology. There are undoubtedly similarities among all the psychologies that have been called ecological. Obviously, they all deem animal and human environments important for psychologists to study. However, the differences in the core problems they treat and their theoretical elaborations are large enough that they are best regarded as distinct.

There are a number of other articles that discuss the relevance of Gibson's work for cognition. Runeson and Bingham (1983), Turvey and Carello (1981), and Turvey, Shaw, Reed, and Mace (1981) dwell heavily on metatheoretical and philosophical aspects of Gibson's work as they relate it to cognition. Neisser

[1] I thank Professor Kenneth Hammond for pointing out the early Brunswik/Lewin references.

(1976, 1984) and Shepard (1984) show how Gibson's work can influence research on cognitive topics such as imagery and memory. The purpose of this chapter that distinguishes it from those papers is to review the immediate, straightforward extensions into cognitive areas that Gibson himself suggested.

The major claims of Gibson's ecological approach to perception are now well known (Fodor & Pylyshyn, 1981; Ullman, 1980): that perception of the environment is direct and unmediated by images or representations; that no form of memory, schemata, or other cognitive structure contributes to perception; that information is "in the world"; that perception is a matter of extracting invariants from the optic array; that perceiving is more like resonance than it is like "processing"; that the properties of the environment directly perceived include meaningful properties reflecting an animal's interests and utilities; that computation is not involved in perceiving; and that hidden as well as unhidden surfaces can be visually perceived.

What seems to be much less well known are the meaning of these claims and the foundations on which they rest. This chapter reviews the major components of the ecological approach with special attention to three somewhat neglected supporting concepts: within ecological optics, the concept of the ambient optic array and the lessons of the occluding edge; then, overarching Gibson's theorizing, the definition of perception.

Gibson's approach has two types of implications for cognition. First it elaborates perception itself in a way that does not require cognitive processes to be brought into perception to explain perception. Most theorists (e.g., Fodor & Pylyshyn, 1981; Hochberg, 1982; Rock, 1983) take it for granted that cognition is necessary to explain perception. Second, the ecological theory of perception, more precisely the theory of information pickup, not only does not utilize cognition to explain perception but extends perception to displace some apparently clear cases of cognition. Finally, there are suggestions of how Gibson's approach can form the foundation for an extended theory of "cognition" with a completely different scheme for classifying "processes."

Gibson's book (1966) on the mechanisms of perception devotes space to every perceptual "modality." His ideas are framed generally enough to apply to every "modality." The novelties proper to his perceptual theory apply to hearing, touching, smelling, tasting, and orienting as well as to vision. However, the bulk of his work was on visual perception, and most of the detailed theory is visual. Hence I describe the ecological approach to visual perception at great length. The implications for cognition that I present most easily follow from the visual theory.

THE THEORY OF INFORMATION PICKUP

Gibson called the theory of perception that developed within the ecological approach the theory of information pickup. If all the interlocking components of the theory have been fashioned to fit properly, then perception can be said to be a matter of an animal's picking up or detecting information. The words *picking up, detecting,* and others (such as *extracting*) used by Gibson imply prior existence of the information *as* informative structure. Obviously, to understand what Gibson meant by information pickup, then, one must carefully study what he meant by *information* and what he meant by *pickup*.

Information

Information refers to structure carried in media by light, mechanical energy, or chemical energy. The structure must be intrinsically *informative* about the sources of its structure by virtue of being lawfully specific to those sources of structure. The relevant contrast here is to concepts that would have stimulation be intrinsically informative of nothing more than its own existence. As stimulation, light rays, for example, are not informative about their sources. One cannot know from the light ray itself if its source is near or distant, a reflecting surface or a radiant surface. Receptors in an eye stimulated by a ray of light can at best be informed of the presence of the ray of light—and that, of course, is a vast oversimplification. Indeed given the complexity of nervous systems and the presence of spontaneous activity in them, theorists in the Johannes Müller tradition of specific nerve energies would say that one can be informed only of the activity of the nervous system itself. For perceivers to be informed about the sources of stimulation in such cases, they must make a large contribution by having a store of alternatives that are selected among according to those stimulating conditions.

In this view, in accord with classical information theory, the function of stimulation is to select among a "known" set of alternatives. It has no power of its own. A single lamp in the Old North Church belfry could mean "by land" to Paul Revere, "by day" to Gerald Ford according to one story, or any number of other things depending on the set of prearranged options. With no such prearranged options it is just a light high above the ground.

Most theorists of visual perception do not trace the uninformative nature of light back to individual light rays but to the ambiguities inherent in a single view. Even a *distribution* of intensities may arise from an indefinite number of environmental sources, hence such a distribution is also intrinsically uninformative. For a distribution of intensities to act informatively, a perceiver must have some means of *interpreting* or decoding the distribution according to a restricted set of possibilities.

One can frame the issue this way: Is seeing a light in a tower window high above the ground to be understood in the same way that Paul Revere learned of the British route or in some other way? Without denying the existence and utility of "Paul Revere" information, Gibson argued that there was a very different sense of information to be developed and that this was the more appropriate sense for understanding perception. In his sense of information the structure of light could be intrinsically informative. His theory implies that sensitivity to structure must exist in a perceiver but that there does not have to be an added interpretation process based on some prearranged code.

