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THE EQUATION OF INFORMATION AND MEANING FROM THE PERSPECTIVES OF SITUATION SEMANTICS AND GIBSON'S ECOLOGICAL REALISM

1. Introduction

As Barwise and Perry suggest, their theory of meaning is consistent on several fronts with Ecological Realism as it has been developed by the psychologist James J. Gibson. The most important convergence from our perspective is the shared conviction that meaning is neither in the brain – the residence openly preferred by orthodox psychologists – nor in some nether world – a location intimated by Fregean semantics. Rather, meaning is contained in the system defined by the nested relations between the real properties of a living thing and the real properties of the environment with respect to which the living thing conducts its daily affairs.

How is this type of realist account of meaning supported? Both Gibson and Barwise and Perry have attempted to ground meaning in information. But both are extremely careful about the sense in which information is to be used. Gibson (1966) pointed out that information theory in the style of Shannon (1949) was not adequate to the demands of perceiving – obtaining information about activity-relevant properties of the environment. Whereas information for communication engineering is assumed to be finite and transmittable, information for perceptual systems is inexhaustible and noticeable (i.e., *not carried*, as through a channel) (Gibson, 1979). To characterize information as a quantifiable reduction in uncertainty does not require a consideration of meaning; to characterize information as the specification of the observer's environment demands it. Similarly, Barwise and Perry deny Dretske's (1981) assertion that meaning and information are dissociable. Instead, situation semantics and ecological psychology place what Barwise and Perry call "constraints on the structure of reality" at the heart of their attempts to consider meaning and information conjointly. That is to say, if an event A is linked systematically to another event B, A is information about B; the linkage is meaningful.

It is in the nature of the linkage that the different emphases of the two approaches can be seen. Gibson (1954, 1966) identified three such relationships: convention, projection, and natural law. These underwrite the relationships between, for example, an automobile and its license, an

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automobile and its shadow, and a moving automobile and the optical flow pattern it generates, respectively. Examples of the last type – what Barwise and Perry refer to as information based on nomic structural constraints – are at the core of the Gibsonian program. An understanding of the information required for animals to control locomotion in a cluttered surround is considered propaedeutic to understanding information of the other types. The focus is on uncovering laws at the ecological scale (i.e., appropriate to a given animal-econiche system) (Turvey, Shaw, Reed, and Mace, 1981) that underlie information in the specificational sense (Reed, 1981; Turvey & Kugler, 1984a, 1984b), captured as follows:[1]

(1) $$\text{Situation-type } A \underset{\text{specifies}}{\overset{\text{generates by law}}{\rightleftarrows}} \text{Situation-type } B$$

Information in the pictorial sense and information in the indicational sense (that central to linguistic meaning) can be schematized similarly:

(2) $$\text{Situation-type } C \underset{\text{depicts}}{\overset{\text{produces by projection}}{\rightleftarrows}} \text{Situation-type } D,$$

and

(3) $$\text{Situation-type } E \underset{\text{indicates}}{\overset{\text{is conventionally linked to}}{\rightleftarrows}} \text{Situation-type } F,$$

respectively. For Gibson, both of these are predicated on information in the specificational scene. A representational picture, for example, is a surface treated in such a way as to make available some of the same (formless and timeless) invariants that are available in the real scene (Gibson, 1979). In the same vein, the symbolic waggle dance of the bee indicates the location of a source of honey in the invariant pattern of dips and twists. In all cases, meaning is there to be discovered, whether the animal is immersed in a lawfully structured sea of energy, encounters an arrested array of persisting invariants, or confronts culturally determined conventions. That is to say, even if the constraints are at some remove from the animal-environment system, each new individual need not reinvent or recreate them. Rather, the systematicity of the relationships must be noticed. But the fundamentality of information in the specificational sense runs still deeper. In order for information in the indicational sense to be efficacious, information in the specificational sense already must be available. For example, in order for a stop sign to regulate the dynamics of traffic flow and, therefore, for its meaning to be realized, information specifying the retardation of forward motion and the time-to-contact with the place where velocity must go to zero, must be available.

We will pursue the notion of information in the specificational sense in the section that follows in an effort to support the arguments of Gibson and Barwise and Perry that meaning and information can be equated.

