Phenomenal Worlds and Nervous System Activity

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Abstract

The epistemological situation of a single cell is considered. In chemotaxis, the relation between perception and action is found to be lawful and bidirectional. Consideration of the perception/action relation allows a characterization of the phenomenal world of the cell. This phenomenal world is grounded in perceptual distinctions that are relevant to the sustained viability of the cell. Moving up the phylogenetic chain, this lawfulness, and its relation to the phenomenal world of experience, is found to be essentially unchanged in multicellular organisms. Nervous systems add some innovation, in allowing distal responses and the non-linear combination of information, but from cell to human, the differentiation of the phenomenal world is found to arise from the lawfulness of the perception/action relation, which in turn reflects the biological constitution of the organism, and not a pre-given objective world. This recognition suggests that rather than looking within the nervous system for representations of pre-given, external, entities, one might do better to explore the fit between the function of the nervous system and the phenomenal, meaningful, world encountered by the organism in experience. **Keywords:** representation; epistemology; ecological psychology; enaction; phenomenology; neutral monism;

Figure 1: The hummingbird's beak and the flower share a long history of co-evolution.

Introduction

The utility of the notion of representation in nervous systems has been much debated, and its central explanatory role in accounting for interaction between an organism and its environment is under considerable attack from many quarters. To some, representations are firmly established explanatory constructs, as, e.g. in the preservation of retinotopic mapping in the visual system through several successive processing steps) (Tusa, Palmer, & Rosenquist, 1978), or in rather more abstract form, as evidenced by mental rotation tasks (Shepard & Cooper, 1986). To others, the very notion of representations constitutes a homuncular mistake (Dreyfus, 2002). This essay will concern itself primarily with representation as it is evoked to explain the potential for perception and action in an environment. It will not address higher order representations, assumed to underlie intellectual activity such as chess playing or the use of propositional language.

A humming bird's beak is exquisitely matched to the shape of the trumpet of a specific flower (Figure 1). The flower's shape, in turn, is a perfect fit to the bird's beak. Both are the product of a long process of co-evolution. Nobody would be tempted to describe this state of affairs by saying that the beak represents the flower, or vice versa. A long history of co-evolution has produced a matching pair in beak and trumpet. This state of affairs seems to parallel the relationship between nervous system activity and the phenomenal world very well.

I wish to take this (perhaps perplexing) analogy seriously. To do so, it is useful to consider the phylogenesis of perception/action systems, and to extend our view back to the epistemological situation of a single cell. This example has been given detailed consideration recently by several theorists from both phenomenological (Thompson, 2007) and biocentric traditions (Lyon & Keijzer, 2007; Van Duijn, Keijzer, & Franken, 2006), and hearkens back to the account of the continuity of cognition and life put forward within the enactive tradition (Maturana & Varela, 1987). Even the simplest prokaryotic cells exhibit complex behavior individually, and, especially, collectively. What follows is thus a cartoon-ishly simplified sketch whose purpose is to illustrate the epistemological basis for a phenomenal world. By phenomenal world is meant the totality of immediate experience for an individual.

An attempt to describe in human language what the phenomenal world of a cell is like may seem like pure folly (Nagel, 1974). However, without claiming to have an experience similar to that of the cell, we may consider the structure of the encounter between a cell and its environment, noting what information is available to the cell, and what it is information about. In this way we can attempt to uncover the basis for encountering a world, and thus having an experience, as long as we restrict our analysis to a suitably pared-down case. Therein, it is to be hoped, lies the utility of a cellular example. A more ambitious example is found in Jakob von Uexküell's spirited attempt to describe (and draw!) the phenomenal worlds of a variety of animals, from paramecium to dog (Uexküll, 1989), in which he considers the set of perceptual distinctions potentially available to the individual based on their capacity to make discriminations and to act in their environment[1].

[1] von Uexküll retains a clear distinction between the perceiving

Perception/action and the epistemological predicament of a single cell

For a lone cell in a medium, movement is based on chemotaxis, which is the process by which a cell appears to swim up a nutrient gradient or away from a source of toxins (Figure 2). Through cellular movement (described in detail in van Duijn et al., 2006), a chemical concentration gradient is available at the membrane of the cell. The movement of the cell stands in lawful relation to this gradient. If one assumes some agentive nature to the cell, this looks like perceptually guided action, but that conventional interpretation assumes a causal direction (perception resulting in action) that the situation does not warrant. Movement of the cell makes the gradient manifest (and so action gives rise to perception), while the gradient itself can account for the form of movement (whereby perception gives rise to action). In this situation, perception and action are inseparable, and collectively instantiate a single functional relation between organism and environment. For this simple example, the relation is very direct and is mediated only by the biochemical processes within the cell that extend from receptors on the membrane to activation of the flagellae that propel the cell.