Development of the Ecological Concept of Information

Gibson's concept of information resulted from what began as a search for "higher order" variables of stimulation that would correspond to perceived properties of the world. His program of perceptual psychophysics was based on the hypothesis that what perceivers perceived was a function of stimulus patterning and that the relevant stimulus pattern was a function of the environment. According to Gibson (1960, 1982b), "If experience is specific to excitation, and excitation to stimulation, and stimulation to the external environment, then experience will be specific to the environment, within the limits of this chain of specificities" (p. 346). It was possible, he thought, that the presumed lack of correspondence between the environment and stimulation, and stimulation and perceptual experience, reflected a failure to discover the proper variables, not a failure of the correspondence.

The best known result of this program was Gibson's hypothesis that gradients of texture could act as unitary stimuli yielding perception of the slant of rigid surfaces relative to the line of sight (Gibson, 1947/1982a, 1950). If a gradient could be defined over an arbitrary number of different surface textures and yield the same perceived slant, it seemed justifiable to call the gradient a "stimulus" for slant perception. Because gradients are defined over textures and textures are already patterns, gradients are patterns of patterns. That is what Gibson meant by "higher order." With the key insight of "higher order" variables, it seemed that diligence and some cleverness would be sufficient to discover the true correspondences between stimuli and perception of the environment.

By the mid 1950s, however, Gibson began to reject the major assumptions of the psychophysical program (Gibson, 1982e). This must seem odd to many readers because the theory of information pickup does not, on the face of it, seem very different from "perception as a function of stimulation." Both say that optical patterning (for the case of vision) is the basis of perceiving the environment. So why the new terms? Why did Gibson regard the theory of information pickup as a radical new theory and the 1950 vintage ideas like texture gradients as merely "bright ideas" (Gibson, 1982e, p. 95)?

Ecological Information

So far we have said that Gibson regarded information as structure specific to its sources. To say more about information it would be helpful to turn again to light and vision and the new discipline Gibson called Ecological Optics. Ecological Optics is the theory of the lawful structuring of light by its sources at a level appropriate for perception. Hence it is where the theory of optical information is developed. Parallel disciplines studying the structuring of mechanical (for acoustics and haptics) and chemical (for taste and smell) energy could also be developed.

Gibson wanted to understand perception of the environment. From the foundations of physical, geometric, or physiological optics, to fully understand perception of the environment seems hopelessly complex. Any scientific discipline must work with simplified, idealized concepts in order to reason clearly and precisely. Gibson cut the Gordian knot tying perceptual theory to traditional branches of optics and formed concepts that abstracted directly over the animal and environment system, rather than waiting for elaborations of concepts from the other areas to build up to broad characterizations of environments. Instead of working with primitives such as points, lines, planes, and projections, he began with the ambient optic array.

The Ambient Optic Array

The ambient optic array is structured light *surrounding* a point of observation. It consists of multiple reflected light filling a medium. This means that there must be sources of light, reflecting surfaces, and a medium. With enough light bouncing from surface to surface, the medium becomes filled with light. The same set of reflecting surfaces that make the light-filled medium possible at all also accounts for differences of intensity in different directions from any point of observation. These differences exist by virtue of differences in arrangement (layout) relative to one another and to the illumination, differences in texture, and differences in pigment structure. Note that because this structure is a structure of differences it is invariant under changes of intensity of illumination.

The components of the array are a nested series of units with the earth–sky contrast being the first subdivision; that is, a terrestrial optic array is relatively light and untextured in the sky and darker and much more richly textured on the ground. The contrasting hemispheres corresponding to the sky and earth is a structure that is invariant under changes of illumination from day to night, and under changes in point of observation.

A number of conclusions can be drawn already. First, consider a homogeneous surround of light. It is ambient and it can cause receptors to fire, but there is *nothing* to see. There is nowhere to direct one's gaze and not even accommodation is possible. Gibson stressed that such light is *unfocusable*. To him this helped distinguish between a stimulus and stimulus information (or just information); that is, light can get to an eye and fire receptors but give rise to no perception. Gibson's interpretation of the Ganzfeld experiments attempting to show people homogeneous light was that visual perception literally fails under such conditions. It cannot work if there are no contrasts. It is a case of stimulation without information. In darkness, Gibson (1979) noted that visual perception fails for lack of stimulation *and* information. In homogeneous light, it fails for lack of information.

The language of stimuli implies something coming *from* the environment *to* an observer. In vision it implies light traveling from a source to an eye. The optic array (information), however, just exists. At the level of earth–sky, once one is born, one never goes outside of it (except for astronauts). One may obscure the sky or the earth by going into enclosures, but the sky and earth are always there as the outer limit on the array. At the level of places on the earth, eyes come to them, explore them, and leave for other places, perhaps to return, perhaps not. The motions of photons through the medium are assumed as a physical cause of illumination, but ecological optics begins after that with the assumption of an illuminated medium.

