Evolution and Perception

Frank P. DeVita

Boston University

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Introduction and Scope

When thinking of perception, we often think of vision. This is partly due to our anthropomorphic tendencies, but it also relates to the paradigmatic character of vision as an environmentally oriented information processing system (Hooker, 1978). Biologically speaking, vision is the detection of changes in light by an organism, largely for the purpose of some behavior (e.g. hunting or avoidance of predators). This general formula of detection for behavior applies across species. The term "perception" also carries with it the implication of an *actively* perceiving subject, but this implication is not helpful in biological discussions pertaining to the nature of evolution and selection in general, for we cannot say that all species actively perceive or have perceptual apparatuses *qua* animal species. Rather, some merely have molecular detection systems. Therefore, we must either broaden our definition of perception if we are to talk about it in the context of evolution and biological systems that process environmental information. In this paper, I (1) offer that a "lossless" information-centric conception derived from perceptual realism that I call *bioinformatic realism* is useful for biological and evolutionary discussions of perception, (2) show how bioinformatic realism is possible by describing the flow of information in biological systems and, (3) overall, argue for the coherence of bioinfomatic realism from an evolutionary perspective, considering some objections and counterpoints to my view along the way.

Information Processing and Evolutionary Fitness

Without information about its environment, an organism (or species) may perish at the hands of ecological change. Access to ecological information then, is advantageous for a number of reasons, including nourishment, hunting, mate selection, avoidance of predators and many other factors bound up with biological fitness. Environmental information is extracted by animal species in the process we refer to as "perception," but many other organisms also extract information by processes that we do not call "perception," e.g. heliotropic plants and microorganisms. Thus I claim that the evolutionary discussion of "perception" in the broadest sense is really a discussion of information flow between the external world and an organism. The integrity of this information, its processing and the possibility of fitness enhancement in light of it are therefore crucial in evolutionary debates, for *all* organisms must detect physical changes in the environment and extract ecological information as a condition for the possibility for fitness enhancing behavior. Furthermore, this information must be veridical with respect to the actual state-of-affairs in the world, for otherwise, ensuing behavior could be potentially fitness reducing. Considering the generally high energetic cost of a perceptual apparatus or detection system and the need for veridical information about the environment, there is reason to believe that information processing in biological systems must be largely "lossless" if it is to be maximally fitness enhancing. That is, "perception" *qua* environmentally oriented information processing must detect the *actual* state of affairs in the environment in order for fitness to be maximized.

I have borrowed the terms "lossless" and "lossy" used throughout the paper from information and coding theory, where they refer to the quality of data compression in which information is constructed exactly as it is from the source in a compressed datum (lossless) or is constructed with distortion due to the discarding/loss of source data. In this paper, I use the terms to refer to the integrity of information during detection and processing. Here, "lossless" to refers to information detection and processing that preserves the integrity of information from the environment, and "lossy" to refers to information detection and processing that reconstructs information for the organism such that the original source information is modified or changed in the process of reconstruction or reconstitution. This evolutionary information processing interpretation of "perception" is useful for biological and evolutionary discussions because is applicable to all biological species and allows us to speak cogently about the relationship between perception and evolution, which, in my view, is a essentially relation between environmental information and biological systems.

If an organism needs to acquire relatively lossless information about its environment, there is also strong reasons to consider perceptual realism as important to the evolutionary discussion of environmentally oriented information processing systems, and we can use concepts from this view to articulate a more formal understanding of information flow between organism and environment. By definition, perceptual realism implies that objects have an independent existence in the external world and that a perceiver (an organism in our case) directly interacts with this reality. With respect to information, we can derive from perceptual realism that an organism interacts *directly* with environmental information. In terms of biology, this means that the organism extracts and utilizes information directly from the environment itself.

