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THE ECOLOGY OF J. J. GIBSON'S PERCEPTION

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Abstract—*J. J. Gibson's approach to the study of perception emphasizes the way an active observer picks up information from the environment. The central postulates of Gibson's approach are that (1) visual space is defined by information (such as texture gradients) contained on environmental surfaces, (2) the crucial information for perception is information that remains invariant as an observer moves through the environment, and (3) this invariant information is picked up directly, so that no intervening mental processes are necessary for visual perception. This paper summarizes Gibson's approach as it is stated in his three books,* Perception of the Visual World *(1950),* The Senses Considered as Perceptual Systems *(1966) and* The Ecological Approach to Visual Perception *(1979) and evaluates the final form of his approach described in his third, and last, book.*

I. INTRODUCTION

So important has J. J. Gibson's presence been to the field of perception, that I was delighted when a copy of his book, *The Ecological Approach to Visual Perception* [1], was sent to me for review in *Leonardo.* Written over a period of 10 years, this book, which appeared less than a year before Gibson's death, gives us an opportunity to see the culmination of Gibson's career of over 50 years in perception.

I took the occasion of writing this review as an opportunity not only to read Gibson's new book and reread his old ones, but also to see how his work has been represented in textbooks and to talk to people about him. From looking at textbooks, I found that nowhere in the most widely used books are the essentials of Gibson's approach spelled out, and from informally surveying many of my colleagues who teach courses in sensation and perception I found that few of them teach Gibsonian perception in their courses. It, therefore, seems appropriate to consider not only Gibson's ideas as expressed in *The Ecological Approach to Visual Perception* (1979) [1], but also to consider his overall theory as developed in his two other books, *Perception of the Visual World* (1950) [2] and *The Senses Considered as Perceptual Systems* (1966) [3].

II. A SUMMARY OF GIBSONIAN PERCEPTION

In *Perception and the Visual World* [2], Gibson states that his approach to perception grew out of aviation experiments that he did during World War II. In doing these experiments, Gibson concluded that the usual laboratory approach to the study of depth perception is not well suited to improving a pilot's ability to land an airplane, and that, instead, it is necessary to take the study of perception outdoors into the natural environment. Thus began Gibson's 'ground theory' of space perception, a theory he contrasts with the older 'air theories' of perception. Visual space, according to the 'ground theory', is defined not by an object or an array of objects in the air (as occurs for depth cues such as interposition, relative size, etc.) but rather is defined by the ground, a continuous surface or array of adjoining surfaces. Thus, the spatial character of the visual world is defined not by objects but by information contained in the ground upon which these objects rest.

Perhaps the most well-known example of this ground-based information is the texture gradient (Fig. 1). Although texture gradients are described under the heading of *depth cues* (along with cues such as aerial perspective, interposition, and relative size) in many textbooks [4–6], this categorization of texture gradients would, undoubtedly, not please Gibson. He considered the information provided by texture gradients to be superior to the information provided by depth cues, because texture gradients are precise geometrical correlates of physical distance, whereas depth cues are less exact. For example, the spacing on the gradient in Fig. 1 decreases in a geometrically definable way as distance increases, but the degradation of far away images caused by a depth cue like atmospheric perspective depends on the quality of the air on a given day.

Gibson's concern with the characteristics of the information responsible for perception led him to emphasize the fact that real life perception involves not a stationary observer fixating on a small light in a laboratory, but, rather, an active observer who is constantly moving his or her eyes, head and body relative to the environment. To deal with the fact that this movement of observers results in a constantly changing image on the retina, Gibson notes that although an observer's movement may cause the image on the retina to be in constant flux, there is *information* on the retina that remains constant. As Gibson puts it in Ref. 2, Chapt. 8,

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Fig. 1. A texture gradient with two bricks.

movement of an observer causes a *transformation* of the image, 'a regular and lawful event which leaves certain properties of the pattern *invariant*'. For example, as an observer moves relative to a texture gradient, the contours that define the textures of the gradient sweep across the retina, but the texture of the gradient remains constant (assuming that the gradient is regularly spaced, a point I shall return to later), and the scale of depth of the scene, therefore, remains constant. The idea of invariant features of the environment, which is introduced only briefly in Ref. 2, became one of the central principles of Gibson's approach and is discussed at length in Refs. 1 and 3.