Because an optic array does not travel to observers but just exists, one can study the optical transitions from one region to another, and, for superordinate regions, transitions *within* them. The very stable features of an array, caused by very stable large-scale relations among surfaces, can support evolution. Gibson (1979) used the fact that animals with compound eyes, as well as animals with chambered eyes, show visually guided behavior (such as avoidance in the presence of an expanding shadow specifying a looming object; cf. Schiff, 1965) as evidence that they are designed to take advantage of information in the array even though they have no retinal images. Thus retinal images are not necessary for vision, but information is. Information, discussed this way, as something prior to animals phylogenetically, ontogenetically, and episodically, is real. It is not created by them or for them (except in senses described later in the discussion of affordances).

The stability and ubiquity of the sky–earth contrast makes it an effective absolute visual frame of reference for ecological optics. The sky–earth framework does not move. All changes of position are ultimately defined with respect to it. The clearest perceptual information for great distances or wide open spaces is information for a stretch of ground from a point of observation to the horizon; that is, the closest thing to the literal experience of "space" is to experience an uncluttered terrain. To present one literally with space would be to present a Ganzfeld and that experience, if anything, is like the experience of a heavy fog. It is certainly not an experience of vast "space." Even in his psychophysical days Gibson (1950) argued for the ground as a better framework for perception than any concept of "space." Hence he called his theory a *ground* theory in contrast to most other theories that he called *air* theories because they studied the perception of isolated objects, as if one were looking at birds or airplanes directly against a backdrop of the sky.

Perception occurs for *embodied* observers. This guarantees that no animal can see all 360 degrees of the ambient optic array at once. The body parts that an animal sees hide parts of the array. Thus eye turning relative to the array—by moving head or feet—is necessary to scan the whole array at any one place. The body of an observer causes part of the structure of an array at any observed place. It is an invariant across changes of location in the environment. It is an optical specification of "here" with the horizon as maximal "there." Thinking still of an open, flat terrain, one can understand that for a given height of the point of observation, there is a "here–there" dimension of distance invariantly specified under locomotion.

The frame of reference role of the sky–earth container (the ultimate terrestrial exterior treated optically as an interior) can be seen in the case of head movements relative to the horizontal. The horizon *is* the horizontal. An optic array sample with the horizon in the middle means that the head is level. This is a case where a fact about the observer ("here") is given in a fact about the maximal "there" (horizon). It is one reason for being uncomfortable with the distinction between "proximal" and "distal." If all one sees is the ground, one is looking down. If all one sees is the sky, one is looking up. An orientation of the eyes on this dimension is always specified in the optic array. Gibson maintained that such optical changes and nonchanges are used by perceivers to control their movements relative to the environment. Airplane pilots lose their sense of the orientation relative to the ground when flying in the middle of clouds and can be very surprised at what they see when they emerge. Dolezal (1982) showed that wearing tubes on the eyes to obscure peripheral vision of the body and ground at the feet caused a loss of the keen sense of head orientation relative to the midline of the body (is it to the left, right, how far?).

We have now developed enough to illustrate better what Gibson meant by defining information as structure specific to its sources. Consider the ambient optic array of a person alone on the prairie in the daytime. The optical structure is a nested one beginning with sky above and earth below. As one walks some of the subordinate structure of the earth is clarified by coming closer to it. Some is obscured by the body as one passes. The body is always visible, from feet on the ground to nose and eye sockets. There is optic flow outward from the horizon from the point being approached. The sky and earth remain stable throughout the walk. They both stretch to the horizon in all directions all the time. How could one simulate the optical structure of this situation without structuring by just the components of this situation? Can one make something look like "the outdoors" under conditions of free exploration without its *being* the outdoors? Even high-budget movies, with money for the technology of illusion, are made "on location." To the untutored eye, one might make a scene in Texas look somewhat like one in Kansas, but one cannot make a city studio look like a 5-mile walk in Kansas. And I certainly cannot imagine how one would specify *me* taking a long walk outdoors on the prairie without my taking a long walk on the prairie. Cinerama films and Disneyland displays that create vivid impressions of environments reinforce the point. Even to make an interesting approximation to an illusion of locomoting outdoors requires surrounding an observer as much as possible. But these surrounds are limited and one can readily find the boundaries—something one cannot do for the prairie until arriving at the mountains, and even then the mountains are connected to the prairie and the sky is still the same sky. The idea I am trying to convey rather imprecisely is that optical structure is lawfully determined by the surface layout (including the surfaces of the perceiver's body). Where this is true the structure is specific to its source and detecting the structure *is* detecting the source in surface properties. One does not detect something meaningless first and then interpret it meaningfully. There is only one step. That is the one Gibson referred to as information pickup. This does *not* say that the supporting processes for the act of pickup are not complex. There are many degrees of freedom to be coordinated. The alternative hypothesis, that there are two acts, one the detection of something meaningless and the other of interpretation, is equally simple relative to the underlying complex of supporting processes.

If this concept of information specific to its sources holds true for *any* cases, then information pickup is possible in those cases and a subject matter has been carved out. One can continue, asking "what other cases qualify?"