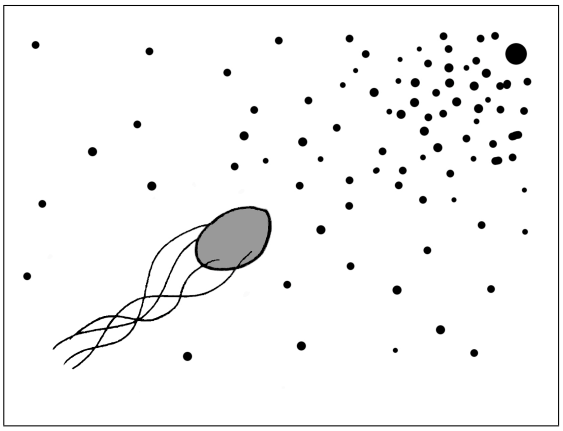

Figure 2: In chemotaxis, an E. Coli cell alternates between periods of undirected tumbling, and coordinated swimming in a single direction. The likelihood of changing from coordinated movement to uncoordinated tumbling is inversely proportional to the concentration of nutrient sensed, producing, on average, movement towards the nutrient source. (Van Duijn et al., 2006)

What world does such a cell encounter? For our present purposes, we can exhaustively describe the phenomenal world of this simple (and simplified) cell, and that description can be couched in terms of perception or action. It is important, then, to bear in mind that these are simply different facets of the same functional relationship.

subject and the environment perceived around them. The present account goes further in insisting on a unity of subject and object in immediate experience.

If we consider perception, or those features of the world that are distinguishable for the cell, we find a single distinction, and it is a spatial one. The gradient expressed at the membrane makes one and only one distinction possible: it distinguishes this direction from that direction, where 'this' is the direction in which more nutrient lies. Or one might adopt a less discrete view of the space inhabited by the cell, and say instead that the gradient gives rise to a simple non-uniform distribution in three-dimensional space. What is central to either descriptive convention is that an undifferentiated spatial environment becomes meaningfully differentiated by virtue of the gradient encountered. A similar consideration of the potential for action of the cell again highlights a simple differentiation. Instead of movement being equally likely in all directions, action is now directed towards the nutrient source (or away from toxins). The space of potential action is thus shaped by the gradient.

The cell thus encounters a differentiated world. Admittedly, its structure is minimal, because this is a deliberately pared down example. Nevertheless, as external observers, we can make the following observation: The single distinction the cell is capable of making is a distinction firmly rooted in the cell's own constitution. A chemical gradient, considered in the absence of a sensing organism, has no special ontological status, and is not information bearing. To the cell, however, the gradient is the basis by which the world resolves from homogeneity into a differentiated space. We can readily imagine the presence of several other chemical or energetic gradients at the environment/cell border to which the cell is entirely indifferent. Because they bear no significance to the sustained identity of the cell, they form no part of the phenomenal world of the cell, just as the many television broadcast signals that permeate the space around you form no part of your phenomenal world. The world the cell encounters is drawn in terms of the cell's own constitution. (If sensitivity should arise to some aspect of the environment that is irrelevant to the maintenance of the identity of the organism, there will be no reason for this sensitivity to be preserved or honed in subsequent evolutionary change.)

The perception/action relation in more complex beings

The example of a single cell is informative precisely because we can retain oversight over all aspects of the phenomenal world that arises, or is brought forth (to use the parlance of Maturana and Varela, 1987), for the cell. As we consider more complex organisms, multi-cellular organisms, organisms with nervous systems, and ultimately, humans, the fundamental characteristics of the epistemological situation do not change in principle.

The box jellyfish larva has what has been described as the simplest visual system in the animal kingdom (Nordström, Wallén, Seymour, & Nilsson, 2003). The entire animal has only 5 differentiated cell types, three of which are found in the membrane (Figure 3). Most membrane cells have sin-

gle ciliae which vibrate in uncontrolled fashion, producing an undirected force. A second type of membrane cell is photo-sensitive, and the action of the light within the cell causes their ciliae to adopt a specific angle with respect to the light gradient. (The third type is irrelevant in the present context.) Collectively, these photo-sensitive cells with their ciliae act as a distributed rudder, steering the otherwise uncontrolled motion of the larva with respect to the light gradient. Again, perception and action are directly, inextricably, and reciprocally, linked. They constitute a single functional relation, and they serve to exploit lawful properties of the environment that are matched to the constitution of the organism.

