Ecological Theory of Perception

During World War II, difficulties had been encountered in the flying of aircraft, particularly landing, and in the training of pilots (Gibson, 1979/1986). Tests had been given for depth perception using the static, frozen-in-time, stimulus presentations in two dimensions that are intended to assess perception of monocular and binocular depth cues. Tests might be for linear perspective or apparent size, or other monocular or binocular cues of depth. None of these tests, as it turned out, were able to predict how well a student pilot would perform. The traditional theory of depth perception was not working; it failed to apply where it should have. Gibson puzzled over this and came to realize that the traditional theory of depth perception was wrong. Helmholtz (1866, in F. H. Allport, 1955) had struggled with the fact that visual perception of three dimensions was based upon a two-dimensional structure—the retina (the retina was flat and visual sensations without depth; Gibson, 1966). It was not possible, given that barrier, to perceive the three dimensions immediately. Helmholtz proposed that cues, which were signs of distance, provided the basis for making unconscious inferences regarding size and distance (Hilgard, 1987).

Based upon his research Gibson (1979/1986) began to suspect that the traditional list of depth cues was simply not sufficient. Pondering the situation, he theorized that light provided information and that the changes taking place in the surrounding field of light (an array of reflections from objects) provided a form of information that the static displays did not. In the "optic array," an "optic flow pattern" was provided, by the changes in the structure of surrounding light, with information about one's position relative to environmental objects, and changes in that relation as one moves through time and space. It was clear to Gibson that each approach—the classical approach and his—had a very different conception regarding the stimulus of perception. Gibson was of the view that visual perception is due to the fact that ambient (surrounding) light conveys visual information that is accessible directly rather than being based upon visual cues (or clues) from the retina which have to be interpreted. Regarding his work prior to this realization, Gibson wrote:

> I failed to distinguish between stimulation proper and stimulus information, between what happens at passive receptors and what is available to active perceptual systems. Traditional psychophysics is a laboratory discipline in which physical stimuli are applied to an observer. He is prodded with controlled and systematically varied bits of energy so as to discover how his experience varies correspondingly. This procedure

> makes it difficult or impossible for the observer to extract invariants over time. Stimulus prods do not ordinarily carry information about the environment. (Gibson, 1979/1986, p. 149)

Gibson was working from the assumption that humans actively extract information from the environment that they use to guide their deliberations regarding how to act next. More than that, Gibson was putting forward an "ecological theory" that proposed that there was no absolute division between subject and object, perceiver and perceived (analogous to the assumed division into the stimulus–response sequences of discrete events). There was a symbiosis between the perceptual apparatus and the environment that it evolved to perceive; perceiver and thing perceived were a system in which there was a constant, ongoing provision of feedback that served as information for the purposeful regulation of continuing activities.

Based upon his recent revelations, regarding the apparent, direct access to the real environment for perception, Gibson, between 1957 and 1961, worked toward developing a new theory of perception that would be consistent with direct realism – an *ecological theory of perception* (Lombardo, 1987). Up to that point, the person was seen as an individual who was isolated from the environment and that resulted in a metaphysical dichotomy (in the sense that two divisible and completely separate entities confronted and opposed each other). There was the subject (the individual who perceived the world) and the object (that which was perceived). The result of such conceptual dichotomization was the puzzle of how an individual could perceive the world and to what degree phenomenological experience reflects the true nature of that objective world. This was the difficulty that Gibson would struggle with.

Psychology has long paid homage to evolutionary theory without appreciating the full implication of that theory for psychology. Darwin, on the other hand, was completely aware of the possible contribution of his theory to psychology:

> In the distant future I see open fields for far more important researches. Psychology will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation. Light will be thrown on the origin of man and his history. (Darwin, 1859/1979)

Mental powers evolved. They are not of a separate realm called mind nor are they apart from the world of nature; they are processes of nature, natural and material. Humans do not gaze upon the world from some distant, non-organic, supra-natural, plateau, separate from and independent of the remainder of living forms. We are of nature, bound to nature, its product. Mental processes are material processes (not of some separate substance called mind) that evolved because they were serviceable to continued existence in a material world.

