PSYCHOLOGIA

An International Journal of Psychology in the Orient

In 1957 Dr. Koji Sato, the first Editor of this Journal, founded Psychologia Society and published the first issue.

Purpose: As a channel of communication and feedback from the East to the West and as a forum for international discussions, Psychologia publishes symposia, general surveys, reviews, brief reports, notes and discussions, as well as representative original works in very broad fields of psychology.

Publication: Quarterly (March, June, September and December).

Contribution: The manuscripts should be sent to the Editor at the address given below. Instructions for the preparation of manuscripts are given on the inside back cover.

Annual Subscription: Volume 39, 1996 (4 issues)

Japan	¥10,000 (Institute & Library)
	¥ 7,000 (Individual)
Foreign	¥ 8,000 (Institute & Library)
	(¥14,500: two-year rate)
	¥ 5,000 (Individual)
	(¥ 9,000: two-year rate)

All back issues to date are also available.

Purchase orders, advertisements and all business correspondences should be sent to:

President, Takao Umemoto
Psychologia Society
Department of Educational Psychology,
Faculty of Education,
Kyoto University, Kyoto 606-01, Japan.
TEL: 075-753-3051
FAX: 075-753-3049

This Journal is supported by the Grant-in-Aid for Publication of Scientific Research Result from the Ministry of Education, Science and Culture of Japan.

Psychologia, 1996, **39**, 1–16

WHAT IS ECOLOGICAL PSYCHOLOGY?*

Tin-Cheung CHAN and Robert E. SHAW

The Chinese University of Hong Kong, Hong Kong and The University of Connecticut, U.S.A.

Ecological psychology comprises two fundamental complementary areas of study: perception and action, as introduced by the American psychologist, J. J. Gibson and the Russian physiologist, Nikolai A. Bernstein, respectively. For Gibson perception is the direct pick-up of invariant information by which animals control their actions to reach environmental goals, not the passive registration of elementary sensations from which experiences are (unconsciously) inferred or computed. Where Gibson rejects the computer metaphor in the study of perception, Bernstein rejects the executive metaphor in the study of action. Both views challenge psychology to develop a functionally integrated organism-environment system, governed by laws, in the place of a psychology of internal states or isolatable faculties, governed by rules. Here the smallest unit of analysis is taken to be the perceiving-acting cycle situated in intentional contexts. The historical motivation of ecological psychology is reviewed and critically discussed.

Two Contemporary Psychologies: Contrasting Approaches

Over the past quarter century two new approaches to psychology have emerged to supplant faculty psychology and behaviorism: the immensely popular and influential cognitive science approach (Posner, 1989), and the less well-known but complementary ecological science approach (Gibson, 1966, 1979; Michaels & Carello, 1981; Bruce & Green, 1990; Lombardo, 1987). These two views have contrasting historical and philosophical roots. Put briefly: Where cognitive psychology, being an end-product of rationalism, phenomenalism, and structuralism, is based on mental processes, and entails *mind-body dualism*, so ecological psychology, having derived from empiricism, realism, and functionalism, is based on the functional fit of organisms to their environments and entails *organism-environment duality*. Dualism implies an incommensurability between two distinct natural kinds—the knower and the known—and relies on reason to overcome the difference so that the known world is made more hospitable to the knower. Duality, by contrast, implies a commensurability between the knower and the known, and relies on perception to maintain or improve the knower's adaptability to the world. Where cognitive science tends to focus on human intelligence and language processing as underlying perceiving and acting, ecological psychology intends theories that address all species—regardless of their level of intelligence (e.g., insects); consequently, it assumes perceiving and acting are primitive processes—with language and cognition being derivative. Hence their treatment of cognition is crucial in comparing these two

* All correspondence should be addressed to Tin-Cheung Chan, Department of Psychology, The Chinese University of Hong Kong, Shatin, N. T., Hong Kong.

approaches.

Cognition might be defined neutrally, favoring neither cognitive science nor ecological psychology, as those processes by which knowers come to know their worlds—any such processes as perceiving, acting, inferring, remembering, or imagining—so long as they are tolerably accurate. Which of the cognitive processes are taken to be primary, and depended upon by the others, determines one's philosophical position. On the one hand, if one believes in the primacy of cognition over perception, then one tends toward rationalism and cognitive science. On the other hand, if one believes in the primacy of perception over cognition, then one tends toward empiricism and ecological psychology. This is, of course, a gross oversimplification since neither of these approaches can be easily identified with classical rationalism nor classical empiricism but the flavor of the contrast seems accurate.

The contrast between cognitive science and ecological psychology is greatest when the former elects to model psychological processes by rules that ignore natural constraints from the environment in which agents must perceive in order to act and act in order to perceive. Here ecological psychology can not compromise; its pragmatic and functional roots must take precedence over its empiricistic leanings, and it must challenge cognitive science, likewise, to overcome its rationalistic leanings. However these contrasts may already be waning, for these approaches are driven to become more alike as they are forced to deal with the dynamic interaction of actors with their environments. To do so, both approaches come to need the same tools of physics and mathematics. They each must describe how actors, whether natural or artificial, can obtain information specific to the forces that they must apply to pursue goals within their environments. Hence although their differences are philosophically profound, the need for practical solutions may eventually force a convergence and cooperation. A case can be made that the field of robotics has already begun such convergence with ecological psychology onto common objectives (Effken & Shaw, 1992).

In this paper we shall attempt to spell out the major tenets of ecological psychology for the purposes outlined above. We begin by giving a brief history of ecological psychology as an area of study.