An invariant, as defined by Gibson, is 'non-change that persists during change' [3, p. 201] and 'lawful change in the array' [1, p. 175]. In his three books, Gibson mentions over two dozen examples of invariants, properties of the environment that remain constant as an observer moves or when the illumination changes. (Some of those mentioned by Gibson in his three books are: Straight lines, points, continuity [2, p. 153]; cues for behavior [2, p. 216]; proportions [3, p. 3], higher order variables of stimulus energy such as ratios of light intensity [3, p. 3]; the Earth below, the air above [3, p. 8]; rectilinearity [3, p. 201]; margins between patches of luminance [3, p. 222]; the combination of fire paired with sound, warmth and odor [3, p. 272]; gravity [3, p. 319]; separation of two hemispheres of light at the horizon [1, p. 76]; unchanging relations among four angles in a rectangle [1, p. 72]; a unique combination of invariants (a compound invariant) [1, p. 83]; layout of surface on the terrestrial environment, reflectances of different areas, the range of colors [1, p. 87]; the horizon cuts equally sized objects in the same proportions [1, p. 178]; the occluding edge of one's nose [1, p. 249]; size [1, p. 272]; the penumbra of a shadow [1, p. 286].)

Five of the more important invariants, not mentioned in the list above, may be described as follows:

1. Increasing density of optical texture [1, pp. 67, 149, 250, 272]. As described above, texture gradients like the one in Fig. 1 remain constant as an observer moves in relation to the gradient. This constancy of texture helps define the scale of space, since equal amounts of texture represent equal amounts of terrain [1, p. 83], and also helps determine the perception of sizes of objects, since the bases of equally sized objects cover equal numbers of texture units.

2. Flow patterns of gradients [3, p. 162; 1, p. 182]. Movement of an observer causes textures in the environment to flow. If a person is moving straight ahead, the gradient flows everywhere with the exception of the point toward which the person is moving, which, being at the center of the optical flow pattern, stays constant. Thus, a person's ability to stay on course as he or she moves towards an object is attributed to the ability to keep the unchanging (invariant) center of the optical flow pattern centered on the desired destination.

3. Structure common to two successive views. [3, p. 261]. As a person moves through the environment or scans it by making eye movements, the views seen at successive points in time overlap. This overlap helps the person to perceive a coherent, continuous scene even as the scene is changing.

4. Nondisruption of edges that are covering or uncovering [1, p. 76]. As an observer's point of observation changes, surfaces in the environment are seen to move relative to one another. This movement, known in the classical literature of perception as *motion parallax*, results in a progressive disruption of the components of surfaces that are being covered (the components disappear from view) or uncovered (the components are exposed to view). The surface that is doing the covering or uncovering is defined, according to Gibson, by its nondisruption, and this nondisruption is, for Gibson, an invariant.

5. Affordances [3, p. 285; 1, pp. 18, 127, 143]. An affordance is 'what the environment *offers* the animal, what it *provides* or *furnishes*'. For example, a ledge affords sitting, air affords breathing and water affords drinking and bathing. Thus, affordances refer to the meanings that objects have for observers and these meanings remain invariant in most situations.

The first four invariants listed above have in common a concern for the role of an active observer. The idea that perception can be explained *only* in terms of observers that move is a theme that runs through Gibson's work and that he has applied not only to vision but also to other senses.

Thus, in his paper Observations on Active Touch [7] he analyzes touch in a new way by describing touch not in terms of an experimenter's push on the skin, but in terms of an observer who actively explores the surfaces of objects; and he shows that the observer's perceptions are totally different in the two situations.

Something common to Gibson's invariants is that they are descriptions of characteristics of the environment, or, more properly, descriptions of characteristics of the stimuli for perception. The stimuli for perception are, however, not merely described in Gibson's analysis, but they are given a place of premier importance. Gibson asserts not only that invariants provide the information necessary for perception, but that this information exists in a form that can be used immediately, without being transformed, processed or manipulated in any way.

Gibson, in fact, states that space and other qualities of the environment are perceived *directly*, without the aid of an intervening mental process. For example, the Helmholtzian explanation of size constancy requires that a process of 'unconscious inference' somehow takes both retinal size and physical distance into account to achieve constancy, whereas, Gibson's explanation requires only that an observer see how many units of a texture gradient are covered by the base of an object. Thus, the fact that the two bricks on the gradient of Fig. 1 cover the same number of texture units at the point at which they rest on the ground indicates *directly* that they are the same size and, therefore, eliminates, according to Gibson, the need for unconscious inference or any other intervening mental process. Perception is explained, according to Gibson, by considering the stimuli in the environment, rather than by considering what happens to these stimuli after they enter a person's eyes.