Darwin's theory was that nature provides obstacles to survival, e.g., drought, famine, pestilence, changing climate, and so on, and that those individuals that were suited to these changed conditions would thrive and survive. This meant that variability of characteristics, within a species, would enhance chances for the survival of the species (not particular individuals). Those individuals, from the species as a whole, that could adapt to changing conditions would be the ones that would carry the species forward (in terms of evolutionary development). The adapting individuals were selected by nature (a purely random, non-conscious, unintentional process) to continue to exist and have offspring. The adaptive characteristics were passed on to offspring through reproduction. By these means adaptive characteristics would be passed throughout the surviving members of the species and, through a very gradual process, could result in alterations of the species characteristics (morphologically or behaviorally). Darwin surmised that mental processes, upon appearing, were serviceable to continued existence and would therefore be favored by random selection processes.

Functional psychologists, as would Gibson later, were concerned with investigating the relationship, or function, of psychological processes with the physical world (Lombardo, 1987). It was the recognition of the importance of evolution to the development of psychological processes that led the functionalist psychologists (James and Dewey) to argue that mental processes should be considered functions of a living organism that supported continued existence (Heidbreder, 1933). This marked a radical shift for psychology. Psychologists, at the latter part of the 19th century, had been focusing on states of consciousness and on what the structural makeup of these mental states was (e.g., Wundt's analysis of the mind through introspection and Titchener's structural psychology). This set a limit to psychological investigation and rendered consciousness independent of the processes of living (at least in its investigation).

The focus in psychology had long been upon the rational aspect of the mind but, with the functionalists, a shift was taking place toward the practical side of mind, i.e., what its purpose was, its function (James, 1905). It was apparent from James' writing that he recognized the importance of evolutionary theory for psychology:

> The theory of evolution is mainly responsible for this. Man, we now have reason to believe, has been evolved from infra-human ancestors, in whom pure reason hardly existed, if at all, and whose mind, so far as it can have had any function, would appear to have an organ for adapting their movements to the impressions received from the environment, so as to escape the better from destruction. Consciousness would thus seem in the first instance to be nothing but a sort of superadded biological perfection,-useless unless it prompted to useful conduct, and inexplicable apart from that consideration. (James, 1905, pp. 23–24)

James clearly was of the view that consciousness was something that came into existence and that its first appearance was due to its being serviceable to continued existence, i.e., to dealing with the problems that confront a living being in its struggle to maintain its existence.

Dewey (1910/1951) developed this line of thinking further by addressing what he felt was the problem of focusing upon the "mind" rather than focusing upon the "mind-in-the-environment." To Dewey, there had been a failure to appreciate that it was only in, and through, life in the environment that these have their existence:

> What we are really after is the process of experience, the way in which it arises and behaves. We want to know its course, its history, its laws. We want to know its various typical forms; how each originates; how it is related to others; the part it plays in maintaining an inclusive, expanding, connected course of experience. (Dewey, 1910/1951, pp. 248–249)

It was Dewey's contention that the psychologist has, as data, not isolated mental processes, but, operations and acts, e.g., perceiving not perception, remembering not memory, loving not love, etc. Gibson, too, would be developing this line of thinking by proposing that perception is not passive reception of stimulation, it is active and intentional (Lombardo, 1987). In Dewey's conception, it is the acts themselves that are concrete experiences, not their content. To understand them we have to consider the conditions under which they arise.

The modes of consciousness have no importance, to Dewey, unless they are translated back into acts.

It is only through our active engagement with the environment that we evolved into the species that we are and it is only through active engagement with the environment that each of us maintains his or her personal existence. We are what we are because of the environment that we evolved to function in and, most importantly, we function *in* our environment rather than mechanically interact with it as a wholly independent agent. Humans and their environment, as are other species and their environments (the planet forming numerous environments that are species specific, i.e., ecological niches), are in unity. We may conceptualize them, in thought, as distinct, e.g., person and environment, subject and object; but these are abstractions, concepts. In the concrete, i.e., the actual conditions of existence, people are intimately and essentially connected with the environment, there is a mutualism, an embeddedness, within the environment.