Ecological Psychology: Its Origins and Aspirations

Ecological psychology is a developing branch of ecological science intending, in the broadest sense, to be a multidisciplinary approach to the study of living systems, their environments, and the mutual and reciprocal relationships (the duality) by which they are coupled to form a functional unit called *an ecosystem*. Traditionally, ecological science has emphasized the study of the biological bases of energy interactions between animals and their physical environments across molecular, cellular, organismic, and population scales. The field is now extended by ecological psychology to include the study of information transactions between living systems

and their environments that bear on the planning, execution, and control of intentional behaviors.

The late James J. Gibson used the term *ecological psychology* for the study of problems of perception and their relationship to the control of actions. He believed that analyzing the environment that is perceived and acted upon was as much the duty of psychologists as analyzing the agents themselves. This analysis of the environment as the source of information and constraints on actions he called *ecological physics* (ecological optics, ecological acoustics, etc. when specific energy spectra were singled out for study). Of crucial importance to ecological psychology, also, are the social aspects of the environment, that is, the way agents or their products mutually constrain each other's perceptions and actions in either cooperative or competitive ways.

Another historical strain associated with ecological psychology originates from the seminal work of the Russian physiologist, Nicolai Bernstein, on biomechanics. By suggesting that action, like perception, cannot be studied without reference to the environment (just as the environment as a source of perceptual information cannot be studied without reference to the organism), Bernstein's focus on action, therefore, complements Gibson's focus on perception. Together their views have motivated a reformulation of the traditional questions about the nature of perceiving and acting, namely, that one depends on the other.

More recently, the role of cognition—memories, intentions, inferences, language—has been emphasized by ecological psychologists as furnishing a source of constraint on the perceptual control of actions. Moreover, the field seems to be converging on the view that the smallest unit of analysis is not the perceiving-acting cycle alone but the perceiving-acting cycle functioning in an intentional context, the study of which might appropriately be called *the intentional dynamics* of ecosystems (Shaw & Kinsella-Shaw, 1988; Shaw, Kugler, & Kinsella-Shaw, 1990). More will be said about this later.

Landmarks in the Development Ecological Psychology

The first conference on ecological psychology was held at Cornell University in the summer of 1970. The topic was the new field of *ecological optics*. Eleanor J. Gibson, the eminent developmental psychologist and Gibson's wife, remembers this conference as an important beginning: "As I look at the many photographs taken during this week-long meeting, it seems to me that it was an historic occasion, giving birth to a new theory of perception. Most of the old students came, and friends from other universities—David Lee from Edinburgh, Bob Shaw from Minnesota, Gunnar Johansson and Sverker Runeson from Uppsala. Concepts like the 'ambient optic array' (the basis of the new optics) and disturbances of structure in the array that specify events were heatedly discussed and argued over" (Foreword to MacLeod & Pick, 1974).

At the next conference, held by Shaw and John Bransford at Minnesota in the

summer of 1973, a wide range of topics were discussed under the tacitly agreed upon commitment that "a full appreciation of what the animal's or human's world is like provided an indispensable context of constraint for understanding how information about such a world may be processed" (Foreword to Shaw & Bransford, 1977). The ecological movement was given a significant impetus by the First International Conference on Event Perception held at the University of Connecticut in June 1981 (Warren & Shaw, 1985), which spawned more than a decade of such conferences that are still held bi-annually in different parts of the world.

Shortly after the Connecticut conference, the International Society of Ecological Psychology (ISEP) was established. Begining with *Reasons for Realism: Selected Essays of James J. Gibson* (Reed & Jones, 1982), a series of volumes edited by Shaw, Turvey, and Mace, entitled Resources for Ecological Psychology was established and continues today. In 1988 the Center for the Ecological Study of perception and Action (CESPA) was established at the University of Connecticut, with the journal of *Ecological Psychology* beginning publication in 1989. Even a cursory search of major journals (e.g., *Journal of Experimental Psychology: Human Perception and Performance* and *Perception and Psychophysics*) reveals that an increasing number of papers from the ecological perspective are making their appearance. Similarly, it is becoming commonplace for textbooks to include discussions of ecological psychology as one of the current viable movements in the field (e.g., Bruce & Green, 1990; Gleitman, 1990).

Criticisms and Misunderstandings

In spite of the increased interest in this new field there still seems to be a serious lack of understanding regarding what ecological psychology is about. Gleitman (1990), for example, in his otherwise exemplary introductory textbook, wrongly regards the ecological approach as essentially nativistic. On the contrary, like the earlier Gestalt approach, ecological psychology is intended to be a law-based account (Turvey, Shaw, Reed & Mace, 1981); it assumes that psychological systems have evolved, developed, or learned how to adapt to their environmental situations (which may be either physically or socially defined). Thus although genetic pre-attunement of organisms is a recognized aspect of the approach, it is not the central aspect nor is there, in the philosophical sense, any reliance on innate ideas.

Others have criticized the ecological approach of failing to offer detailed models of perceptual or action mechanisms in the manner that cognitive psychologists often try to do (Fodor & Pylyshyn, 1981; Kubovy & Pomerantz, 1981). Such criticisms belie a complete misunderstanding of what ecological psychology is all about. There have been many attempts to develop information processing models for perception. Such approaches assume that the states and stages of such processing reside 'in the head'; likewise, that action is to be explained by plans and motor programs 'in the head'. The ecological approach takes exception to the view that one should try to model those neural processes residing in the head before one has modelled the context in which the

head resides; namely, in an active organism in an environment. So-called 'in the head' processes, or neurodynamics, surely exist and play an indispensable role, but they are at best incomplete, local descriptions of a more global, coherent process which these approaches leave unaddressed. The organism, as a perceiving agent, together with it environmental stituation, form a system that has functional integrity—an *ecosystem*, whose behavior is the *perceiving-acting cycle* of an organism over space-time.

