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REASONS FOR REALISM

Selected Essays of James J. Gibson

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4.6 Notes on Action

PART I: THE THEORY OF PROPRIOCEPTION AND ITS RELATION TO VOLITION: AN ATTEMPT AT CLARIFICATION*[1]

It sounds reasonable to assume that there is a close connection between proprioception and the voluntary control of movement. An individual needs to know what he has done in order to decide what to do next. Something like this reasoning seems to underlie the enthusiasm for Von Holst's theory of "reafference" and the "efference copy."[2] But it seems to me misguided. Proprioception, especially visual proprioception, will have to be understood in its own right before we can even begin to wrestle with the formidable problem of volition.

Followers of Von Holst assume that all movements except for "reflexes" are caused by motor *commands* initiated in the brain. An *efferent copy* of the command is stored and compared with the afferent input. If the input cancels the copy, it is interpreted as proprioception; if not, it is interpreted as exteroception.[3] This is thought to explain (for example) why the world does not seem to move when the eyes move.

I have a different theory of proprioception based on perceptual systems in-

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[1]Gibson (1941a, pp. 801-810) discussed the dichotomy between voluntary and involuntary behavior and questioned the existence of a single dimension between involuntary and voluntary activity (cf. E. J. Gibson, 1939; J. J. Gibson, 1936a). (Eds.)

[2]Von Holst & Mittelstaedt (1950). See Gallistel (1980) for a review of theorizing concerning "efference copies" and "corollary discharges" as supplements to sensations in perception. (Eds.)

[3]Gibson's critique here also applies to more recent versions of this theory in which the motor copy is not hypothesized to cancel out afferent input, but rather as an information signal in a system set to evaluate afference (see McKay, 1973 for details). (Eds.)

stead of sensory channels. For the visual system, I assume that a disturbance in the structure of the optic array is *exterospecific* if it specifies a motion or event in the environment. It is *propriospecific* if it specifies a movement of the observer himself relative to the stable environment, a locomotion, *or* if it specifies a movement of a *part of the observer's body* relative to the body as a whole. Note that a movement of the observer or of a part of his body may be passive as well as active, i.e., may be imposed instead of initiated (as in passive locomotion in a vehicle, or passive turning of the head in a rotating chair, or passive movement of a limb). Hence a "motor command" *is not necessarily entailed in a bodily movement*. The first question is what distinguishes an optical motion or disturbance that is exterospecific from one that is propriospecific? Is there a difference between the optical consequences of an external event and those of a bodily movement?

There seem to be three types of bodily movement, either active or passive: first, locomotion, or displacement of the point of observation (the head) relative to the environment; second, limb-movement relative to the body (e.g., manipulation); and third, exploratory movement of the head-eye visual system itself, i.e., head-turning and eye-turning. Consider them in order.

Displacement of the point of observation. Locomotion has the inevitable consequence of what I have called *motion perspective* in the ambient optic array.[4] This kind of optical change specifies locomotion and nothing else, just as an unchanging optic array specifies a motionless observer. That is to say, there is no possible event in the normal environment that could bring about this unique optical change, given the facts of ecological optics—no motion in the environment that could cause this motion in light. The fact that a man who faces a "Cinerama" screen can be given a temporary *illusion* of locomotion only reinforces this assertion. Motion perspective involves the complete ambient array. It is strictly propriospecific.[5]

Limb movement relative to the body. An *occupied* point of observation involves not only an ambient optic array but also a *field of view*, i.e., a sample of the ambient array that is specific to the observer himself (Gibson, 1979a: Ch. 13—Eds.). The limbs and body of the animal normally *protrude* into the field of view, and the hands of a primate are important "semi-objects" in the field of view. A primate usually sees the movements of his hands. These optical deformations are also strictly propriospecific. No possible event in the environment could cause these particular optical changes.

Head-turning and eye-turning. When the head is rotated on either a vertical or a horizontal axis the edges of the field of view "sweep" across the ambient

[4]Cf. Ch. 2.2 and Lee (1974). (Eds.)