Gibson's Ecological Theory

In his ecological theory, Gibson (1966, 1979/1986) emphasizes the inseparable relation between perceptual systems and the physical world in which they evolved. The words animal and environment, from this perspective, imply each other; they cannot be disconnected. Reciprocity exists between animal and environment and, while they are distinguishable, they are mutually supportive (Lombardo, 1987).

> The ecological approach takes as its unit of study the animal in its environment, considered as an interactive system. The relations within this system are reciprocal, with the reciprocity including a species evolving in an environment to which it becomes adapted, and an individual acting in its own niche, developing and learning. (Gibson and Pick, 2000, p. 14)

In this reciprocal interaction the environment makes available resources, opportunities and information for action. Actions themselves result in feedback (more information) that can lead to alterations in action. When chasing down prey, for instance, if it begins to pull away from one, speed can either be increased to compensate and overtake, or the chase broken off if that is not possible. In progressing toward some end, whatever that may be, one can continuously monitor one's progress and make adjustments as required.

Perception can be conceived of as an evolved adaptation to lawful relations between the environment and the energy arrays, e.g., optic, acoustic, chemical, that surround individuals and act upon their sensory receptors. It is through the ecological reciprocity that Gibson transcends the barrier of the senses and discovers the basis for direct realism. This was not a position, however, that Gibson arrived at easily or without a great deal of thought and experimentation. In order to get to that point Gibson, who had originally been aligned with the *constructionists*, had to realize that problems existed for that perspective.

Gibson (1966, 1979/1986) came to reject the constructionist position of Helmholtz and his followers. Their emphasis upon sensory receptors for stimulation and the need to guess about what might be acting upon receptors rendered perception nothing short of a miracle.

> the brain is faced with the tremendous task of constructing a phenomenal environment out of spots differing in brightness and color. If these are what is seen directly, what is given for perception, if these are the data of sense, then the fact of perception is almost miraculous. (Gibson, 1979/1986, p. 61)

Surely there was something wrong with this. It was this that Gibson would set to addressing.

Gibson's discontent was not simply with the stimulus materials and experimental methods of the constructionists. With Helmholtz the place of commencement for the study of vision was at the retina, with sense impressions and receptor reactions. Up to 1950 this had been Gibson's focus, i.e., the retinal image as the stimulus for the eye (Gibson, 1966). With a change in perspective, he proposed that Newton had misled us when he suggested that light rays painted a picture of the visible object on the back of the eye. The retinal image, contrary to this, is not a picture. That is misleading since it suggests something looked at. The retinal image is a scintillation—a flash or a trace—because the retina jerks about (saccadic movement) and it has a gap called the blind spot where the optic nerve leaves the eye. It was a further misconception, argued Gibson, to think that a retinal sensory pattern can be impressed on the brain neural tissue since the neural pattern never existed in the retinal mosaic. A further reason for discounting the retina as the basis for visual perception was what was found through cross-species comparisons. The visual organs of octopi, rabbits, bees, spiders, flies, and humans differ widely but all suggest visual perception of those conditions in the environment that are essential to surviving.

Having rejected the retinal image, Gibson turned to the ambient (surrounding) optic array (arrangements of light available to the eye). Light surrounding the individual conveys information about objects. Whereas Helmholtz looked at sense impressions made upon the eye, Gibson turned to information that entered through the eye. Gibson differed as well in his treatment of how stimulation occurred. Gibson rejected a favorite apparatus in visual research—the immovable headrest. He would emphasize ambient vision (looking around) and ambulatory vision (sampling light by moving about). Static displays would be replaced by visual events and active searches for information. Gone was the passive recipient of stimulation.

Organisms, as Gibson emphasized, are seldom passive. Stimulation is often acquired through personal action, obtained rather than imposed. Due to such active engagement with the world, stimulus input can be modified through both motor movement and movement of the sensory organs. The nose, mouth, ears, skin, and eyes are mobile, and due to that can explore and orient to the conditions of existence. Animals and humans select stimuli and enhance it by orientation and adjustment of the sense organs (e.g., turning toward the source of a sound).