The perceiving-acting cycle consists of the detection of goal-specific information and the control of goal-relevant behaviors, each constantly feeding off the other. Actions are directed by the information detected, and the availability of information to be detected is affected by the actions performed. Any modelling should begin with the perceiving-acting cycle as situated in an intentional context (e.g., organisms seeking food, to escape danger, trying to catch a ball, land an airplane, paint a picture, or treat a disease). The information flow of interest to traditional cognitive models flows through the head; the information flow of interest to ecological psychology flows in a continuous loop between the actor and the perceived environment.

This complaint that ecological psychologists will have no real scientific credibility until they join the modelling game is thus mistaken in two ways: First, it assumes that such models are the sole goal of theoretical psychology; and, secondly, that such models deserve credibility before a fuller understanding of the role of environmental constraints on such processes is achieved. But a logically prior scientific goal is addressed by ecological psychology: What is the job description that any such models would have to satisfy? For how can one model a process *before* their lawful functionality is understood? Thus ecological psychologists recognize the need for such local ('in the head') models but only after certain logically prior questions about global processes (between organism and environment) have been addressed, such as: What are the sources of invariant information in the environment, and how does such information constrain actions (Gibson's question)? Dually, given the seemingly intractable number of degrees of freedom for combining motor units (neurons, muscles and limbs), how can an intentional act unfold so efficiently and decisively (Bernstein's question)?

A final point of criticism sometimes raised is that stimulation cannot in itself be meaningful because it is merely physical; any meaning that it might have for an agent can only have been added by the agent. This view that an agent creates its own meanings is called *phenomenalism*. Phenomenalism is the view that the external world is subjectively constructed from sense data, that it consists of one's own percepts. This contradicts the realist's view of the role of the environment. By contrast, in ecological psychology the environment is functionally defined in terms of the fit of an organism's actions to the informational structure of the environment: we see what we can do; we select what to do; do it, then we see if we have done it as intended. Although we cannot be sure what the world *really is*, we must assume it allows us to perceive the consequences of our acts—otherwise, psychology would be a futile enterprise. And although the physical world may not be perfectly revealed in our

perceptions, our forceful interactions, as constrained by our information transactions, must be revealed with sufficient fidelity to explain their consequences—the moving of our body-masses about in the environment.

Phenomenology can be viewed as analysis in which the meaning of the world is revealed before any reflection. Such experience is awareness of transcendent facts (invariant information) that allows a direct and natural (primitive) contact with the world that any creature, great or small, can enjoy equally well. As one of Gibson's favorite philosophers, the French phenomenologist, Merleau-Ponty, put it: Phenomenological analysis "is endowing that contact [with the meanings of the world] with philosophical status... It tries to give a direct description of our experience as it is" (Merleau-Ponty, 1963, 1969, p. 27). The phenomenological psychologist, Robert MacLeod, one of Gibson's dearest and oldest friends and colleague at Cornell, once suggested that Gibson was such a good experimentalist because he was such an excellent phenomenologist (MacLeod & Pick, 1974). Gibson, in his modesty or contrariness, apparently, was uncomfortable with this appraisal, as MacLeod reports. If so, then it is ironic, for he made this ability to be a phenomenologist an ordinary trait of all organisms; through their abilities to perceive, they each attain direct awareness of the meanings (affordance) of the world for them as actors—as opportunities for action and the means for controlling them (Gibson, 1979). The mistake of phenomenalists in their criticism of ecological realism is not realizing that the object of perception is not *the* world-as-such (i.e., as studied by the physicist), but that scale of energy distributions making up the environment within which goals-perceived and goals-acted toward are the same. It is the environment where, as the Finnish philosopher, Jaako Hintikka (Shaw & Turvey, 1981) observed, the object of intention and the object of reference are one and the same.

Most criticism of ecological psychology is made in ignorance of its program and working assumptions. Consequently, it would be useful to have these clarified. As already alluded to, there are two broad areas of study addressed by this approach: perception and action. Ideally, these are addressed together in the same experimental design. How this should be done is a topic of serious and continual discussion among ecological psychologists. This strategy of wedding the study of perception to the study of action argues that they cannot be investigated successfully if left unrelated in either theory and experimental design. This belief led Gibson's followers to band together with action theorists of the same ilk. The basis for such a cooperative enterprise was latent in the work of both Gibson and Bernstein. Both Gibson and Bernstein sought to find descriptions of perception and action, respectively, which lowered the dimensionality of the process so as to minimize the need for executive mediators.

The New Realists' Program as Forerunner to Ecological Psychology

A group of functionalists at the beginning of the century, who were followers of William James, called the New Realists, favored a theory that came to be called *direct*

perception (Michaels & Carello, 1981). Direct perception is the keystone of ecological psychology—a functionalist view that fits neither classical rationalism nor classical empiricism. William James (1890), the father of both American psychology and pragmatic philosophy, disagreed sharply with Bishop Berkeley's (1954, 1709) belief that perception is based on elementary sensations, and that such sensations are not changed by learning but become enriched through association with other elementary sensations. For James, perceiving contributes information to the 'stream of consciousness' that is sufficiently rich to specify the functional relationship of the individual to his world.

The individual differentiates this information into the objects of perception. Helmholtz (1962) and other phenomenalists, however, argued that the stimulation received was too impoverished to be the basis of such knowledge, and so had to be enriched by cognitive or memorial processes before the objects of perception came to be. Where the content of such constructions originated (if not from perceiving the world) and how this content acquired the appropriate intentionality, that is, became directed to 'mean' the properties of the world (if not by reference to the world), is left an impenetrable mystery. This paradox of assuming innate knowledge in order to explain the acquisition of knowledge is sometimes referred to as the *cognitive paradox*. The avoidance of this paradox was the chief reason that Gibson adopted, in modified form, the New Realists' thesis of *direct perception*. What this thesis was, and how and why Gibson modified it, is central to understanding the motivation for founding a psychology at the ecological scale to compete with behaviorism, Gestalt psychology, and dualistic cognitive psychologies.