Perceptual realism is contrasted with perceptual antirealism and constructivism, which both hold that objects perceived still exist independently of a perceiver, but that perception is actually *of* an intermediary entity or reconstruction of the actual state of the world, respectively (n.b., these intermediaries have been referred to as "ideas," "appearances" or "sense data" in the history of philosophy). From the information perspective, we can derive that, in the antirealist's view, information is extracted from the world and *reconstituted* (by the organism) such that the reconstituted entity conveys the environmental state of affairs to the organism. Biologically, this view suggests that the organism extracts information directly from the environment, but utilizes it through a reconstructed and, in my view, lossy form. Through reconstitution, information may become distorted as in, for example, the erroneous copying of digital information that results in corrupted files or that of spoken information in a game of "telephone."

Given the above considerations and the roughly high cost associated with detection/perception systems, it is suspect at best to hold that a "lossy" environmentally oriented information processing system would be strongly selected for, especially considering the multiplicity of perceptual apparatuses in existence. Thus, with respect to information extraction and processing by biological organisms, a *bioinfomatic realism* derived from perceptual realism seems to be most compatible with evolutionary notions of maximizing fitness. The main idea is this: The more veridical, accurate and lossless information is *for the organism*, the more advantageous and potentially fitness enhancing its behavior will likely be. The groundwork for my view can be found in arguments advocating realism over post-Kantian constructivism and constructivism in general (Boutler, 2002 & Raftopoulous 2008, respectively) and involves claims derived from such arguments. These include, (1) that there is an organism-independent external world, (2) that changes in this external world constitute the information available to an organism through selective information processing and (3) that the perceptual apparatus/detection system interacts directly with veridical information and transmits it to the organism losslessly, i.e. without significant alteration, modification, reconstruction or reconstitution. Thus, I argue for thinking about "perception" in terms of a relatively lossless environmentally oriented information processing system in the context of biological and evolutionary discussions, i.e. from a bioinfomatic realist perspective.

Bioinformatic Realism

Restated, my view is that if information must be derived from changes in the environment through perceptual and detection systems, its acquisition must not be erroneous if it is to be maximally fitness enhancing. Error is not an issue if information processing does not involve an intermediate reconstitution or reconstruction. Granted, each organism will have access to only a limited portion of the complete set of information about the world based on its perceptual/detection structures, but there is no reason to assume that these structures extract "raw" information and then must "package" it such that the organism can "make sense of it" as the bioinfomatic antirealist/constructivist position might suggest. In terms of information integrity, this would be an undesirable mechanism, for if a coding error were to occur in this process of (re)construction of the intermediary, this could be fitness reducing and adversely affect survival. For example, if the perceptual/cognitive apparatus of the trapdoor spider does not veridically reconstruct changes in pressure and vibration, it will not be able to effectively capture prey. Thus, bioinfomatic realism holds that the organism does not reconstruct information in this scenario, but rather that the organism interacts directly with ecological information, and thus that direct, relatively lossless environmentally oriented information processing is really what is being discussed in biological and evolutionary discussions of "perception."

With respect to information and fitness, a non-constructive, realist processing system is most desirable because it preserves information integrity and ensures that behavior in response to environmental changes is based on the actual state of the environment. If information is processed in this way, the organism directly accesses information about environmental changes rather than a (re)constitution of it. An intermediate informational entity also seems superfluous from an organism-level optimization perspective because the optimal information-organism relation would entail direct access to environmental information rather than direct access to an intermediary representation of the same information. Lossless information obtained by direct access will be the most useful because it is veridical and thus it seems puzzling to argue that a "lossy" processing system would be strongly selected for considering the energy cost associated with perceptual and detection systems in general.

An objection to my view may state that the antirealist/constructivist system is necessary given the very nature of perceptual apparatuses, as biological systems that have to *transduce* changes in the environment from a physical medium (e.g. photons) to a biological one (e.g. neural or molecular activity). However, I maintain that even transduced information is not necessarily (re)constructed information. Biological transduction of environmental information may be the movement of "raw" information from the environment *through* perceptual and detection systems to the organism *qua* biological "agent." Thus, in bioinfomatic realism, the information obtained by the organism simply *is the* information produced by environmental change (e.g. changes in light energy). That is, the organism *directly* perceives its environment, even though it may only do so selectively based on the constraints of a perceptual/detection apparatus (e.g. human vision only extracts electromagnetic information in the visible range of the light spectrum). By contrast, perceptual antirealism implies that environmental changes are only known *indirectly*. For reasons discussed above, this configuration seems minimally optimal with respect to information processing, selection and the possibility of fitness enhancing behavior. Now, A consideration of environmental changes themselves, the information they provide and the utilization of this information is important to establish the conditions for the possibility of bioinfomatic realism and an argument for the necessity of relatively lossless environmentally oriented information processing in biological organisms.