Gibson (1966) distinguishes between receptors, organs, and systems. The receptor is the immobile aspect of the system of input; a passive system that initiates nerve impulses when activated by stimulus energy. The organ, on the other hand, refers to the mobile parts that are involved in exploratory movements and adjustments. At the lowest level of the receptor is the single cell that responds to incoming energy. Such receptors likely form receptor units. Such groups connect with a single nerve fiber. Such units may then be grouped into more complex structures having overlapping receptive fields. All in all, it seems clear that the classical assumption of the receptor unit as being composed of a transducer cell mosaic, each of which has its own nerve fiber connecting to its own distinct cell in the brain is wrong. The units of sensation are not anatomical but functional in their organization. Such units have their input modified as a function of sequential order (the changes taking place in energy patterns over time) and adjacently (in terms of a relation of energy, simultaneously over receptors). Sensation, the response of the receptor cells, does not equate with perception.

To make his point, Gibson offered the following thought experiment. Imagine holding a pair of scissors in your hand. The pressure of the scissors on the skin can be felt. Is it, however, the sensations of pressure that one is aware of or does one perceive the scissors? Imagine, further, that you are cutting paper with the scissors. Is it the sensations of the touch of the

scissors that you feel or the cutting of the paper? Imagine now that you are blind and use a cane. Is it the vibrations in the cane that you respond to or the object that the cane comes in contact with? The perception is of the cutting and of the object not of the separate sensations that must be combined to form a percept.

One further example from Gibson captures the phenomena that he wants us to understand. When one touches an object like a ball in one's hand, through holding it, there are five distinct sensation groups of touch coming from each of the fingers, and also from the palm, but one's perception is of a singular object—the ball. Under such circumstances one's perception is of whole objects rather than singular sensations. Sensations, thus, as Gibson suggested, need not be specified in consciousness.

Rather than perception being based upon receptors, the true organs of sensitivity have to be considered parts in an overall system (Gibson, 1966). Gibson made mention of seven perceptual systems. These were the basic orienting system, the auditory system, the haptic system, the tasting system, the smelling system, the somatic system, and the visual system. As an example of Gibson's point, the visual system, as he has conceived of it, involves more than the eye. A single eye is a lower order system but it does possess an adjustable lens and pupil as parts. When the muscles that attach to the eye are added one has a higher order system that is now capable of scanning the environment. At an even higher level of systemic organization are the two eyes operating in conjunction; a dual system that can act upon distant objects with processes of convergence and divergence. Even more complex, is the two-eyes-with-head-and-body-system whose components cooperate in maintaining posture, locomotion, inspecting objects, tracking, chasing, and so on, all of which, of course, are transcending the passive receptor. While the brain has not yet been mentioned that should not be taken as a suggestion that it is not involved; it is, but not in the ways that the classical theory had hypothesized.

> Instead of supposing that the brain constructs or computes the objective information from a kaleidoscopic inflow of sensations, we may suppose that the orienting of the organs of perception is governed by the brain so that the whole system of input and output resonates to the external information. (Gibson, 1966, p. 5)

What we have is an integrated "eye-head-brain-body-system" and, being a system, all parts affect each other. Not only is the visual system composed of subcomponents, it overlaps with

the other perceptual systems rather than being an isolated function. A combination of systems can, as we saw with the mention of system redundancy, pick up the same information.

Having evolved for information pickup from the environment, the perceptual systems are directed outward; they obtain information, employ it, and enhance it (Lombardo, 1987). It is in the objective world that the basis of perception is to be found, not in the supposed constructions of the brain.

> the brain cannot generate a perception. The brain may produce sensations, hallucinations, dreams, illusions, and after-images, but not perceptions. The brain, as part of the integrated animal system, "perceives" the environment, but the objectivity and veridicality of perception is due to information. (Lombardo, 1987, p. 305)

In Gibson's theory, information plays the central role.

The natural stimulus for perception has certain characteristics (Gibson, 1966). First, it always has adjacent order in that it has a pattern in space—a structure, e.g., different patterns of reflectance from various shapes of objects. Second, there is a structure in time, e.g., a musical melody. In such phenomena there are transitions that occur in the stimulus over time so, given that, the stimulus cannot be a single instance. Lastly, there are elements of change and of non-change and these instances of change and non-change are themselves stimuli. Transformations in patterns are equally as stimulating as stable patterns. Change over time was something that Gibson chose to focus on and he found, as a result, that critical perceptual information appears in the form of temporal patterns and structures that do not exist at a single instance, e.g., object movement (Neisser, 1985). *Events* would be important to understanding perception. Events are aspects of reality that undergo change over time and in space. An obvious example is that of speech perception since a sequence of sound utterances are involved. Touch may also serve as an example if one considers the exploration of an object with the hands, e.g., the feel of a sculpture.