The New Realists were a group of six philosophers and psychologists who, early this century, met over a period of a few years (1910–1912) to crystallize the realist theme that ran through James' philosophy (Harlow, 1931), and to consolidate the views that ran through their own writings (e.g., Holt et. al., 1992). Their main objective was to avoid dualisms (mind-body; subject-object) and to promote a view that *experiences of objects perceived* and the *objects perceived* had the same ontological status. Within this group was E. B. Holt who had studied with James at Harvard, and who Gibson, as a graduate student at Princeton, studied with more than a decade later. Holt, and the other New Realists, worked out a 'direct' form of realism designed to avoid the dualism of the more typical 'indirect' formulations. The essential points of the New Realist's thesis were, first, that all the appearances of an object are its intrinsic properties and are directly and publicly perceivable; and, second, that each perceiver can differentiate a subset of properties that differs perspectivally from other subsets in some lawful manner. This thesis was designed to counteract certain idealist philosophers in vogue at the turn of the century (e.g., Hegel, Bradley & Bergson)

In the seventeenth century John Locke developed the philosophical basis for indirect realism with the following eloquent argument: Since the mind, in all its thoughts and reasonings, has no other immediate object but its own ideas, which it alone does or can contemplate, it is evident that our knowledge is only conversant

about them. Knowledge, then, seems to be nothing but the direct perception of the contents of our own ideas, single or connected. Hence our knowledge of the world must be indirect since it is mediated by these ideas, which we know as directly as we do pains (Pratt, 1937). But if Locke's statement is taken literally, as it was by those idealists opposed to realism, then it implies the impossibility of knowing anything outside of one's own mind. There is no intentionality, for our thoughts cannot be about the world but only about themselves. Perceiving and imagining are completely indistinguishable.

Such involuted reasoning leads inexorably into agnosticism regarding the existence of an external reality, ending inevitably in the *cul de sac* of solipsism (Fodor, 1982). A more temperate interpretation of Locke's argument, where one believes that some ideas somehow acquire intentionality, allows for realism but an indirect one only—with dualism being an unavoidable consequent. How such ideas acquire intentionality so that they point beyond themselves to objects and events in the external world is left unexplained. The New Realists thought there was a way to explain the origins of intentionality, avoid Locke's cognitive paradox, and nullify dualism. They thought there was a fallacy at the heart of indirect realism; its acceptance of the Doctrine of Internal Relations. The antidote to this doctrine, they believed, was the Doctrine of External Relations which provides logical support for their claim that perception is direct and public.

The Doctrines of Internal and External Relations

The Doctrine of Internal Relations asserts that each entity acquires its identity from the role it plays in the whole to which it belongs. Identity is determined by how the entity fits and functions as a member of the collective. Here there are no true objects, only subjects. Monism is presumed because all things are related, and therefore must be essentially similar to be so related. Locke's dictum that we can know only our own thoughts leads to a mentalistic monism because the external materialism cannot be accessed, much less understood by its opposite kind. Attempts to build causal chains between incommensurate kinds (e.g., mind-to-matter or matter-to-mind connections) fail because of the lack of continuity over their connections; indeed, such connection is undefinable. However well-defined, continuous connections can underwrite causality between things of like kind, whether they be material bodies or mental processes. It is the internal consistency of such relations that makes causality possible. If this reasoning is correct, then the only way dualism survives under this doctrine is parallelism, with mind and body being separate and noninteracting. If then we live materially in a world governed by causal conditions, we could not know this world but only imagine its nature. The knower and the known retain their distinction but at the price of total independence. For the New Realists this price was too high to pay.

The Doctrine of External Relations asserts that no object is essentially changed by its participation in the whole, save with respect to the functions it assumes by the

place it occupies in the collective. But here individual identity is deemed an objective rather than a subjective property. Pluralism is presumed because no object loses its identity and therefore remains distinct regardless of its interrelationships to other objects. Objects differ but may be causally related without losing their individual identity. Thus a real object could be caused to appear in consciousness and still be independent of that relation and the mind that knows it.

A criticism of this view is that each appearance of an object creates a new object equally as real as the first thereby violating parsimony. For some, this has provided a *reductio ad absrudum* argument that fatally infirms the doctrine, just as the problem of how intentionality originates and the cognitive paradox fatally infirms the competing doctrine of internal relations (Pratt, 1937). This criticism is voided if, as Whitehead (1929) recognized, objects are not circumscribed to a simple location but have existence everywhere they may be perceptually sampled—with a more dense character where we locate them proximally through touch, and a less dense character where we locate them distally through sight. The appearance of the object in different perceptions by different people or in different perspectives to the same person or through distinct sense modalities is replaced by its omnipresent character extension. Perceiving is not action-at-a-distance; it is a process of resonating to the character of the object that is present where the sensing takes place—a *field* notion. The brain and sensory systems modulate characters of the character-complex (i.e., the object of perception). Hence all perceiving is by contact regardless of the sense. There is no need for the traditional proximal-distal distinction since the proximal is but an extended character of the distal. As Gibson was to conclude, this aspect of the external relations doctrine explained the invariance of social perception: We all share the same environment and participate in its character-complex. He clarified how this social sharing could take place by introducing the notion of invariant perceptual information. We will return to this concept later.