Given the above summary of Gibson's ideas, I shall now consider the contribution made in his last book.

III. THE ECOLOGICAL APPROACH TO VISUAL PERCEPTION [1]

In the Introduction of the book Gibson says: 'This book is a sequel to *The Perception of the Visual World*, which came out in 1950. It is rather different, however, because my explanation of vision was then based on the retinal image, whereas it is now based on what I call the ambient optic array. I now believe we must take an ecological approach to the problems of perception .... When no constraints are put on the visual system, we look around, walk up to something interesting, and move around it so as to see it from all sides, and go from one vista to another. That is natural vision, and that is what this book is about .... The process of perception ... is not the processing of sensory inputs, however, but the extracting of invariants from the stimulus flux. The old idea that sensory inputs are converted into perceptions by operations of the mind is rejected. A radically new way of thinking about perception is proposed ... ' [1].

This statement gives an accurate picture of Gibson's emphasis. Throughout the book he stresses the importance of movement of an observer and of invariants for perception, and in so doing he continues a theme begun in his other two books [2, 3]. The major new contribution is an expanded discussion of affordances (which were only briefly introduced in Ref. 3). Thus, he reaffirms his commitment to invariance and direct perception, expands his discussion of affordances and summarizes the evidence supporting these ideas. I will consider Gibson's treatment of affordances, invariances and direct perception, in turn.

A. Affordances

Gibson's discussion of affordances focuses on how information in light specifies what the environment affords. Thus, he asks, 'if there is information in light for the perception of surfaces, is there information for the perception of what they afford?' And he answers this question by stating that 'The "values" and "meanings" of things in the environment can be directly perceived' [1, p. 127]. Thus, according to him, perception of an object involves not only perception of the visual characteristics of that object, but also involves perception of what the object affords. And this perception of the object's affordance, like the perception of the object's visual characteristics, occurs directly—it is specified in the light.

Gibson correctly anticipates an objection that most readers would have when he states that the skeptic may not be convinced that what food affords, something that tastes good, is specified in light. 'The taste of a thing, (the skeptic) will say, is not specified in light; you can see its form or color and texture, but not its palatability; you have to taste it for that' [1, p. 140]. Unfortunately, he does not offer a way out for the skeptic. Instead, he says that affordances are specified by 'invariant combinations of invariants' [1, p. 140] but he does not help readers to understand exactly how these 'higher order invariants' specify affordances. The idea that the meanings of objects are important to observers is an important one—a person's first reaction to a flight of stairs may, in fact, be 'here is a way to go up' rather than, 'here is a series of surfaces'. The problem comes with Gibson's statement that what an object affords is specified in the light, and his failure to deal adequately with the fact that affordances must be learned. A wooden chair may afford sitting for a human, but something to gnaw on for a beaver, even though the information provided by the light is the same for both. Learning must occur before the information in the light can indicate what something affords, but he mentions learning only briefly at the end of the chapter when he states that 'affordances ... are usually perceivable directly, without an excessive amount of learning' [1, p. 143]. What is missing here is the amplification of this statement. Learning must be involved in a person's understanding of the meanings of objects, and this involvement deserves more discussion than Gibson gives it.

B. Invariants

According to Gibson, invariants explain how a person perceives the world. For example, the ability to correctly perceive the sizes of objects is attributed to the information provided by texture gradients (Fig. 1) and the ability to stay on course as a person move towards an object is attributed to our ability to keep the unchanging (invariant) center of the optical flow pattern centered on the desired destination.

Note that Gibson's approach has, so far, been described without reference to any empirical research. In fact, it has been noted that 'Gibson wrote with a strange authority, merely stating his position rather than marshalling experimental evidence' [8]. The problem is that, despite Gibson's authority and the intuitive appeal of the idea of invariance, some experimental evidence must be presented to support the idea that invariants are, in fact, *used* by the perceptual system. For example, is the information in texture gradients actually used by the perceptual system to determine depth? There are some studies on texture gradients [9, 10] but few on most of the other invariants.