In his work with World War Two pilots Gibson discovered that *optic flow patterns* were being experienced by pilots and that these were crucial to successful landing (Eysenck, 1993). Imagine, for instance, walking down a hall towards a door at the end. As one fixes one's eyes on the target door, the surrounding walls sweep across the visual field expanding outwards from a center that is fixed by the point of focus for the eyes. The center of expansion specifies both direction and speed of movement, and proximity of approach. Far

things are in the foveal region and near things are passing through the periphery. Such fields of *optic flow* present information that is important to both vision and movement.

Movement away from a center (centrifugal) and movement toward a center (centripetal) inform of one's movement in the world with respect to objects. Changes in optical structure have a double reference. They inform about the environment and they inform about the perceiver relative to the environment. A moving observer produces smoothly organized changes in the entire array. Of course changes also take place in the optic array due to the movement of objects in the world. Changes in the structure of the optical array involve both change and stability. While living beings move about, objects like buildings and monuments remain relatively stable and stationary.

Such flow patterns call into question the notion of the retinal image as a still picture or series of such pictures. We are confronted with a continuous presentation and must abandon the notion of stimulation as composed of discrete stimuli.

> The act of picking up information, moreover, is a continuous act, an activity that is ceaseless and unbroken. The sea of energy in which we live flows and changes without sharp breaks. Even the tiny fraction of this energy that affects the receptors in the eyes, ears, nose, mouth, and skin is a flux, not a sequence. (Gibson, 1979/1986, p. 240).

Perceiving to Gibson should be seen as a stream rather than as discrete events; this is akin to James' (1890/1950) stream of consciousness. Stimulation and perception are continuous events.

The key to vision of course is light. Light illuminates surfaces of objects, some more, some less, depending on how they are in relation to the source of illumination. Objects nearby are greatly illuminated and those more further removed are illuminated more dimly, and, if there are interceding objects even less so. Objects absorb light and reflect it. There are differing degrees of illumination and shade. Depending on their surfaces, objects may be smooth or irregular and, due to differences in their surfaces, will reflect light differently. As a result of being reflected off of objects light is structured and this structure provides information about the objects that the light is a reflection from.

> The leaves of a tree face in all directions so as to pick up the *energy* in ambient light and use it for photosynthesis. But the tree cannot pick up the *information* in ambient

> light and use it for behavior. The animal can. His receptors use energy, of course, for photochemical reactions and nervous excitation, but his eyes use differences of energy in different directions. The information lies in the *structure* of ambient light, that is, in its having an *arrangement* or being an *array*. (Gibson, 1966, p. 208)

Single lines, as conveyed by structured light, are a basis for considerable information. Lines inform of edges, corners, horizons, outlines, borders, and other phenomena (J. Gibson, 1979/1986). Lines do not inform of texture, shade, or reflectance but that information is also available in structured light. Others of the so-called clues to perception, rather than being deductions of the brain, are also available in structured light, e.g., *occlusion*, *linear perspective*, *distance from the horizon*, *haze*, *texture*, and *vanishing points*. Information about object distance is thus provided by light and does not require unconscious inferences. Moreover, movement provides further information. Objects appear and disappear as one moves about. *Looming* tells of an object's approach. *Motion gradients* relate objects in the visual field with each other with respect to a point of fixation. Light provides us with what Gibson has referred to as higher-order variables, i.e., patterns of simultaneous and successive order.

We must remember that Gibson bases his theory of information pickup upon the theory of evolution. In the struggle to survive and meet environmental demands, organisms have developed perceptive capacities that have proved useful in continuing existence and reproduction. Species that inhabit different ecological niches develop perceptual systems that facilitate effective functioning in that niche. So too do human perceptual systems function in ways that adapt us to, or coordinate us with, the conditions of our existence and, thereby, promote survival. Through the course of evolution humans have established perceptual systems rather than senses that involve activities rather than passive receipt of stimulation, e.g., sniffing, looking, tasting. Such systems are generally subordinate to an orienting aspect: "a system can orient, explore, investigate, adjust, optimize, resonate, extract, and come to an equilibrium, whereas a sense cannot" (Gibson, 1979/1986, p. 245). A perceptual system has a greater capacity for extracting information than a sense.