In summary: Perception brings the object perceived into a new relation, that of being an object of awareness, and creates a new character of the object: its meaning for the perceiver. What then is known when we perceive if not the object of perception? What is real is the object's character complex (or field) in which we as perceivers and actors participate. This meaning derives from how we participate. We perceive by differentiating a local region of this character complex (a perspective), and we act by integrating one perspective with another over space-time. This doctrine requires that we give up the view that objects have simple location in favor of them having distributed presence. But rather than objects as simple entities, we have object-complexes; these comprise characters that are lawfully distributed by perspective transformations over all space-time locations (just as radio or television signals may be 'broadcast' over the electromagnetic field). The object's local character is altered by the field law, falling off with distance. Although the object's identity is invariant over the distributed characters, the densest local character (the one we can touch) is what we prefer to call *the* object. Under this view the *true* object is simply its information field, so there can be no distinction made between the object,

the object-information, and the object-experienced. Hence perception is direct!

Functionalism and Perceptual Meaning

In his article "New Reasons for Realism", Gibson (1967), like the New Realists before him, acknowledges a debt to the act psychology of Franz Brentano (1874), who believed that the objects of perception are in the world and not merely in the mind. About this debt Gibson (1979) had this to say:

> "Perceiving is an achievement of the individual, not an appearance in the theater of the mind. It is a keeping-in-touch with the world, an experiencing of things rather than a having of experiences. It involves awareness-of instead of just awareness. It may be an awareness of something in the environment or something in the obserer or both at once, but there is no content of awareness independent of that of which one is aware. This is close to the act psychology of the nineteenth century except that perception is not a mental act. Neither is it a bodily act. Perceiving is a psychosomatic act, not of the mind or of the body but of a living observer" (pp. 239–240).

Here it is clear that Gibson, as phenomenologists have done, endorses the Doctrine of External Relations and uses it as a means to dissolve the mind-body dualism. There is a subtlety regarding the proper interpretation of 'external' in understanding this doctrine. For the New Realists, as it was later for Gibson, *external* as opposed to *internal* relations refer to the preservation and dissolution of identity rather than to a spatial boundary separating objects. It is a functional rather than a structural difference. This is made quite clear by Gibson giving the functional concept of *affordance* the most pivotal position in his psychology. An *affordance* is a property of the environment that *provides an opportunity for adaptive action*. Positive affordances are properties to be maximized (such as shelter or food) and negative affordances are those to be minimized (such as danger or injury).

Ecological psychology is a kind of 'organic' or functional realism, assuming, instead, that perception is of meaningful functions of objects that offer opportunities for actions by properly attuned and relevantly skilled actors. This is in close agreement with the philosopher John Dewey's (1896) argument against mechanistic theories that treat sensori-motor stages as being a simple concatenative structure by which physical energy, physiological stimulation, psychological experiences, and motor responses are linearly connected (a so-called 'reflex arc'). Rather, for Dewey, perception and action are integrated into an indivisible, organic whole, not a causal chain of discrete stages—a whole whose meaning is not stationary but arises from, and is altered by, the organism's 'act' of making continuous motor adjustments to the world—a circular process called *the perceiving-acting cycle* (Shaw, Kugler & Kinsella-Shaw, 1990). This cycle connects James' 'stream of perceptual consciousness' with Dewey's 'stream of behavioral consciousness'.

Hence the process of perceiving the world is to track its meaning that changes dynamically as the perceiver's actions unfold. These meanings are not defined

mentally nor physiologically but ecologically— which, as we have observed, means phenomenologically—at the level of awareness of self-as-perceiver of an environment in which one acts. Finally, we return to the problems that motivated Gibson and Bernstein to develop their innovative approaches.

Gibson's Problem: Reducing the Role of Mediating Constructs in Perceptual Theory

Since Descartes and Locke, traditional theories have regarded perception as the result of sensations produced by an array of stimuli of different intensities at the sensory transducers. Such sensations, however, provide poor representations of the external world. Take the case of visual perception: The image on the retina is inverted, impoverished (i.e., a two dimensional image as opposed to three dimensional reality), distorted (in both size and perspective), and full of holes (the blind spot). Furthermore, perception has been found to be different from the associated sensations. An often cited piece of evidence is that although a proximal stimulus is fixed, the perception can vary (e.g., the Necker cube); and, conversely, although a proximal stimulus may vary, the perception can remain unchanged (e.g., perceptual constancy).

These and other empirical facts indicate that there is no isomorphic mapping between a proximal stimulus and the associated perception. For the empiricists, perception must be supplemented by sources other than sensation, namely, knowledge and reasoning. The empiricists, therefore, have to postulate certain mediating entities to relate the knower to the knower's world. Various mechanisms have been hypothesized to furnish mediating entities. For Helmholtz mediation is achieved through 'unconscious' inference to supplement the impoverished or distorted sensations (Helmholtz, 1909, 1962), or through the testing of hypoteses (Gregory, 1973), or through problem-solving (Rock, 1975)—all of which run, perhaps, like a computer program (Neisser, 1967). Recent arguments in support of perceiving being computational and nativistic have been made by Fodor (1975). From these premises he correctly concludes that solipsism is unavoidable (1982). Such a conclusion is certainly difficult to accept for empiricists and ecological psychologists alike.

Gibson's Solution: Perception Results from the Detection of Meaningful Invariants

Gibson (1979) realized that the difficulty the empiricists face is due to the phenomenalist's assumption that perception comes directly from physiological sensations. He argued that there is information that specifies properties of things in the world unequivocally. Firstly, he pointed out that information is abundant. In visual perception, ambient light reflected from surfaces to the point of observation carries with it structures specific to the surrounding surfaces. Secondly, animals detect information, not through stationary sensory receptors, such as the retina, but

through active *perceptual systems*. For instance, the visual system extracts information by moving the point of observation. This requires that the eye-head-trunk-legs-feet be considered part of the visual system. Likewise, the haptic (touch) system extracts information about size, weight, shape and length of an object through hefting, grasping and wielding. This requires that the haptic system comprise in addition to the cutaneous (tactile) subsystem, the muscular and the bone-articulated subsystems (Gibson, 1966).