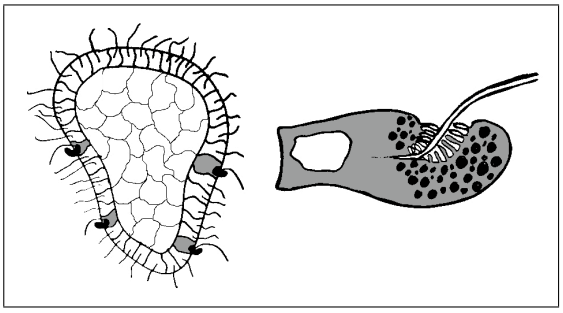

Figure 3: Left: Most epithelial cells have cilia which move randomly. Interspersed between these are ocelli which are equipped with photoreceptors. Right: An ocellus combines photoreceptive microvilli that act directly to orient the movable cilium, thus creating a distributed rudder. Each ocellus acts as an independent sensory-motor unit. (After Nordström et al., 2003)

With the introduction of nervous systems, nothing fundamental changes. The presence of a nervous system allows an organism to do two things that those without nervous systems can not. Firstly, information expressed as a physical, chemical or energetic gradient at the membrane can now elicit a rapid distal response in the organism. This is a very substantial innovation, allowing larger, more responsive organisms that are capable of much more nuanced and varied interaction with their environments. A stimulus manifested at one point on the border may produce a response in an entirely different location.

The second major innovation that arises with a nervous system is that information from two or more locations on the membrane can be combined, allowing highly non-linear response characteristics to continuous gradient differentials, and vice versa. Again, this vastly increases the degree of mediation, or indirectness in the perception/action relation. For the external observer, it becomes much harder to uncover the lawfulness of the relation, but there is no reason to think that the relation suddenly changes its lawful character. Indeed, even in humans, we can sometimes see this very direct relation, as for example in the strong link between postural sway and the optic flow occasioned by a moving environment such as a swaying room (Lishman & Lee, 1973).

Despite the richness that arises in the perception/action relationship with the introduction of a nervous system, the fundamental insight that the action of the organism stands in lawful relation to the physical/chemical/energetic gradient expressed at the sensory border with the environment persists. This is as true of the simplest animals with nervous systems, such as the hydra, as it is of humans. In as much as the phenomenal world of the organism arises from its embedding as a perceiving/acting system within a rich environment, the world encountered by either hydra or human is drawn in basic strokes derived from the perception/action relation. The kind of distinctions possible to such an organism are those that are now, or (phylogenetically) were once of some functional significance to the maintenance of its identity as an individual organism. Although the phenomenal world arises now, based on the perception/action system of a single organism, its structure is a function of the phylogenetic lineage of that individual, considered as an extended unity. The world encountered in experience is thus drawn in strokes grounded in the constitution and needs of a living being with its evolutionary history, and is in no sense pre-given.

Nervous systems, as we have seen, allow considerable mediation between information gradients and movement. One result of this is that the organism appears to possess a great degree of autonomy in its motion through an increasingly complex environment. Our received notions of agency and free will may lead us to ignore the lawfulness that underlies the perception/action relation. While this lawfulness may be apparent in the minimalist case of the single cell, it is largely obscured in animals with complex nervous systems and sophisticated behavioural repertoires. Indeed, a full reconciliation of our accounts of agency with our increasing appreciation of the lawfulness that characterizes the operation of biological systems is still outstanding (Wegner, 2003). However this apparent autonomy does not invalidate the observation that all distinctions made by the organism in perceiving/acting are predicated upon the physico-chemico-energetic flux at the border between organism and environment. This is as true for humans as cells. The information required for a human to apprehend a distant object is expressed in the structure of the optic flow on the retina. Vision, touch, audition, all function through structured energetic distributions at the boundary between biological organism and environment. In recognition of this, it has been suggested that touch, rather than vision, ought to provide us with our conceptual paradigm for perception, as it forces us to recognize that structured energy distributions at the surface are the means by which we perceive anything (Noe, 2006). We tend to be less aware of this when thinking about vision, both because of the seductiveness of the false analogy between the eyes and optical instruments with lenses or windows, and because the structured distributions for vision are hidden, at the back of the eyeball.

Those distinctions that perception/action systems retain through phylogenesis must be presumed to be those that contribute to the continued viability of the organism's lineage.

Given the phylogenetic distance between a human and a single cell, many of the distinctions we are capable of making, and that thus serve to differentiate the world as experienced, are presumably interpretable only with reference to distant ancestors and their associated environments. Evolution differentiates, modifies, and refines, but it does not do spring cleaning. It is therefore not surprising that the worlds we encounter in immediate experience appear entirely distinct from us - so much so that we conventionally describe an inner (mental) and an outer (physical) realm as if they were entirely distinct. Yet considered thus, it is apparant that the phenomenal world, the world revealed in immediate experience, is in no sense distinct from the perceiving/acting organism, but is, rather, a function of the organism (together with its entire phylogenetic lineage) and its embedding within a continually evolving environment.