2. Information in the specificational sense and situation-type meaning

Consider a transparent medium (air or water) that is densely filled with light scattered by a substantial surface below. Now consider a point of observation that is moving in the medium rectilinearly relative to the ground. In order to define an optical field that flows relative to the point of observation, each point of the ambient light can be assigned a vector that is opposite that of the vector of the point of observation. If, for example, the point of observation is moving toward a point, then the optical field will flow outwards from that 'target point'. That is, there is a lawful relation of the type: forward rectilinear motion of a point of observation (F) $\longrightarrow$ global optical outflow (O). (This is an instance of a more general law of ecological optics formulated as: a particular motion of a point of observation relative to a surround $\longrightarrow$ a particular global transformation of the ambient optical field.) Turning the relation around, global optical outflow is said to be information about forward rectilinear motion of a point of observation in the sense that, given that there are no other *natural* ways of producing global optical outflow (Turvey, 1979), global outflow is specific to forward rectilinear motion. This is Gibson's way of defining the information contained in the light – it is *optical structure lawfully generated by the layout of surfaces and by movements of the point of observation relative to the layout.* We can capture the essence of the Gibsonian view in terms of Barwise and Perry's situation-type:

$$\text{(4)} \qquad \text{Situation-type } F \underset{\text{specifies}}{\overset{\text{lawfully generates}}{\rightleftarrows}} \text{Situation-type } O.$$

Put very simply, under Gibson's ecological analysis, *O means F.*

In many circles, however, there is a reluctance to use the term 'means' or to construct a phrase of the form 'O's meaning is F' in the absence of a living thing, an agent. Thus, for Barwise and Perry a relation such as (4) is only one half of their theory of meaning as it might apply to a given animal. The other half is the attunement of the animal in question to the relations. For them, information and meaning are equated but the equation holds, strictly speaking, only when there is attunement of the animal. In short, in Barwise and Perry's situation semantics, the meaning of an event o that is of the event-type O is a product of the relation $F \rightleftarrows O$ *and* attunement to the relation. Putting a living thing that sees and locomotes (and which, therefore, must be attuned by definition) at the point of observation relative to an artificially generated outflowing global optical field, underscores the identity of information and meaning to which the ecological approach and situation semantics subscribe. If *O* means *F*, then for a human observer maintaining an upright stance, global optical outflow will induce backward postural adjustments since forward movement rather than vertical stasis is 'occurring'. Experimentally, this is shown to be so (Lishman and Lee, 1973; Lee and Aronson, 1974).

We are not fully comfortable with the notion that the relation of *O* and *F* can be talked about in two ways. (1) as '*O* informs about *F*' in the absence of an attuned agent, and (2) as '*O* means *F*' given an attuned agent. Our discomfort arises from the desire to develop a consistent direct realist position in perceptual theory (Michaels and Carello, 1981; Turvey et al., 1981; Shaw, Turvey, and Mace, 1982) and our recognition of how elusive this realist goal has been in the past. It may be a quibble but it seems to us that a realist perspective is undercut to the degree that we cannot talk clearly and confidently about situations and events as having meanings for the activities of organisms indifferent to the psychological states of organisms. Given the low-level development of the concept of attunement in situation semantics, there is a danger that attunement might be read in a psychologically contributory sense, viz., the organism is able to interpret the information, that is, to ascribe meaning to the information.

From a realist viewpoint, meanings are discovered by animals, not invented or created by them. The nomic structural constraints of ecological optics relate kinetic and kinematic facts at the ecological scale to optical structure. They are the sine qua non for the evolution of visually guided locomotion, whether the forces for locomotion be produced by legs, fins, wings, or machine (Gibson, 1979). To say that the lawfully produced optical properties are merely information fails to convey the existential import of the nomic constraints of ecological optics: They have been the basis for the successful locomotion of an indefinitely large number of species for a very long period of time. Indeed, we would speculate (and, we hope, not glibly) that attunement to these constraints could not have come about unless they were already meaningful, that is, unless the kinetic consequences of a (naturally occurring) global optical pattern always held.