Invariants and Variants

As a structure surrounding an animal, an optic array can be explored or observed in the active sense of the word. For Gibson *observation* and other words for perceiving all designated active exploration. When this occurs, the array changes in some ways, but not in all. One way that the array of an idealized frozen environment changes occurs when an observer moves. Everything in the array flows (as alluded to previously) and there are regular exchanges of array components that are revealed and concealed (discussed more later). But within the flow some relations of components to one another stay the same. These invariants specify stable features of the environment. The changes, or variants, specify movement of the observer relative to the stable environment. Specification means the same thing it did before: In an ambient optic array, there is no other way the pattern of variants and invariants could come about. This point is when discussing the contributions of the theory of the environment and the theory of perceiving to the theory of information. The emphasis here is on the fact that specificity in an optic array depends on distinguishing variants and invariants and that these are natural concepts for an optic array. Because invariants are defined only with respect to variants, it follows that change is *necessary* to reveal nonchange. It also follows that systematic movements of an observer can be specified only relative to invariant structure. One could not see oneself locomoting or turning one's head in a Ganzfeld or in an ambient chaos.

An early example of an invariant in an optic array can be found in Gibson's early analysis of the gradient structure of optic flow generated by locomotion (Gibson, 1950; Gibson, Olum, & Rosenblatt, 1955). Originally he thought of the gradients of texture as higher order variables in the retinal image, but he considered the ecological optics interpretation to be a great clarification (Gibson, 1982e). In ecological optics, the optic array with its earth–sky "envelope" is the

relevant frame of reference, not the eye, as in the retinal gradients; and the concept of invariants relative to variants replaced "higher order" variable. Gibson admitted that he never could say clearly what "higher order" meant, whereas the pairing of variants and invariants put mutual boundaries on them. The problem of "how high is higher order, and how does one count?" does not arise. This is not to say that all specific invariants and variants are immediately manifest without laborious research, only that the concept of invariant is much better than the concept of "higher order."

Gibson postulated four kinds of invariants that underlie change in the optic array that he reviewed together in the second appendix of his 1979 book: "those that underlie change of *illumination*, those that underlie change of the *point of observation*, those that underlie *overlapping samples*, and those that underlie a *local disturbance of structure*" (p. 310). The third kind of change in the list refers to something like head turning, which changes the sample of the same array but does not transform the array as would happen in moving to a new point of observation. The fourth refers to events, changes in the environment not due to the other three factors. Many invariants remain to be discovered. The program is young, but the classification of variants helps to be clear about what is meant by an invariant. There are explicit terms for structure specific to the world and for structure specific to the observer, for changes and nonchanges in each.

Optical Transitions: Occluding Edges and the Perception of Persistence

The construct of the ambient optic array naturally induces the study of orderly transitions as a fundamental part of optics. As structure produced by what an observer is *inside* of, it leads one to seek out the order that belongs to exploring a stable interior such as a room, a forest clearing, or a prairie; the order in making transitions from one interior to another; and the order in going around detached and attached objects. With a prior concept of the systematicity that *exists* in each case, one can get an idea of what is *possible* to detect on the basis of optical structure. None of these three cases has received much attention, although the latter is beginning to (Koenderink, 1984; Shaw, McIntyre, & Mace, 1974).

The most significant transition studied in ecological optics, according to Gibson, is the one that specifies an occluding edge. Opaque surfaces are among the primitives of the world assumed by ecological optics. By reflection, they make possible the ambient optic array in the first place, but they also hide many surfaces at any particular point of observation.

The place where one surface hides its own backside or a background surface relative to a fixed point of observation is an occluding edge. George Kaplan (1969; Gibson, Kaplan, Reynolds, & Wheeler, 1969) showed that such an edge could be optically specified by the progressive disruption of optical texture (developing a precise formulation of the optics of occlusion is still in its early stages; it is an important continuing task of ecological optics—cf. Mace & Turvey, 1983). Kaplan filmed a white sheet of paper, randomly spotted by blobs of ink, frame by frame. Each new frame was created by cutting a thin column out of its predecessor, sliding one side over to close the gap, and adding new random texture in the area left by the displacement. The operation was repeated at the same place to the same extent for all frames of any particular sequence. No margin was visible in any single frame. However, when the film was shown, one surface was seen clearly to be passing behind another at the place where the texture was removed from the display. This effect is as vivid as anything else one might see in a filmed display.

The main point is that even though the texture "belonging to" the occluded surface was going out of sight, the surface was seen to persist. What was perceived was not "disappearance of texture," but "disappearance-from-this-point-of-view" with continued projection to some other point of view. There is a critical distinction to be made between disappearance of a surface from the face of the earth and disappearance of a surface from the view of a face. If a surface exists, then it does project into the optic array from some point of view. If it does not exist, it projects to no point of view. Gibson et al. (1969) showed that specifically different optical transitions can be demonstrated. They showed that *disappearance* is a vague, imprecise term because a visible surface can go out of sight from a point of view in at least three ways: being covered, turning around itself, going into the distance. Two other ways to specify persistence despite "disappearance" that can be distinguished are turning off the lights in an enclosed place and closing one's eyes. A surface can go out of existence in more ways: evaporation and sublimation, fading and increasing transparency, and consumption by eating were demonstrated in their film. Melting, breaking, crumbling, and exploding are other possibilities. Each of these is a distinctively different optical transition. Thus if one can detect a transition as a unit, then these changes can, in principle, be distinguished on the basis of optical information.