There are five differences between perceptual systems and senses (Gibson, 1979/1986). (1) Special senses have receptive units in banks of receptors that are connected to projection areas in the brain. There is no discussion, when considering the senses, of adjustments that occur in the organ containing the receptors, e.g., *accommodation*, *fixation*, or *scanning*. All

such movements, within perceptual systems, support information pickup and are essential to an adequate theory of perception. (2) Receptors receive stimuli passively but with systems there is an active input–output loop for extraction of information. (3) Sense input is based upon innate sensations but perceptual systems are subject to learning and maturation. (4) Inputs to senses have the qualities of the stimulated receptors (Müller's specific nerve energies) but perceptual systems are specific to qualities in the world, particularly what they support the organism in doing in the world. (5) When dealing with sense, attention takes place within the nervous system but in perceptual systems attention pervades the whole system of input and output, attention is directed toward the external environment or within. The process of attention in the nervous system is an instance of consciousness that can be focused but in the case of attention in the perceptual system attention is capable of being educated. Children, for example, become more adept at what to attend to in the environment and demonstrate preferential looking (Gibson and Pick, 2000).

Going beyond the stimuli that are provided by the natural world, humans respond to stimuli that have been generated by humans, i.e., symbolic forms like language. In speech, writing, painting, music, etc., humans developed a capacity to stimulate others as well as themselves. These sources of stimulation are artificial and generate a new kind of perception called knowledge, a *perception at second hand* that is based upon an acquaintance with the world and that can act upon direct perception by affecting thinking. Vocal speech, for instance, contains symbols that convey meaning about things in the environment that are common to most, if not all, humans—the term "water" for example. Such symbols enable people to think of the same things and to have common concepts. While these are abstract stimuli, that does not mean that they are not grounded in material reality. There are no symbols that do not have their basis in material processes. Verbal symbols are conveyed through sound, written and painted symbols through light, or Braille through mechanical-tactile contact. All knowledge forms involve sensitivity.

The relation of a perceptual stimulus to its environmental cause is of a different nature than a symbol and what it refers to (Gibson, 1966). *Perceptual meaning* is of a different order than *symbolic meaning*. The perceptual stimulus depends upon laws of physics and biology but the symbol is dependent upon a linguistic community and is a human invention. Conventions of symbolic speech have to be learned since language codes are cultural products. *Perceptual cognition* or knowledge *of* the environment has to be distinguished from *symbolic cognition*

or knowledge *about* the environment. Unlike the direct response to things of *perceptual cognition*, as it is based upon stimulus information, *symbolic cognition* is in indirect response to things as based upon coded information provided by other people. (The coded information is responded to directly; it is what it refers to that is responded to indirectly.) Speech is a vehicle for an indirect apprehension of understanding. I for instance, have never seen the Hubble space telescope but I can relate to it indirectly by seeing pictures of it or being told about it.

> The process by which an individual becomes aware of what exists and what goes on around him is perception. The process by which a human individual is *made* aware of things outside his immediate environment is one stage higher. It is mediated perception. It involves the action of another person besides the perceiver. A man or a child can, as we say, *be told* about things, or *be taught*, or *be given to understand*, or *be informed*, or *be shown*. Speech, that triumph of the human species, is the earliest and perhaps the principal vehicle for this indirect apprehension. (Gibson, 1966, p. 234)

Gibson (1966) made a case in favor of direct realism in perception theory and epistemology. He pointed out that perception theories that assume that perception is due to sensations (sense data or impressions) end up having to postulate operations by which such sensations are converted into perceptions. The senses themselves can only support an awareness of the receptors that have been stimulated by small quantities of energy. From this perspective, all that we know directly is shifting sense data so perception of objects is mediated by sensation; perception of objects is, by nature of the processes involved, indirect. To Gibson, the notion that all that can ever be experienced directly are the immediate sense data is quite simply false.

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