Information, Environment, and Action

Environmental changes are fundamentally physical. They include, for example, changes in luminosity, the presence or absence of chemicals, the movement of objects and the behavior of other organisms. We have so far established that (1) organisms must expressly and accurately detect and respond to these changes if the probability of survival and successful reproduction is to be maximized, for fitness is fundamentally bound up with the ability to detect environmental changes, and (2) that detection of environmental change is bound up with information processing. Moreover, we have reasoned that relatively lossless processing of the limited set of environmental information compatible with an organism's particular perceptual apparatus is the optimal information extraction and utilization system. However, lossless information extraction alone is not sufficient for enhanced fitness.

An organism must *do* something with or with respect to the information it obtains from the environment in order for its detection behavior to be potentially fitness enhancing. Thus, detection must be paired with a response or *action*. That is, once an organism detects environmental changes, it must use this information in a way conducive to increasing fitness, i.e. respond in a beneficial way to an environmental change, if fitness enhancement by behavior is to be a logical possibility. I maintain that this detection of environmental changes must be relatively lossless if an organism's fitness is to be maximally enhanced, and this realist model can be mapped on to the phenomena of microorganism chemotaxis and human visual experience.

Flagellated microorganisms move randomly by alternating "runs," in which flagella rotate counterclockwise in a bundle to push the cell forward, and orientation changing "tumbles," in which flagella rotate counterclockwise, separating the bundles and randomly orienting the cell, thus causing the next "run" to be in a new direction. In the presence of a chemical gradient, runs are longer and more frequent relative to tumbles and the cell moves "up" the gradient. In the absence of a gradient, the nutrient receptor associated protein CheA is phosphorylated, which initiates a cascade that phosphorylates another accessory protein (CheY) that, in turn, interacts with flagellar machinery to induce counterclockwise motion and "tumbling." When the gradient is present, the CheY remains dephosphorylated, inducing counterclockwise flagellar rotation and "running" (Stock, Stock & Lukat 1991, Madigan et. al. 2009). In this situation, the microorganism interacts directly with environmental information to behave, namely, the chemical molecules in its immediate environment.

In human vision, the eye functions as the external sense organ, detecting changes in electromagnetic energy in the environment. Electromagnetic waves from a light source interact with objects, scatter, traverse the lens and hit the retina in a process by which the scattered light carries information about the environment (because it physically interacts with objects in the world). The retina captures this information. After retinal contact and stimulation of photoreceptor cells (rods and cones) by "information-laden" light, graded potentials travel through bipolar and amacrine cells until action potentials initiated in ganglion cells are evoked and travel through the optic chiasm, lateral geniculate nucleus and optic track to the visual cortex in the occipital lobe of the brain (Widmaier et. al. 2006). The brain then presents the environmental state of affairs as visual experience and we can respond to these changes with behavior that ensures our survival, e.g. waiting to step into the street if a speeding vehicle is approaching. In this case, the human perceptual system brings information about the environment to the subject *through* its biological structures, illustrating the direct interaction between organism and ecological information. The physiology described here does not suggest that information had to be "unscrambled," but rather supports that it is selectively extracted based on constraints set by the perceptual apparatus.