If the occlusion transition is different from the others and is detected as such then persistence of the occluded surfaces is specified. This is not to say that the unseen can be seen. One cannot see the rude faces being made behind one's back. But such faces are not usually made to be persisting structure. They are changed when one turns around and are distinguished from, say, the back wall of the room that remains connected to the floor, the adjoining walls, and ceiling throughout repeated inspections. The ordering of views that are possible is determined by the persisting structure of the array created by the room, and detecting this persisting structure is to detect the arrangement of the surfaces of the room.

The persistence specified in occlusion makes it possible to perceive environmental surfaces as connected and as existing concurrently. Not only does the disappearance of a surface by occlusion specify its persistence, but a surface that comes into sight by "disocclusion" is seen to preexist; that is, seeing it revealed is not confused with seeing it come into existence. That which is viewed "now-from-here" can be perceived as connected with those surfaces that are not seen by virtue of occlusion.

As we have seen, the ecological optics analysis of the ambient optic array into variants and invariants allows the separation of that which belongs to the environment from that which belongs to the self. The point of view belongs to the self. As it changes, in Gibson's theory of information, one can perceive when it is the point of view changing and when it is the environment changing. When the point of view changes in a stable environment, the persistence of that environment is specified by invariants in two of the four classes listed earlier. A consequence of the optics of occlusion is that as one uncovers new surfaces by exploration, one is extending the amount of connected, concurrently existing surface that one has detected. This is very important when we get to Gibson's definition of perception.

Information—Recapitulation and Affordances

Information is structure lawfully structured by its sources. For vision it is optical structure. We have reviewed some of the concepts required to make this work, especially in the optic array. It is important to stress, even though it must be brief in this chapter, that as an ecological concept, *information* requires a theory of what there is to be perceived as well as the informative optical structure. "What there is," in turn, requires that a fair amount be included about the animal as well as the environment. What there is to be perceived (visually here) must be limited to properties that can be shown to structure light and to do so at a level accessible to animals. Gibson's theory of the ecological environment to be perceived divides it into substances, media, and the surfaces formed by their boundaries. Even these are ecological concepts, because what counts as substance or medium (water is the main ambiguous case) depends on the animal. As already indicated, surfaces are the primary object of perception for Gibson.

Gibson (1982d) listed these perceivable properties of surfaces: The property of being rigid, viscous, or fluid; the property of being radiant or reflecting; the property of high to low reflectance of the incident light; the property of having uniform or nonuniform reflectance; the property of being smooth or rough (and if rough, whether texture is coarse or fine and the form it takes); the property of being dull or shiny; the property of being opaque or transparent; the property of being at a higher or lower temperature than the skin. He added that surfaces are not discrete and denumerable like detached objects, that they do not have location but rather layout, that they do not have the physical sense of color, and that they do not have the geometrical sense of form. Gibson (1979) defined places, attached objects, detached objects, and their changes (events) and asserted that these too could be perceived.

Affordances are the last and most important item on the list of what can be perceived. Gibson coined the term affordance to designate the utilities of surface and medium properties and their combinations for animal activities. Besides Gibson (1979), discussions of affordances may be found in Gibson and Spelke (1983), Turvey et al. (1981), and Warren (1984). The activities of an animal in an environment imply the ability to perceive the opportunities to perform and to control those activities. To walk is to be able to distinguish surfaces and their arrangements that allow walking from those surface arrangements that do not. Affordances are objective properties of the ecosystem. Whether something can be walked on, grasped, or swung from is a fact that depends on the size and abilities of an animal and the material structure of the environmental features. Affordances are ecological properties inasmuch as they do depend jointly on the properties of animal and environment for their determination.

What is important to note is that there are some such features that are optically distinct. One can study, as Warren (1984) did for stair climbing, the extent to which useful properties are specifiable in optical structure. If so, then in principle the information could be detected and the property perceived. The material requirements for action put heavy constraints on what can be specified and hence could ever be said to be perceived. Contra Fodor & Pylyshyn (1981), properties like "grandmother" and "shoe" *as such* are not likely candidates for being specifiable and hence perceivable in the sense of information pickup. Properties that make some shoes useful for protecting feet presumably *are* specified, but this is not to say that shoes *qua* shoes are specified. If I am seeking foot protection, a shoe box may be more appropriate than my son's baby shoes.

What it Means to Perceive Reconceived

To keep the theory of information pickup coherent and plausible, great care must be taken to *define* what it is to perceive. Gibson's version is a surprising twist of the traditional Aristotelian version. It is an information-based criterion. Here is one of his later definitions (Gibson, 1979):

> To perceive is to be aware of the surfaces of the environment and of oneself in it. The interchange between hidden and unhidden surfaces is essential to this awareness. These are existing surfaces; they are specified at some points of observation. Perceiving gets wider and finer and longer and richer and fuller as the observer explores the environment. The full awareness of surfaces includes their layout, their substances, their events and their affordances. Note how this definition includes within perception a part of memory, expectation, knowledge, and meaning—some part but not all of those mental processes in each case. (p. 255)

Of most direct importance for discussing cognition is the role Gibson gave to existing surfaces. They get the role that the "present" played in classical theories. Since at least Aristotle, perception has been distinguished from memory and expectation by having the responsibility for sensing the present, whereas memory was defined as a faculty responsible for the past and expectation for the future.