[5]A number of experiments corroborate this claim (Lee & Lishman, 1977a, 1977b; Lishman & Lee, 1973; Warren, 1976). (Eds.)

optic array, revealing its structure at the leading edge and concealing it at the trailing edge. This occurs whether the head rotation is active or passive, obtained or imposed. It is uniquely propriospecific; it specifies head-turning relative to the persisting array projected form the persisting environment. Note that the environment cannot possibly rotate around the animal. When this impossibility is artificially simulated with an "optokinetic drum" the observer "feels" himself being turned (or "sees" himself turning—it makes no difference which).[6] Animals in this experiment generally compensate by turning so as to maintain the same field of view, this being one way of maintaining a posture.

There are, of course, rotations of the *eyes* in the head that are compensatory for head-turning, and these are perhaps the most fundamental of all eye-movements. This adaptive nystagmus underlies all the more complex ocular adjustments, including those that accompany the foveated eyes of some animals, and it serves the same function, of stabilizing the eyes relative to the environment except for saccades.

The sweeping of the edge of the field of view across the ambient array, the visual sensation, can scarcely be noticed by the human observer. It is ordinarily simply registered for what it is, a specific of head-turning relative to the environment. And the rapid shift of the *occular* field of view that accompanies a saccadic eye rotation cannot be noticed at all. I suggest that it too is normally registered for what it specifies, a saccade. There is a history of theorizing about the puzzle of why no retinal sensation of "motion" is obtained when the eyes jerk, during the century from Helmholtz to Von Holst, but I think it is a false puzzle.[7] The shift of the retina behind the potential retinal image, the extended image, is normally propriospecific. I suspect that all the experimental results with eye-movements and points of light in a dark room can be reconciled with this hypothesis but this is only a suspicion. The rapid displacement of a point in the dark may prove to be indistinguishable from an equivalent rapid rotation of the eye in that situation. If so, it is one of the very rare cases in which visual exteroception need be confused with visual proprioception.

The foregoing theory of visual proprioception says nothing about volition. It applies as well to passive movements as to active movements. Proprioception is taken to be the awareness of the self that accompanies the perception of the environment.

What about intended movements, then? And what about the "intentionality" of perception, the active, striving nature of perception when an observer is seeking information instead of simply having it presented to him? This seems to me a question at an entirely different level. And it is not answered by supposing that the brain issues commands to the muscles, for that is the worst sort of

[6]This feeling of head-turning has long been claimed to be the result of afference from or efference to the eyes during the nystagmic eye movements that occur in this situation (Dichgans & Brandt, 1978). However, a recent experiment has shown that visual proprioception of head rotation is independent of eye movements (Brandt, Dichgans & Koenig, 1973). (Eds.)

[7]McKay (1973), L. Matin (1972), and E. Matin (1974) review this literature. (Eds.)

mentalism. Between so-called involuntary reflexes and so-called voluntary movements there are surely many intermediate kinds of action. They will never be worked out unless the voluntary-involuntary dichotomy is abandoned. Reflexes are not machine-like on the one hand and purposive acts are not soul-like on the other.[8] It is fruitless to assume that behavior develops by an increasing voluntary control of primitive involuntary reflexes. What sounds to me promising is to begin with the assumption that active perception is controlled by a search for the affordances of the environment and that active behavior is controlled by the perceiving of these affordances.

PART II: NOTE FOR A TENTATIVE REDEFINITION OF BEHAVIOR*

If behavior does not consist of responses what does it consist of? The failure of the stimulus-response formula in psychology is being recognized more and more widely but what do we have to take its place?[9] An interest in studying behavior should not be confused with the assumptions of behaviorism. The most stultifying of these was the formula of responses or reactions, originally supposed to be triggered by stimuli but later extended to include those "emitted" by an organism in the absence of stimuli. All kinds of responses and response-combinations have been postulated including "inner" responses, "mediating" responses, and "molar" responses; but the formula cannot be made to work in psychology, and it should be abandoned.