This lack of experimental evidence is, in fact, something of which Gibson was aware. In an early exposition of this approach, he stated in 1959 that 'it has been extraordinarily fruitful in suggesting to the author hypotheses for experiments and in opening up new ways of experimenting on old problems. The important question is whether it will serve the same function for others' [11]. But 20 years later he states in his last book that 'The experiments I will report ... are mostly my own, and the evidence, therefore, is scanty. Other students of information based perception are at work, but the facts have not yet been accumulated' [1, p. 3]. The problem is that invariants are so complex that it is difficult to know how to go about isolating these invariants and then studying them. Recently, some investigators have taken up the challenge of investigating invariants [12], but this work has just begun, and it remains to be seen whether enough empirical evidence can be accumulated to support Gibson's claim that the pickup of invariants can explain the totality of human visual experience.

C. Direct Perception

Gibson begins Chapter Nine of his last book [1] with the statement 'when I assert that perception of the environment is direct, I mean that it is not mediated by *retinal* pictures, *neural* pictures, or *mental* pictures. Direct perception is the activity of getting information from the ambient array of light' [1, p. 147].

If, when reading this definition the word 'pictures' is emphasized, then Gibson's view is not inconsistent with the views of many other researchers. Many would accept the idea that it is not *pictures*, be they retinal, neural or mental, that are important in determining perception, but, rather, it is information, some aspect of the retinal image or resulting neural signal that is correlated with the external environment, that determines visual perceptions. Thus, Gibson's assertion that animals with compound eyes like the dragonfly [1, p. 62] or the fiddler crab [1, p. 176] can see, even in the absence of a retinal image, poses no problem for most psychologists and physiologists, who require not that information be in the form of a picture but only that it be correlated with the environment.

The idea of direct perception has usually, however, been discussed not in relation to neural signals but in terms of cognitive processes. Gibson's claim is simply that perception can occur directly, in a single step, based only on the information contained in the stimulus, with no intervening cognitive processing being necessary. Thus, direct perception changes a multistage process into a one-stage process, so that instead of (1) perceiving forms and (2) then interpreting depth cues, a person perceives the layout directly in terms of invariants. As Gibson puts it, a person simply 'picks up' the invariants. But while he demonstrates that perception is a function of features on the ambient array of light, he fails to show that this perception is 'direct'. Thus, in Chapter Nine, Experimental Evidence for Direct Perception, he shows that a person's perception of depth in a 'pseudotunnel' [1, p. 153] is dependent on the number of intensity transitions in the tunnel, but it is hard to see how demonstrating this relationship tells anything about the *process* that leads to the perception of depth in the tunnel.

Perhaps the most clear-cut example that Gibson cites to support direct perception is his experiment [1, p. 160], which showed that an observer can accurately judge the heights of stakes placed on the texture gradient formed by a plowed field. The observer perceives the size of the stakes directly, it is argued, by noting the number of units in the texture gradient covered by the base of each stake, thereby eliminating the need to take distance into account. But, anyone who has walked around with a camera trying to find examples of texture gradients to photograph realizes that homogeneous texture gradients analogous to Gibson's regularly plowed field are hard to find. Thus, in the real world one often encounters a nearby object resting on a surface that has densely packed texture and a far away object resting on a surface with a more widely spaced texture. In this situation a person would have to move his or her eyes from one object to the other to see both objects clearly in foveal vision [13], and the person would then have to carry out some sort of mental operation to account for the change in the density between the two gradients. The ability to make accurate judgments of size in situations such as this is difficult to explain in terms of the direct pickup of information about the number of texture units covered by the objects.

IV. CONCLUSIONS

What has Gibson left to us? At the very least, he has sensitized those concerned with visual perception to the fact that to truly understand perception they must consider the information that an active observer uses while moving through the environment. But many would argue that his contribution goes far beyond this. Gibson was bold enough to propose a global approach to space perception at a time when most psychologists were occupied with much narrower concerns. He chose to focus not on providing *data*, but on providing a *framework* to help researchers think about perception.

It seems to me, however, that Gibson's framework will not be widely accepted until others have supplied the supporting evidence. The present lack of experimental support for his approach can be traced at least in part to the complexity of the problem: While it may be true that there is more to visual perception than seeing stimuli in a laboratory, it is another thing to be able to do meaningful experiments in the complex environment that exists outside. It may, therefore, be difficult to show that his invariants are actually used by the visual perceptual system and even more difficult to show that perception occurs directly.

Whether or not some of the specifics of Gibson's approach turn out to be 'proveable', one thing is certain: He has made it necessary to think about perception in a new way, and, as Ulric Neisser [14] states: 'Gibson's insights are too far reaching and too provocative to be ignored. They shed an entirely new light on the problems of perception; it is structured light rich in information. By offering us a new description of the stimulus for vision, he has presented us with a new vision of theoretical possibilities as well.'

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