We now consider a more complex account of human nervous system function that is usually described as representational. Work in human motor control has convincingly demonstrated that skillful action is based, in part, upon the ability of the central nervous system to predict events probabilistically (Körding & Wolpert, 2004). The probabilistic models that best account for variability in action have been found to be nearly optimal in a Bayesian sense. That is, the action is optimized with respect to the prior probabilities of event distributions in the environment. This is conventionally described as the representation of a probabilistic model of the environment that is computed by the brain. It can, however, equally be seen as an optimal fit between the neural dynamics of the brain and the characteristics of the environment relevant to the action of the organism. Viewed in this light, even the complex, seemingly autonomous, action of a higher mammalian organism illustrates the optimal fit between its constitution and those informational aspect of the environment that are relevant to its functioning.

Discussion

The argument here suggests a somewhat unorthodox account of what it is that nervous systems do. Nervous systems mediate the perception/action relation, thereby giving rise to phenomenal worlds. This claim hardly suffices to account for much of the presumed role of nervous systems in higher order cognition, nor is it so intended. Instead, it points to the essential unity between the subject and the world encountered by the subject in immediate experience. In this vein, it is in keeping with a central claim of neutral monism (James, 1904) that in immediate experience, there is no distinction between the experiencer and the experience, or between the object and the perception of the object. William James (1904) observed:

> The instant field of the present is at all times what I call the 'pure' experience. It is only virtually or potentially either object or subject as yet. For the time being, it is plain, unqualified actuality, or existence, a simple *that.* (James 1904, p. 23)

James, of course, maintained a clear distinction between the field of pure experience and the derived world of concepts. (A similar distinction is well preserved in many interpretations of Buddhist thought, though that would lead us too far afield here.)

Whereas many received accounts of perception start with a nervous system which is distinct from the world being represented, this analysis suggests instead that there has been a long evolutionary process of co-development between the perception/action capabilities of an organism and the world experienced by that organism. The fundamental separation suggested by a representational account is replaced by a relationship of co-determination between organism and phenomenal world.

This account of the deeply intertwined nature of the relationship between the organism and the environment suggests a retelling of an old story: that of the affordance principle underlying the discipline of ecological psychology (Heft, 2003). According to the present account of the phylogenesis of perception/action systems, all distinctions an organism is capable of making in an environment are those that are, or have been in its phylogenetic past, of utility in guiding action in the service of maintaining the structure and viability of the organism. Affordances, by this account, are not additional properties some things in an environment have, such as the graspability of a door handle or the climbability of a set of steps. The affordance principle goes much deeper. The entire phenomenal world that arises through the action of nervous systems completely embedded in complex bodies, immersed in information rich environments, arises because some aspects of the environment offer action possibilities to the organism. Every 'thing' we encounter, every distinction we can make in our phenomenal world, arises from the lawful exploitation of some aspect of the environment that affords action, now or in the phylogenetic past. This, I believe, is what the enactive approach talks about when the phrase 'bringing forth a phenomenal world"' is employed (Maturana and Varela, 1987).

The notion of representation, then, that has guided so much theorizing within cognitive science, appears now as a focus on one half of an inseparable pair. Whereas ecological psychology, by and large, has focused on the structure of the information gradient expressed at the sensory surface, cognitive psychology, with its focus upon representation, has looked almost exclusively inwards, at the nervous system. A conventional psychophysics experiment done in a carefully controlled environment then appears in a slightly new light. It is just as if we were to attempt to study the beak of the humming bird through experiments in which the bird feeds from a flat, rigorously controllable, plastic bird feeder instead of from the trumpet of its natural match, the flower. It is not that one would learn nothing about the beak from this exercise, but that many important aspects thereof would surely be missed. This will come as no news to ethologists.

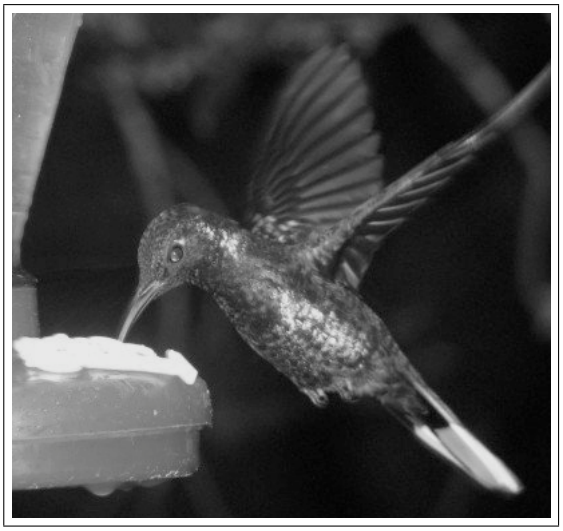

Figure 4: The beak and the feeder share no common history.

Acknowledgments

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