Thus time as represented by the past–present–future sequence is the basis for classifying processes or faculties. By distinguishing between information for the changing point of view and for persisting surfaces, Gibson underscored the fact that the traditional demarcation of perception, memory, and expectation is defined relative to the observer. He proposed to have the delineation be tied to the persisting, presently existing surfaces instead! Thus, no matter how long it takes to reveal and build the awareness of a connected set of surfaces, up to a lifetime, that total awareness of the existing world is perception. A large connected surface such as the territory in the Louisiana Purchase would take a long time to explore. But for Gibson, the logic of it is of a piece with detecting persisting properties of the surfaces extending slightly to the left and right of one's current head position. As long as the information being detected belongs to concurrently persisting surfaces, the detection of their invariant properties constitutes perception.

Persisting surfaces in an environment can be explored reversibly. They can go out of sight (hearing, touch, etc.) from some point of view, but as long as they exist, information for them must continue to be available and the possibility of exploring them remains within the environment. One can, in principle "get there from here" because "there" is connected to "here." Some real pathway exists. When one explores back and forth on such a reversible pathway, persistent properties of surfaces can emerge.

The perceiving conceived by Gibson is an animal's achievement of controlled and controllable "contact" with the environment. It is an activity, an activity of the *whole body* acting on and in the environment to obtain information, the major point of Gibson's book on perceptual systems (1966). Thus Gibson talked of *obtaining* and *extracting* information. Obtaining and extracting in this sense requires coordinated movement. Walking closer to something one wishes to clarify perceptually is a functional part of whatever modality or modalities are guiding the investigatory act; that is, the legs function perceptually by bringing one in a perceptually controlled way to a place where nested adjustments of head turning, eye pointing, lens accommodation, hand positioning, finger movement, and so forth can perform their clarifying functions—all as a single coordinated act. In this case, leg movement (in the context of maintaining a perceptually controlled stable posture) controls perception by moving the appropriate sensitive surfaces to a desired place, and leg movement is controlled by perception by slowing down and halting when the desired place is reached (keep in mind that a myriad of detailed adjustments of the legs and body are also being perceptually guided).

Other properties of perceiving in Gibson's analysis of information are continuity and nested organization. Gibson used the image of animals being immersed in a sea of energy that contains information. This information can be analyzed in a nested way from global to local, with the most global being the contrast between ground and sky that, for vision, provides the ultimate information for orientation of the whole body. In a completely enclosed architectural space, floor, walls, and ceiling provide the local objects to be perceived for stable posture even though a full analysis returns to the earth–sky. A stable posture is a prerequisite for any other controlled activity and "means of support" is the "object" that must be perceived for this overall stability. On a good day (and night), a person or animal preserves a controlled posture relative to the earth the whole time. This means perceiving some global nonchange within which other changes occur, changes that themselves are nonchanges relative to subordinate changes. Changes involved in performing activities occur *within* the context of global orientation. I might say that I perceive the paper in front of me for some purpose, but a full inventory of what I am perceiving is hard to imagine. It would include my orientation to the room, the house, and the outdoor layout. It would include my orientation to my chair, my desk, and my pencil, and these would involve numerous fine-tuning adjustments that I am not focally aware of. I am aware of all these in the sense that I am controlling bodily adjustments for purposes of exploration and manipulation (which includes sitting still), but not in the sense that I can list them explicitly in words. Perceiving, thought of this way, cannot quit, not just because the life process goes on, but also because the earth–sky, and some more local properties for any particular animal, remain as persisting objects of perception for one's whole life. Neither perceiving nor all the objects of perceiving start and stop during one's lifetime.

A final example of a property of perceiving follows from Gibson's argument that information in the world is inexhaustible. Because information is inexhaustible, perceiving does not change its focus because a "correct" or "matching" percept was computed. Rather, perceiving is guided by the practical requirements of an animal's goals, achievements, and circumstances. An animal has to perceive enough of its environment to accomplish its goals, but that's all. There is no final right or wrong. Moreover, perceiving can get better. If there is always more structure that can be clarified with more exploration, then the possibility for more perceiving is always present.

The upshot of these remarks is to emphasize that the perceiving Gibson described does not come in percepts. It is nested from global to local, and a description of what is being perceived at any particular moment would have to acknowledge all levels.