To fix this equation of information (in the specificational sense) and meaning, consider a point of observation moving on a rectilinear path that is interrupted by a substantial surface perpendicular to the ground. The structured light to the point of observation is usefully construed as nested visual solid angles with the point of observation as their common vertex (Gibson, 1979). Crudely speaking, the larger solid angles correspond to the faces of surface layout and the smaller solid angles correspond to the facets. As a moving point of observation approaches the substantial surface on its path, the corresponding visual solid angles will dilate. Analysis shows that the inverse of the relative rate of dilation is a global property that is specific to the time-to-contact between the point of observation and the surface (Lee, 1976, 1980). To be somewhat pedantic, when a point of observation approaches a surface under constant force conditions (the kinetic perspective) and, therefore, at a constant velocity (the kinematic perspective), it defines a physical situation such that, for any distance between the point and the surface, there is a corresponding time before point and surface contact. The light is lawfully structured by this physical situation of imminent collision such that there are optical properties unique and specific to the facts that a collision will occur and that it will occur at a certain delay. We can identify the time-to-contact optical property, $\tau(t)$, then, in the terms of Barwise and Perry:

(5) $$\text{Situation-type } C(t) \underset{\text{specifies}}{\overset{\text{lawfully generates}}{\rightleftarrows}} \text{Situation-type } \tau(t),$$

where $\tau(t)$ means one thing and one thing only, namely, contact C, at so many seconds from now if the current conditions of motion persist. Contact will occur whether the point of observation is filled by an attuned agent, a blind agent, or a trolley. A given value of $\tau(t)$ means collision at a certain time. This fact of nature is the sort of meaningful invariant to which perceptual systems could adapt and become sensitive or attuned. That $\tau(t)$ is meaningful in the way we have suggested is shown in its use by gannets in controlling their diving for fish (Lee and Reddish, 1981), by flies in initiating their deceleration prior to contacting a surface (Wagner, 1982), and by humans in leaping to hit a ball (Lee et al., 1983).

As we have noted, $\tau(t)$ is information about an upcoming collision *if the current conditions of motion persist*. Obviously, the collision need not be inevitable if the conditions of motion are changed in appropriate ways, for example, if the point of observation stops or veers to the side. Moreover, the strength and timing of the collision can be controlled (as demonstrated by the examples above) if the point of observation accelerates or decelerates appropriately. Is there information for what is appropriate? For example, is there information specific to the circumstance 'deceleration is sufficient to come to a halt before contacting the surface'? Such control information is available in the first derivative of the time-to-contact variable, $d\tau(t)/dt$. In particular, if $d\tau(t)/dt \geq -0.5$, then deceleration is sufficient and there will not be contact; if $d\tau(t)/dt < -0.5$, there will be-contact.

This 'type-of-contact' variable is of particular interest because it is a dimensionless quantity (i.e., it is not attached to any units of measurement) that distinguishes natural categories: contacts vs. noncontacts. The category boundary does not change – the meaning of the situation does not change – with changes in speed of the observation point, its distance from the surface, or the size of the surface. The information specifying the category boundary is lawfuly produced by the movement of a point of observation with respect to a surface. We have suggested elsewhere (Kugler, Turvey, Carello, and Shaw, 1984; Turvey and Kugler, 1984a) that dimensionless quantities that mark off distinct specificational states play the same significant role in law-based explanations of the control of activity as dimensionless quantities that mark off distinct physical states play in law-based explanations of cooperative phenomena.

3. How situation-type meanings become situation meanings

The above are examples of optical properties lawfully linked to particular relationships between a moving *point of observation* and a layout of surfaces. They are examples of nomic structural constraints that underwrite situation-type (or event-type) meanings for locomoting agents, if agents happen to be about. Building the laws of ecological optics around an unoccupied point of observation is an important move: The laws are thereby seen to be general and public, in that any observer, in principle, can occupy any point of observation and share with other observers over time the invariants in the ambient optic array to that point. Given the fact that these situation-type meanings are observer indifferent, however, we need not expect them to fully determine activity when an observer is brought into the picture (just as we do not expect the laws of motion by themselves – operating, as they must, within certain boundary conditions – to fully rationalize a given particle's trajectory). An occupant at a point of observation transforms a situation-type meaning into a situation meaning and while the latter depends on the former, it is not identical with it – as Barwise and Perry take great pains to note.

We wish to show, as do Barwise and Perry, that there is nothing spooky about this transformation of situation-type meaning into situation meaning. An observer occupying a point of observation will have a magnitude (height, weight) that defines an intrinsic scale for the laws of ecological optics, and a repertoire of effectivities (goal-directed activities) that define the uses to which the information based on these laws is to be put. As it is with Barwise and Perry's *discourse situations*, *connections*, and *resource situations*, which squeeze different situation meanings out of an invariant linguistic situation-type meaning (underwritten by *conventional* structural constraints), so it is with *scale* and *intention*, which squeeze different situation meanings out of an invariant situation-type meaning (underwritten by nomic structural constraints). We expect that, formally speaking, these two sets of 'boundary conditions' may have much in common. Let us concentrate, however, on examples of how scale and intention produce situation meanings.