Through the variation of stimulation in active exploration, the perceptual system can extract an unvarying pattern of stimulation, called *an invariant*, that lawfully specifies the environmental property. As a person moves to the edge of a step, for example, some area at the corner of the person's visual field disappears (deletion) and new areas appear that were previously covered by the edge of the step (accretion). The *edge-with-depth* invariant, defined by a particular ratio of deletion to accretion, lawfully specifies the height of the step (Kaplan, 1969). Besides specifying the property of an object, an invariant can also specify an event—a style of change (e.g., rolling, bouncing, growing, etc.) (Shaw, Flascher & Mace, 1994). As a person moves towards an object, all the optical texture of the object flows radially outwards forming a divergent optical flowfield. The divergence of this field specifies to the actor direction and rate of approach.

There is much research confirming the hypothesis of information-perception specificity. That is, for every property perceived, there is a molar property of the structured energy distribution to which the perceived property corresponds. Lee (1980), for example, showed that when an object is moving towards a perceiver, the time-to-contact (i.e., the difference between the time of perception to the time of collision) can be perceived directly. The invariant for such perception is the ratio of the area of the projected image of the object divided by the rate of change that area. Similar detection of invariants occurs in haptic perception. Solomon and Turvey (1988) showed that the length of a rod can be perceived by detecting, while wielding the rod, a mechanical property called the *moment of inertia*. Burton, Turvey, and Solomon (1990) showed that even the shape of object can be discriminated by detecting certain configuration of the moment of inertia.

Bernstein's Problem: Reducing the Role of the Executive in Action Theory

In the 19th century, it was popular to regard motor control as responsible by an executive in the head whose capabilities are not unlike those of a human being—a 'little man', or homunculus. At the disposal of this executive are memories of programs to control movement. In producing a movement, the executive uses the motor program to operate on the motor cortex which causes movement of individual muscles. The job of the 'little man' is similar to that of a pianist, where the keys control the muscles. Bernstein (1967) observed that to produce a single movement, there are many parameters (called the *degrees of freedom*) that must be constrained to effect a determinate outcome. Just to modulate the muscular force involved in

stretching out of a hand, would require the homunculus to control simultaneously 26 parameters (Turvey et al., 1982). If we assume only a few values of the muscles are involved, say, in the simplest case, only two, then there would be 2^{26} degrees of freedom for a simple movement. The computational complexity of this problem has defied solution by standard real-time algorithmic procedures. Clearly, a better solution is to avoid this 'curse of dimensionality' if we can.

Bernstein's Solution: Lowering the Dimensionality of the Controller

Bernstein (1967) asserted that all the muscles need to be lawfully tuned into coordinate structures before the initiation of an action. This is similar to the linking of the four wheels of a car so that in turning, drivers do not have to control the four wheels independently (Turvey, Shaw & Mace, 1978). In this way, dimensionality of the neuro-muscular control is dramatically reduced. The ecological study of action thus is to reveal how the muscles self-organize themselves into coordinate structures, so that a control problem with many degrees of freedom can be handled by a (macro) controller with but one degree of freedom.

To investigate the nature of the constraints that harness the muscles into a coordinate structure, ecological psychologists turn to the study of basic movement—rhythmic movement which is regarded as the cornerstone of the theory of coordination (Turvey, 1990). Many experimental results show that understanding human movement requires principles of nonlinear dynamics. When two people, each watching the other, move their limbs out of phase, going from lower frequency to higher frequency, the movement inevitably shifts to in phase at a critical frequency (Schmidt, Carello & Turvey, 1990). This shift corresponds to nonlinear phase transitions in physics. Like wise, in juggling, the temporal order of the two hands is phase-locked in a way that can be predicted by a principle from physics—Arnold tongues (Beek, 1989). Such results support Bernstein's program of searching for higher-order physical constraints that make the job of managing a large number of degrees of freedom as if they are functionally fewer.

Affordances and Effectivities: Bringing Gibson and Bernstein Together

The specifications of an object's properties are made with respect to the action capabilities of the perceiver. In the case of the step, the specification is not the absolute height but whether or not the actor's leg dimensions allow him to step down. If so, the step affords a passage, otherwise it affords a barrier. The functional relationship of the step to the actor-perceiver when it affords passage defines a real property of the environment for the actor called *the affordance of step-down-ability*. An object of the proper size, shape, and solidity affords grasping—the affordance property of *graspability*—by an actor with an appropriately designed and functional prehensile limb—a grasper. Here we see that for an action to be consummated, there must be a property of the environment, an affordance, that offers an opportunity for the action;

this must be complimented by a property of the actor, an effectivity, that provides the means for realizing that affordance as an goal of the action. Thus an effectivity is a goal-directed biological function; realizing an affordance is the goal toward which this function is directed.

There are many other examples of affordances and their matching effectivities which define actions at the ecological scale. Food affords eating for an actor who can ingest and digest the food. Materials affords various kinds of manufacture, depending on rigidity and malleability, and the proper manufacturing procedures. Other persons and animals afford different kinds of social interactions if we can but join them. Affordances can be positive and negative. Water affords drinking or quenching fire as well as flooding and drowning. Fire affords cooking as well as destruction. Substances may afford ingestion and poisoning. Thus animals have to know the possible actions the environment supports in order to further the exploitation of available resources. The environment is an affordance structure and an organisms, who is adapted to that environment, a system of matching effectivities. This is the basis of animal-environment duality introduced earlier.

