504

The informational support for upright stance

Claudia Carello,[a] M. T. Turvey,[b] and Peter N. Kugler[c]
[a]Department of Psychology, State University of New York, Binghamton, N.Y. 13901, [b]Department of Psychology, University of Connecticut, Storrs, Conn. 06268 and Haskins Laboratories, and [c]Crump Institute of Medical Engineering, University of California, Los Angeles, Calif. 90024

Nashner & McCollum (N & M) suggest that: (1) perturbations of the body relative to the gravitational field and the surface of support parse into a small number of circumscribed kinetic states (regions of disequilibrium), and (2) a functional muscular organization, to restore upright posture, corresponds to each state. Though the authors talk about the sensing of these states, they give no indication of the relevant information. In a related way, we think, their references to neural signals that require interpretation, their appeals to memory (presumably of previous trajectories, previous initial conditions, previous sensory consequences, and previous postural achievements), and their supposition of anatomically defined senses uniquely tied to distinct frames of reference seem to run counter to the general Bernsteinian (1967) strategy that they are pursuing, that is, compressing in a principled fashion a movement problem of potentially very many degrees of freedom into a movement problem of very few degrees of freedom.

In contrast, we are inclined strongly toward Gibson's (1966, 1979) revision of the senses in terms of perceptual systems – active, interrelated systems (as opposed to senses) that detect information (rather than have sensations) about the perceiver–environment relation (rather than about their own states). Taking a Gibsonian stance, we ask whether there could be information *specific* to a circumscribed disequilibrium state, regardless of etiology; whether there could be information *specific* to approaching a region's boundary, regardless of the details of the trajectory; and whether such information can be independent of the mode of attention. We will start with Gibson's strict interpretation of information with respect to vision, demonstrate that equivalent information is obtainable by other perceptual systems, and conclude with speculation about properties that might generalize to the control of stance.

Information is optical structure lawfully generated by the persistent and changing layout of surfaces and by the displacements of the body (as a unit relative to the surface layout and as parts relative to each other). Because the properties of the optic flow field are lawfully related to the properties of the kinetic field underlying them, they are said to *specify* those kinetic properties (see Runeson & Frykholm 1983). Following Lee (1978), the optical flow field is exterospecific (specific to properties of surface layout), expropriospecific (specific to the orientational displacements of the point of observation relative to the surface layout), and propriospecific (specific to the relations among the parts of the body). And it can be specific in each of these ways simultaneously. How can this be? Each class of facts (extero, exproprio, proprio) imposes a distinct patterning – or structure, or form, or morphology (see Kugler & Turvey, in press) – on the optical flow field. These patterning are superposed on each other but differentiable from one another.

Consider one such patterning. An optical flow field can be treated as, roughly, a velocity vector field where the vectors represent angular velocities of the optical elements (see Gibson 1979). When all vectors are undergoing a graduated magnification about a fixed point, then the point of observation is displacing rectilinearly toward the fixed point. It is suggested that any globally smooth velocity vector field specifies a displacement of the point of observation. (Note that the qualitative macroscopic properties of the field are what matter, not the individual vectors.) One can sketch a law at the ecological scale (see Turvey, Shaw, Reed & Mace 1981) roughly of the form:

$$\text{displacement of point of observation} \xrightarrow{\text{LAWFULLY GENERATES}} \text{globally smooth velocity vector field.}$$

This law defines a particular kind of information in Gibson's specificational sense, that is:

$$\text{globally smooth velocity vector field} \xrightarrow{\text{SPECIFIES}} \text{displacement of point of observation relative to surround.}$$

Note that the optical property in the foregoing law is a kinematic abstraction (dimensions: length and time) of an energy distribution (light) structured by properties of a kinetic field (dimensions: mass, length and time), that is, the field determined by the animal and surface layout. Insofar as the same kinematic abstraction could be supported by other energy distributions modulated by the same kinetic facts, this analysis can be generalized to other modes of attention. For example, if a sound field with the same globally smooth morphology could be produced, according to Gibson's law-based/specificational interpretation of information listeners should perceive themselves displacing relative to the surroundings (for confirming evidence, see Dodge 1923; Lackner 1977). Defining this morphology over deformations of the skin should yield the same impression of egomotion (again see Lackner 1977).

This treatment of expropriospecification can be extended to extero- and propriospecification. It is suggested that distinct flow morphologies, now discontinuous rather than smooth, specify facts of surface layout and relations among joints (Gibson 1966; 1979). Again, these morphologies can be instanced by different kinds of energy distributions. Note that it is possible to describe vestibular stimulation – weights displacing in fluid-filled chambers relative to gravity's pull – and haptic-somatic stimulation – nonrigid mechanical deformations of the body's tissues – as kinematic or vector fields. And note further that, in principle, these velocity vector fields are characterizable alternatively as low-dimensional, macroscopic patternings. According to the ecological law formulation from above, if a given disequilibrium state gives rise to identical morphologies in the vector fields that are "attended to" vestibularly, haptically, and visually, then the same postural fact will be apprehended by each mode of attention.

N & M are puzzled by neural signals having equivalent postural consequences when the signals are different. In our view, their puzzlement is based on the wrong formulation: *Information* may be identical when neural signals, stimuli, and so on, are different (see Gibson 1966, p. 55). N & M feel that neural signals must be interpreted. Signal is a metaphor for sensations, and sensations strictly speaking can only be about states of nerves; hence, the need for interpretation. Again, N & M's formula is suspect. *Information* is about, in the sense of specific to, animal-environment facts. It needs to be detected, and its differentiation and pick-up by a perceptual system improve with practice, but to interpret it would be superfluous.

We have suggested that the information about kinetic conditions (such as regions of postural equilibrium) is to be found in the morphology of kinematic fields. Moreoever, the information is indifferent to the medium that has been structured kinematically. We conclude with a speculation about the morphological property specific to approaching a region's boundary – a generalization of the time-to-contact variable, T, and its derivative (Lee 1980).

For the visual system, T is the inverse of the relative rate of dilation of, roughly, the optic array. It specifies when one will contact a surface on the path of locomotion. Its derivative specifies how hard the imminent collision will be (Lee 1980). Our conjecture is that T may be a very general property of kinematic (flow) fields. Any kinetic field will have, as a rule, the equivalents of contactable "surfaces", for example, attractors, basins, and so forth. Is there, as a rule, the equivalent of T in the kinematic abstraction of any kinetic field – for example, nonrigid mechanical distortions of body tissues? Suppose that N & M's regions of equilibrium are detected haptically. Then the proposed availability of T and its derivative would provide a principled haptic basis for regulating forces to prohibit crossing regions.

In sum, Gibson's treatment of information seems relevant to Nashner & McCollum in this sense: The low dimensionality of postural control they promise on the side of action could be reciprocated (as it must) on the side of perception.

ACKNOWLEDGMENT

The writing of this manuscript was supported in part by an Office of Naval Research Contract NOOO14-83-C-0083 awarded to the Haskins Laboratories.