The motion (F') of a point of observation over one surface towards a drop-off to another lower surface will lawfully generate an optical flow (O') distinguished by a discontinuity, viz., a horizontal margin above which optical structure magnifies and gains and below which optical structure magnifies but does not gain. This nomic structural constraint and the information in the specificational sense that it yields can be represented as:

$$\text{(6)} \qquad \text{Situation-type } F' \underset{\text{specifies}}{\overset{\text{lawfully generates}}{\rightleftarrows}} \text{Situation-type } O'$$

The situation-type meaning of O' is 'approaching a brink'. If the point of observation is occupied, say, by a running, four-legged animal then the situation-type meaning is too general and insufficiently constrains the animal's behavior. The richer, particular meanings of 'approaching a step-down place' or 'approaching a jump-down place' or 'approaching a falling off place' are required for the successful control of locomotion. These meanings are situation meanings. They depend on the magnitude of the brink relative to the size of the animal. What is a step-down place for one animal (e.g., a horse) is a jump-down place or a falling-off place for another animal (e.g., a mouse).

The orthodox move is to treat these situation meanings as subjective – that is, as mental categories imposed on an objective, meaningless surround. This is where the spookiness creeps in. Gibson's ecological realism and Barwise and Perry's situation semantics reject this move to subjective categories. Rather, the situation meanings in question must be underwritten by *scaled* nomic structural constraints; they are real relations between real properties of the animal-environment system to which the animal can become attuned.

The strategy, roughly speaking, is to note that (a) the magnitudes of surface layout are describable in units of the animal such as eye height or stride length; (b) above some critical number of a body-scaled unit such as

n (eye heights), a drop-off cannot be negotiated by stepping down; (c) the optical flow can be shown to specify surface layout in body-scaled units (Lee, 1980); and (d) given (c), there is a dimensionless optical property like $d\tau(t)/dt$ which marks off at a critical value distinct specificational states, viz., 'approaching a step-downable place' and 'approaching a non-step-downable place' (Turvey and Kugler, 1984a). That is, given the optical structure O' fashioned by any point of observation approaching any brink in a surface, there is a scale transform s effected by a particular animal a at the point of observation such that $s(O') \longrightarrow O''$, where O'' is the optical structure specific to the brink in the scale of a. In Barwise and Perry's terms, O' is efficient – although its meaning is fixed ('brink'), its "interpretation" ('step-downable', 'not step-downable') varies with s. To reiterate another central theme of situation semantics, "... efficiency is crucial to all meaning."

A similar scenario can be written for the role of intention in transforming situation-type meaning into situation meaning. For example, a baseball fielder bent on catching a flyball transforms situation-type meaning 'impending collision' into 'thing to be intercepted' while a boxer with a glass jaw transforms 'impending collision' into 'thing to be avoided'. Each intention defines a natural category (i.e., selects values of the final conditions of a law) such as 'hard contact' which, in turn, specifies the activities that will produce that category (i.e., constrains values of the initial conditions of the law). Just as understanding the interpretation of an utterance requires understanding its context of use in Barwise and Perry's terms, so understanding how an intention transforms a situation-type meaning into a situation meaning requires understanding the context of laws under which the intention brings the animal, including the convention that defines the initial conditions to be assumed given the final conditions to be obtained (see Turvey et al., 1981, for a more thorough discussion of this line of reasoning).

Throughout Gibson's ecological realism and Barwise and Perry's situation semantics is a commitment to treat meaning as an aspect of reality. This sort of treatment gives rise to explanations of meaning that appeal to natural law; understanding meaning is not qualitatively different from understanding other natural phenomena. The strategy is reinforced, for the Gibsonian program, in never losing sight of the control of locomotion as the paradigmatic problem to be understood. Locomotion is a skill that is not limited to humans and, therefore, the temptation to ascribe it to special mental powers is lessened. Barwise and Perry, on the other hand, are trying to be realists in a bailiwick where mentalese is at its most alluring. We applaud their efforts.

Note

[1] Although we agree with the distinction that Barwise and Perry draw between situation-type and event-type, for purposes of exposition we use situation-type for both circumstances.

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