The concept of affordances defines meaning to be external to the animal. Perception is related to the probable actions of the observers. Thus Michaels and Carello (1981) wrote: "Affordances write perception in the language of action" (p. 47). These are not realized actions but 'prospective' actions possible to be enacted. As affordances allow the animal to know what to do with the environment, they provide meaning to the animal. In the traditional psychology theories, sensory information is meaningless, it has to be enriched with concepts, memories, or inferences (whose sources are not explained) before meaningful percepts and objects can be formed.

For Gibson (1979) however affordances are external to the animal and can be perceived directly by the animals (conforming to the doctrine of external relations). Moreover, the information obtained by an animal is specific to the animal (because of different eye-height and movement involved in producing the invariant) (conforming to the doctrine of internal relations). Thus when one perceives the world, one's own self is co-perceived (a wedding of the two doctrines into a duality). As a result, the meaning derived from the environment is socially available for other actors of the same kind but is nevertheless specific to the animal.

The Philosophy of the Ecological Approach: A Summary Statement

The mainstream approach separates the animal and environment into two incommensurable systems: dynamic (meaningless) quantities are used in the environment while symbols (meaningful) are used in the processing of information. In ecological psychology, because an animal and its environment are co-evolved and co-perceived, they constitute both a biological and a psychological ecosystem. A proper understanding of an animal can only be achieved by taking the animal and its niche toghther as one single unit of analysis at the ecological scale. The ecological

approach asserts that human behaviors can be explained in terms of natural laws (Turvey, Shaw, Reed & Mace, 1981). This position was also taken by the Gestalt psychologists who thought it legitimate to use laws, primarily formulated to explain the behavior of inanimate objects, to explain the behavior of living systems (Köhler, 1969). They claimed that "all biological facts and events can be understood in terms of the laws which hold for facts and events in the inanimate world" (p. 83). Ecological psychologists concur.

Similarly, since the repudiation of vitalism, biological sciences have come to view living systems as ordinary physical systems but with emergent properties due to their great complexity. The animate differs from the inanimate in having developed extraordinary means of making use of the physical principles (Kugler & Turvey, 1987). This natural philosophy does not make ecological psychology reductionistic anymore than it did Gestalt psychology. But it does push the scientific study of intelligent systems away from elementalistic structuralism and atomistic behaviorism toward complex, open systems theory where psychology, biology, and physics, at least at the ecological scale, are treated as being equal partners.

REFERENCES

Beek, P. 1989. Timing and phase locking in cascade juggling. *Ecological Psychology,* **1**, 55–96.

Berkeley, G. 1954. *An essay toward a new theory of vision.* In Berkeley: A new theory of vision and other writings. London: Dent. (Originally published 1709)

Bernstein, N. 1967. *The coordination and regulation of movements.* London: Pergamon.

Brentano, F. 1973. *Psychology from an empirical standpoint.* (O. Kraus, Ed.: English ed., L. L. McAlister, Ed.). New York: Humanities Press (Original work published 1874).

Bruce, V., & Green, P. R. 1990. *Visual perception.* Hillsdale, NJ: Lawrence Erlbaum.

Burton, G., Turvey, M. T., & Solomon, H. Y. 1990. Can shape be perceived by dynamic touch? *Perception & Psychophysics,* **48**, 477–487.

Dewey, J. 1896. The reflex arc concept in psychology. *Psychological Review,* **3**, 357–370.

Effken, J., & Shaw, R. 1992. Ecological perspectives on the new artificial intelligence. *Ecological Psychology,* **4**, 247–270.

Fodor, J. A. 1975. *The language of thought.* Cambridge, MA: Harvard Unversity Press.

Fodor, J. A 1982. Methodological solipsism. In J. Haugeland (Ed.), *Mind design: Philosophy, psychology, artificial intelligence.* Cambridge, MA: MIT.

Fodor, J. A., & Pylyshyn, Z. W. 1981. How direct is visual perception? Some reflections on Gibson's "Ecological Approach." *Cognition,* **9**, 139–196.

Gibson, J. J. 1966. *The senses considered as perceptual systems.* Boston: Hogton Mifflin.

Gibson, J. J. 1967. New reasons for realism. *Synthese,* **17**, 162–172.

Gibson, J. J. 1979. *The ecological approach to visual perception.* Boston, MA: Houghton Mifflin.

Gleitman, H. 1990. *Psychology* (3rd ed.). New York: Norton.

Gregory, R. L. 1973. *Eye and brain* (2nd ed.). New York: McGraw Hill.

Harlow, V. E. 1931. *A bibliography and genetic study of American realism.* Harlow Publishing Co.

Helmholtz, H. Von. 1962. *Treatise on physiological optics, Vol lll* (trans. from the 3rd German ed., J. P. C. Southall), New York: Dover. (Originally published 1962)

Holt, E. B. 1922. *The new realism.* New York: Macmillan.

James, W. 1890. *Principles of psychology.* New York: Henry Holt.

Kaplan, G. 1969. Kinetic description of optical texture: The perception of depth at an edge. *Perception and Psychophysics,* **6**, 193–198.

Kelso, J. A. S. 1982. *Human motor behavior: An introduction.* Hillsdale, NJ: Lawrence Erlbaum.