A substitute formula might be that behavior consists of *postures* and *movements*. Can this be developed? Note that postures and movements are *controlled* rather than being either triggered or emitted, as responses are. They are controlled by information, both external and proper, but not by stimuli. That is, there is always a flow of both exterospecific and propriospecific information available. A flow of information is not composed of "signals." Note also that the classical division of responses into types called involuntary (reflexes) and voluntary does not apply to postures and movements. They are *all* controlled and to say that some control is voluntary is to say nothing. The theory of motor "commands" is self-defeating. Can we now formulate a sort of taxonomy of behavior that makes sense?

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[8]Recent research on reflex components of stepping (Forssberg, Grillner, & Rossignol, 1977), standing (Nashner, 1976), and looking (Gonshor & Melvill-Jones, 1976; Miles & Eighmy, 1980) have shown that reflexes are not responses mechanically coupled to stimuli, but are somewhat adaptive and functional. Conversely, research on simple voluntary movements (Nashner & Cordo, 1981) has revealed automatic and mechanical components of volition. (Eds.)

*Unpublished manuscript, June, 1975.

[9]Even the most anti-behavioristic of cognitive psychologists have not replaced the S-R formula so much as supplemented it (Dennett, 1975). (Eds.)

Postures

Behavior depends on posture and is inseparable from it. This is true in two ways. First, a fixed posture of the body and its members never persists for long; it gives way to a movement, which is a change from one posture to another.[10] Even an equilibrium posture like the upright stance consists of small corrective movements. A stance is an orientation to the surface of support, to gravity, and to the sky-earth contrast. A posture is an *orientation to the environment*. A posture involves both a whole and its parts, that is, a body and its members. A "member" is a moveable unit of the body.

Second, any movement entails the altering of a special posture while maintaining a general posture. Thus, walking involves keeping an upright posture; and pointing with the arm involves a stance of the body. There is always some non-change underlying the change of posture.

Movements

Animate movements have very little to do with Newtonian motions, and mechanics alone is a poor guide to their study. How can animate movements be classified? An obvious distinction is between movement of the whole body and movement of a body-member.

1. Movement of the body-unit relative to the environment layout. There are two abstract pure cases here (a) the displacement of a body relative to the rigid environment i.e., locomotion from place to place, and (b) the "turning" of the body from one orientation to another i.e., the rotation of the body. In walking they are usually combined. There are additional sub-cases of body-rotation ("pitch" and "roll") which, in the case of terrestrial locomotion but not aquatic or aerial, involve "falling," that is, a failure of the upright stance.

Note that all these cases are mechanically complex involving a positive and a negative acceleration, although they are biologically simple. The movement of the head generally "leads" the movement of the rest of the body in these locomotions and turns.

2. Movement of a body member relative to the body-unit.

a. Head-movement. The head is the principal member of the body. It can *turn* relative to the trunk, or *nod* or *tilt* (and the eyes in the head then undergo a compensatory movement which keeps them anchored to the optic array and the fixed environment). Note that a head-movement can occur during a locomotion movement of the body relative to the environment.

[10]Recent work on the mechanisms underlying reaching (Bizzi, 1980) and standing (Nashner & Woolacott, 1979) have shown that postures can change into movements and back (or to a new posture) with great speed. Work on stepping and standing shows that vision plays an important role in controlling the postures and movements underlying balance and locomotion (Berthoz, Lacour, Soechting, & Vidal, 1979). (Eds.)

b. Eye-movement. The eyes can move relative to the head, that is, can rotate. Actually they can do so on any of three axes. The types of eye-movement have been listed and measured. The eyes, head, trunk, and legs make a sort of hierarchy of body members. The eyes and head are oriented to the source of environmental information currently being picked up.

c. Arm and hand movement. The arms move relative to the trunk and the hands relative to the arms. This is the kind of primate behavior called *manipulation*. If the stance of the body is maintained the hands can thus move relative to the layout of the environment, that is, reach, grasp, push, pull, and also point, throw, catch, and strike (see later).

d. Leg movement. For bipeds, when the legs move relative to the trunk they also move relative to the surface of support and thus *propel* the animal. This is terrestrial locomotion. Primates are also capable of "arboreal" locomotion, or climbing, etc.