What Perceiving Is Not. Another way to try to clarify what perceiving is in the theory of information pickup is to say what it is not: (1) To perceive is not to have an experience. Dreams are nonperceptual experiences because they are not based on the active pickup of information in an ambient optic array. When one is sleeping in the ambient array, one is not exploring it. The surfaces in dreams are often not connected to one another and certainly not to persisting surfaces that can be visited, left, and revisited as specified in reversible occlusion. Most theorists agree that not all experiences are perception. Rock (1983) makes it very clear that perception is to be distinguished from other cognition by its connection to "stimuli"; (2) to perceive is not to experience something occasioned by a stimulus. Because of what I already know, I might see a spot on the horizon over a vast expanse of water and say, "Aha! Here comes the QE II with 749 passengers." However, so far as optical information goes, all I can detect at such a distance is that there is something out there on the water. Without a telescope I could not distinguish the QE II from an oil tanker. I could certainly not orient specifically to the layout of surfaces on the QE II. This is an important case because some theorists like Dretske (1981), who say a great deal that is agreeable to and helpful to an ecological perception theorist, would allow this as a case of detecting information if what one sees can select among alternatives a person knows; (3) the last case suggests the need to say clearly that to identify correctly based on perceiving is not perceiving; (4) to perceive is not to arrive at an explicit description in a system of representation as many workers in artificial intelligence define it (Marr, 1982). For Gibson, perceiving involves modulating the complex adjustments of the body performing goal directed activities in the environment. It is action theory, dual to perception theory, that gives perception its semantic closure (Pattee, 1982; Shaw & Turvey, 1981); (5) to perceive is not merely to experience structure as Gestalt psychology suggests. For Gibson it is to experience structure specific to oneself in a persisting layout of surfaces; (6) to perceive visually is not merely to experience light. Remember that in a Ganzfeld, Gibson argued that perceiving literally failed for want of proper "objects," that is, information.

PERCEPTION AND COGNITION

Gibson recognized a clear distinction between the achievements of perception (perceptual knowledge) and the achievements of thought (conceptual knowledge). He did not believe that one could wave one's hand and say that everything was one or the other—or even a mix in the senses found in cognitive approaches to perception. To clarify the distinction between the two kinds of knowledge he offered the following set of contrasts (Gibson, 1974): For perception, the environment consists of substances, medium, and surfaces, not tiny particles like atoms or large astronomical bodies. For perception, the earth is flat, not round. The earth does not move. It is an absolute frame of reference for motion. Gravity is perpendicular to the substratum (things fall *down*). The environment is always upright. Only changes within a moderate range of times are perceptible as such (Shaw, McIntire, & Mace, 1974; Shaw & Pittenger, 1978 have disagreed with Gibson on this point). Illumination reaches a steady state instantly, the speed of light being irrelevant for perception. Finally, perception of the self is always specified and therefore possible ecologically. Gibson argued that it was a mistake to use the conceptual entities and facts of abstract science (such as "space") as if they were possible objects of perception. It was certainly a mistake to use concepts and facts of abstract science as standards of "veridical" perception from which to judge error and illusion.

On the other hand Gibson did believe that the ecological approach offered a firm foundation for a general understanding of knowledge and he did not believe that there was a categorical boundary between perceptual and conceptual cases. Characteristically, he developed a classification scheme, based on the theory of information pickup, to show a *graded* series of cases linking perceptual and conceptual knowledge without blurring what he took to be natural distinctions.

Direct Perception and Cognition

The definition of perception quoted earlier is a definition of what he called *direct perception.* Direct perception means that observers perceive themselves in the environment, surrounded by it, and in relation to it. This is implied by the ambient array in that, to be ambient, the array must be around the observer and it must be occupied by an observer. Another way Gibson defined direct perception was to say that it was extracting information from the ambient array, where ambient has the implications just mentioned. Gibson's treatment of the perception of persistence and change, invariants and variants in the optic array, allowed him to distinguish the part that belongs to an observer and the act of observation from that which belongs to the environment. Both can be observed simultaneously. The concurrent registration of invariants and variants is necessary to make any of his other claims plausible.

Memory and Expectation. Both change and nonchange must be registered over time. Does this mean that the theory of perception depends on memory to provide the link between past and present necessary to perceive change and persistence? If so, how does it work? What evidence and theory from research on memory would help us understand the apprehension of persistence and change? What is *meant* by memory? If all that is meant is that an animal and its abilities persist over time, then calling it memory adds no explanatory value. Such persistence is required to support the function of information pickup described, but that is necessary for any process to have continuity.

Consider the case of looking at a paper bag on the table in front of you—bearing in mind that in ecological terms it is not a paper bag but a connected set of detached surfaces, mostly surrounding air, and offering a myriad of affordances from carrying groceries to filling a sandbox (carefully) to covering one's face at Halloween. After first looking straight at the bag, you turn to the left so that the texture of the object disappears by occlusion. You can look back at it if you like, to scrutinize it more. Do you know that you can look back at it because you remember it and its location? If you do look back at it, bringing it progressively into view, how is retrieving the view in the structured optic array

related to retrieving "a memory"? What if it disappeared by melting? Would you still look for it in the same way?

Gibson stressed the importance of recognizing the differences among types of transitions. If you can discover the difference between melting and going out of sight by occlusion, how do you do that? On Gibson's account, these cases differ in orderly ways. Orderly optical consequences of a change can constitute information—even if it occurs over time, even if it continues to occur for a very long time. The question then is whether or not the information can be detected. It would seem that either *everything* is memory here, or everything is perception and nothing is memory. Setting up this opposition, in light of Gibson's analysis, is pointless because it does not matter what words one uses to designate the process if one admits that information exists and is detected. That is why Gibson talked about information pickup. It is more precise. He did think information pickup was the best explanation of perception as he defined it, but the activity of extracting invariants and variants that specify persistence and change is the main point no matter what one calls it.