Köhler, W. 1969. *The task of Gestalt Psychology.* Princeton, NJ: Princeton University Press.
Kubovy, M., & Pomerantz, J. 1981. *Perceptual organization.* Hillsdale, NJ: Lawrence Erlbaum.
Kugler, P. N. & Turvey, M. T. 1987. *Information, natural law, and the self-assembly of rhythmic movement.* Hillsdale, NJ: Lawrence Erlbaum.
Lee, D. N. 1980. The optic flow field: The foundation of vision. *Philosophical Transactions of the Royal Society of London,* Series B, **290**, 169–179.
Lombardo, T. J. 1987. *The reciprocity of perceiver and anvironment.* Hillsdale, NJ: Lawrence Erlbaum.
Pick, H., & MacLeod, R. 1974. *Studies in perception: Essays in honor of J. J. Gibson*, Ithaca: Cornell University Press.
Merleau-Ponty, M. 1963/1969. What is phenomenology? In A. l. Fisher (Ed.), *The essential writings of Merleau-Ponty* (pp. 27–43). New York: Harcourt, Brace & World, Inc.
Michaels, C. F., & Carello, C. 1981. *Direct perception.* NJ: Prentice-Hall.
Neisser, U. 1967. *Cognitive psychology.* New York: Appleton-Century-Crofts.
Posner, M. I. 1989. *Foundations of cognitive science.* Cambridge: A Bradford Book, M. I. T. Press.
Pratt, J. B. 1937. *Personal realism.* New York: Macmillan.
Reed, E., & Jones, R. 1982. *Reasons for realism.* Hillsdale, NJ: Lawrence Erlbaum.
Rock, I. 1975. *An introduction to perception.* New York: Macmillan.
Schmidt, R. C., Carello, C., & Turvery, M. T. 1990. Phase transitions and critical fluctuations in the visual coordination of rhythmic movements between people. *Journal of Experimental Psychology: Human Perception and Perfromance.* **16**, 227–247.
Shaw, R., & Bransford, J. 1977. Psychological approaches to the problem of knowledge. In R. Shaw & J. Bransford (Eds.) *Perceiving, acting and knowing: Toward an ecological psychology* Hillsdale, NJ: Lawrence Erlbaum.
Shaw, R., Kugler, P., & Kinsella-Shaw, J. 1990. Reciprocities of intentional systems. R. Warren & A. Wertheim (Eds.). *Control of self-motion.* Hillsdale, NJ: Lawrence Erlbaum.
Shaw, R., & Kinsella-Shaw, J. 1988. Ecological Mechanics: A physical geometry for intentional constraints, *Human Movement Science.* **7**, 155.
Shaw, R., & Turvey, M. 1981. Coalitions as models for ecosystems: A realist perspective on perceptual organization. In M. Kubovy & J. Pomerantz (Eds.) *Perceptual organization.* Hillsdale, NJ: Lawrence Erlbaum.
Solomon, Y., & Turvey, M. T. 1988. Haptically perceiving the distances reachable with handheld objects. *Journal of Experimental Psychology: Human Perception and Performance.* **14**, 404–427.
Turvey, M. T. 1990. Coordination. *American Psychologist,* **45**, 938–953.
Turvey, M. T., Shaw, R. E. 1979. The primacy of perceiving: An ecological reformulation of perception for understanding memory. In L. G. Nilsson (Ed.), *Perspectives on memory research: Essays in honor of uppsala University's 500th anniversary.* Hillsdale, NJ: Lawrence Erlbaum.
Turvey, M. T., Shaw. R. E., Reed, E. S., & Mace, W. M., 1981. Ecological laws of perceiving and acting; In reply to Fodor and Pylyshyn. *Cognition,* **9**, 237–304.
Whitehead, A. N. 1929. *Process and reality.* New York: Macmillan.

(*Manuscript received October 20, 1994*)

Psychologia, 1996, **39**, 17–23

AN EXAMINATION OF JAPANESE CHILDREN'S PERFORMANCE ON THE DRAW-A-PERSON: A QUANTITATIVE SCORING SYSTEM*

Donald H. SAKLOFSKE, Katsuo TAMAOKA

University of Saskatchewan, Canada, Matsuyama University, Japan,

Denise HILDEBRAND

and University of Saskatchewan, Canada

The purpose of the study was to investigate Japanese children's performance on a test of non-verbal ability, namely, the *Draw-a-Person: Quantitative Scoring System*—DAP (Naglieri, 1988). The construct validity and concurrent validity of the DAP were examined and Japanese children's performance (n=400) was compared with the American normative group. The relationship between student performance on the DAP and school achievement was also investigated. Results of the study indicated that a general developmental trend (a measure of construct validity) was apparent for both Japanese boys and girls. Although younger Japanese children performed better than their American counterparts, a leveling effect was noted for older Japanese children. Concurrent validity estimates were based on the correlation between the DAP *and the Matrix Analogies Test-Short Form*; correlation coefficients were higher than those reported in the DAP test manual. Generally, school achievement (based on teacher ratings) was not related to student performance on the DAP.

Historically, human figure drawings have been used to provide an estimate of children's developmental status. Harris (1963) pinpoints the 1880's as the initial period in which children's drawings were related to developmental stages. Since then, numerous attempts have been made to standardize the scoring and interpretation of children's drawings in an effort to gauge intellectual development. For example, standardization procedures used in the Goodenough's *Draw-a-Man Test* (1926) included a normative group of nearly 4,000 children (Kamphaus & Pleiss, 1991). In 1963, Harris revised Goodenough's test in order to include both a wider age range and drawings of woman and self. Koppitz (1968) also developed a scoring system which included two types of objective scoring methods: developmental items (relating to age and maturational level) and emotional indicators (relating to attitudes and concerns).

In an effort to provide current norms and lend greater clarity to the scoring and developmental interpretation of children's drawings, Naglieri (1988) designed the *Draw-a-Person: Quantitative Scoring System* (DAP). According to Naglieri (1988), the

* All correspondence concerning this article should be sent to Donald H. Saklofske, Department of Educational Psychology, College of Education, University of Saskatchewan, 28 Campus Drive, Saskatoon, SK Canada, S7N 0X1.