The classes of movement so far listed would fall under the kinds of behavior called locomotion, perceptual exploration, and manipulation. (For "acrobatic" movements, see later.) But there are also kinds of behavior loosely called "performatory" and "sexual" and "social."[11]

e. Movements that change the environment. There are movements of the hands, feet, and jaws that change the layout of the environment or the composition of its substances, or even their existence. Detached objects can be displaced (transported, thrown, kicked) or shaped, or destroyed. Doors can be opened, liquids can be splashed or poured, and food-objects can be eaten. Traces can be made on surfaces. That is to say, events of the environment can be brought about. When tools are used the movements of the hands cause motions of the tool that in turn cause motions or other changes of the layout.

f. Movements for sexual and familial interaction. The sequence of preliminary and consummatory behaviors connected with reproduction is complex and well known. The movements are oriented to another animal of the complementary sex and the control of these movements depends not only on proprioception but also on exteroceptive perception of the movements of the other individual. The type of behavior called *nurturant* follows the same rule.

g. Movements for social interaction. These include predator and prey behaviors, fighting and competition, cooperation, and also various kinds of social play, especially in children.

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[11] Cf. Gibson (1966b, pp. 56–57) for a functional taxonomy of movement systems. (Eds.)

h. Movements for social communication.[12] Postures and gestures of the body, limbs, and hands serve for communication from one animal to another as for example in the act of pointing. But the gestures of the face that we call "expressions" are important for man in the conveying of information about intentions. And, above all, the complex gestures of the vocal tract that produce sounds are a superior means of communication, unaffected by darkness or by occluding edges. In my terminology the face and the vocal mechanism are "members" of the body as much as the head and limbs. They adopt postures and move from one posture to another just as the body does, and the hand. They have a repertory of positions and transitions between positions which are clearly not responses to stimuli.

i. Movement for its own sake. Finally, a type of movement should be listed which is less controlled by exteroception than the others, that is, by objects and events at a distance from the observer. The movements of the dance are of this sort, at least in dancing alone. They obviously go from one posture or "pose" to another. The movements of children in "play" are also often self-controlled, as in tumbling, jumping, whirling around, etc. This kind of play does not need a "plaything," or a "playmate," only a surface of support.

The heart of the foregoing classification, however incomplete, is the substitution of postures and movements-between-postures for responses to stimuli. The postures and movements are felt and seen *relative to the environment.*

Behavior and Perception

What is the relation of perception to behavior thus reformulated? It is more intimate than the relation of sensation-based perception to response-based behavior ever could be. Perception of the environment is always accompanied by co-perception of the self (*proprioception* in my new meaning of that term). We pay attention mainly to the affordances for behavior of the environmental layout—its *behavioral* geometry you might say, as distinguished from its *abstract* geometry. Thus exteroception is seldom divorced from proprioception.[13] The orienting of a perceptual system and the orienting of behavior go together. (But the orienting movements of sense organs and of body members are not reflex responses as Pavlov thought.) The dichotomy of "sensory" and "motor" disappears. It was convenient only for a simplistic level of neurophysiology in any case.

It is still true that the extracting of information for the perception of the world

[12]Cf. Smith (1977). (Eds.)

[13]Lee (1978) suggests that the term "exproprioception" should be used to denote the mutuality of extero- and proprio-ception. (Eds.)

and the extracting of information for the bodily control of performances are different processes, even if complementary. The perception of a goal, its affordance, controls locomotion in one way whereas the visual proprioception of the optical outflow controls locomotion in an entirely different way. The bee who lands on a flower needs to both perceive the flower and control his flight. He has to see an invariant environment in order to identify the flower, and to see himself moving through the environment in order to guide his locomotion. The perceiving and the behaving go together but they are not the same process.

The theories of control so far advanced have been based on the stimulus-response formula; all they add is feedback or response-produced stimuli. A more adequate theory of the steering, guiding, or controlling of behavior can be based on the notion of perceptual systems with built-in proprioceptive functions, and the notion of a general orienting system.