The same can be said for *expectation.* If one maintains that one turns in the right direction toward the bag to scrutinize it because one *expects* it to be at a particular place in the sequence of views, what is added? Why should one appeal to three separate processes to explain the apprehension of the layout of a persisting unified structure (the room, its furniture, the observer)? This would draw attention away from the fact that there are riches of orderliness in the changing and persisting optic array structure of a person exploring the room.

It is difficult to see how appeals to memory and expectation could ever work in the first place if the order did not exist. But if the order exists and that order *is* what is ultimately ascertained (by whatever process), then why not refer to the process in a unitary fashion by calling it perception or information pickup? This does not absolve science of the need to probe more into the details of the pickup process, but it is a very different guide to what one would look for.

Affordances. The previous discussion on affordances should have made it clear that this is a way to bring meaning into the theory of information pickup without having to invest an animal with concepts to do so. The key is to make intrinsic scaling and grouping work in the theory. The argument is that a certain rough fit between an animal's actions and the perceptible environment is constrained by evolution in the first place. The variables must be nonspooky ones that have physical reality in order to have ecological reality. For instance, a ledge is a good height for sitting (for a person) if one can look down and see it about level with one's knees. One does not have to have a metric scale in the head. A ledge is too high to crawl up on easily for most people if its supporting level surface is at eye level or above (measured by whether or not one can see this surface).

The Case of Surfaces That No Longer Exist. As one explores the ambient array in direct perception, the set of connected surfaces that one can put in order expands. As long as the surfaces persist, those that go out of sight can be brought back into sight and can, therefore, continue to be part of the process of extracting invariants from the ambient optic array. The more one does this, the more one can reveal about the environment—without limit. Exploration over time can reveal more about the large-scale structure of an environment (the Lewis and Clark expedition) or the fine structure (a connoisseur of fine paper). What if surfaces are explored and later destroyed when one is not looking? Then the optical occlusion is not reversible because the surfaces are not available to any point of observation. New surfaces can be discovered connected to the persisting surfaces. There is information for a change of layout.

In Gibson's proposed classification, the awareness of surfaces that did exist, but no longer exist, is a distinct case from the awareness of surfaces that continue to exist. He said that *that* could be thought of as a kind of memory (1979). The advantage of this method of classification is that it is information based. Information for surfaces in these phases of existence can be defined. The "past" and the "future" relative to the "present" have never been well defined and do not seem like proper foundations for a distinction as important as that of *perception, memory, and expectation.* To define perception as an apprehension of something in the present as distinct from memory as apprehension of that which has been perceived implies that one can tell when perceiving quits and memory begins. Gibson's suggestion avoids that problem. For him, perceiving *never* quits during a lifetime, but surfaces can cease to exist.

The Case of Surfaces That Come into Existence. The case symmetric to the previous one is that of surfaces coming into existence. The optical transitions to transform existing materials and surfaces into new ones should also be orderly enough to discover. To be aware of such surfaces in relation to persisting ones and a point of observation would be a case of planning or expectation in this new proposal.

Impossible Surfaces. Finally one could consider the case of being aware of surfaces that could not exist and perhaps even differentiate the ways that they could not exist. These would be surfaces that could not be connected to previously existing, presently existing, or future surfaces.

Indirect Perception

The previous cases can be thought of as extensions of direct perception in that they are defined relative to an observer at some place in the environment. These were extensions of direct perception because they were defined in terms of awareness of surfaces, with no mediators.

A second method of classifying types of cognition is on the dimension of direct to indirect. Indirect perception is direct perception of something that in turn contains information for other surface layouts and points of view. Gibson distinguished three broad classes—information mediated by instruments, information mediated by pictures, and information mediated by symbols (including words).

In each case, the possibilities for exploration are very different from those in the ambient array. A picture, for example, can yield, at best, something like the texture of a tree from a particular distance. Looking more carefully at the picture yields more detail about the paint and the canvas, not about the tree. Looking closely at something in the environment yields new nested structure (e.g., the texture of individual pieces of bark) and is one of Gibson's criteria for perceptually distinguishing real things from others, such as pictures. Instruments (telescopes, microscopes) yield information about the environment but in a way that is disconnected from the perception of self in the ambient array. Symbols, of course, raise the problems of codes and such. Apprehension based on symbols is the extreme case of indirect perceiving. It is quite remote from direct perception within Gibson's taxonomy.

To recapitulate, Gibson's theory of information pickup clearly groups problems together in new ways. It is much more important to think about what cases belong to common groupings (and why) than it is to name the groupings (cognition, perception, memory, etc.). By taking the apprehension of environmental surfaces as the fundamental problem, Gibson showed that traditional topics reappeared (or disappeared) in a new light. It is a rich framework for research—a beginning, not an ending.

These are considerations for how one might pursue cognition from an ecological grounding. They call for filling out and testing.

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