In each of these cases, an organism has (1) extracted information about a change in its environment with biological machinery (2) responded to this information (3) increased its fitness *qua* survival by actively controlling its immediate environmental situation. There are indeed general fitness benefits to having such structures that can interact directly with information from the environment. First, the organism can detect the presence of something that contributes to its immediate survival. Second, the organism can respond in a way that increases the likelihood that this immediately beneficial situation can continue. Third, by increasing its likelihood of continued existence, it is increasing the likelihood that it will reproduce. In the case of microorganisms, even one a short time period of nutrient security makes possible the production of many offspring, and it such security is even more beneficial for organisms with longer reproductive cycles. In terms of fitness, the ability to detect and respond to environmental change is thus vital. In terms of information, I see no reason to think that a response to environmental change necessarily involves interaction with a mediating reconstructed informational entity instead of with the ecological information itself. Rather, it seems most logical to say that the organism extracts information directly from the environment by physical detection to the physically limited extent of its detection capacities and uses *this* information to act, not a *reconstruction* of it.

In both the human and microorganism cases, information must retain its integrity for it to be maximally beneficial. That is, it must be about the actual state-of-affairs in the world. If this were not so, behavior may not constitute a fitness reduction because of error in representing environmental information. This problem of information integrity is central to the status of perceptual realism in biology. The bioinfomatic realist solution to the information integrity problem is to understand information as a *constant* in the relation between the changing environment and the living, changing organism. The environment constitutes a "stream" of information that varies in accordance with physical changes. An organism can detect the portion of this stream that is compatible with its perceptual apparatus or detection system, thus interacting directly with a particular "slice" of the informational whole. For example, the human visual and auditory systems are only "in tune" to a bound range of the light and sound spectra, respectively. The detection system extracts the compatible parts of the informational stream and the organism responds to this information with observable behavior. I cannot think of a convincing reason to believe that the information accessed by the organism was derived from the original stream of information and then constructed in the right way by the organism receiving it. With respect to these concerns, it seems more plausible that the "stream" is fully constituted prior to the organism's interaction with it by physical changes themselves and made available to the organism by its detection/perceptual system.

Evolutionary Pressure to Perceive

For any organism, the possibility of acting on the most accurate information in the environment constitutes a general selective pressure to, in the broadest possible sense, "perceive" veridical information. That is, as argued here, to have and use a lossless environmentally oriented information processing system. This paradigm embodies the central ideas motivating bioinfomatic realism and resonates agreeably with evolutionary concerns about fitness maximization and optimization as discussed above. It seems confused for a biological information processing system to utilize an informational intermediate, for this only raises the probability of biological data corruption and compromised information integrity. The only *necessary* intermediary here is the biophysical entities (sense organs, molecular pathways etc.) that connect detection with response. To say that such structures *are* the informational intermediaries also seems confused, for the transduction of information is *through* biological structures, but these structures are distinct from the information itself, which is fully constituted by physical changes. In sum, the realist picture of information flow in biological systems provides sufficient ground for the validity of bioinfomatic realism in biological and evolutionary discussions of perception for, it is apparent that relatively lossless information is a necessary condition for the possibility of maximally fitness-enhancing behavior.

On its face, antirealism and constructivism are contentious because they assume the construction of an intermediary. This seems incompatible in organisms without cognitive systems, and not all species possess cognition capable of producing "ideas" or "sense data." If veridical perception is a condition for the possibility of fitness-enhancing behavior, biological information processing must not distort, alter or compromise information about the environment in constructing a perceptual intermediary. If this were to happen, an organism would run the risk of acting on faulty information, which, in turn, may motivate fitness reducing behavior, which is contrary to the fitness enhancing or optimizing tendencies of natural selection. Thus, in the interest of the integrity of information, I hold that realism about perception is important in broad biological and evolutionary discussions of perception.

Conclusion

By the above discussion, I hope that I have conveyed the complexity surrounding the discussion of perception in a biological and evolutionary context, and the importance of understanding it in an alternative way if we are to speak about this phenomenon in the broadest sense. If our general idea of perception is bound up with higher cognitive ability and associated with humans and animals such that we are hasty to apply it to non-animal biological species, our idea is too narrow for discussions about evolution itself, for *all* species are affected by evolution and natural selection. Thus, when discussing biological phenomena generally, as is many times the case in evolutionary biology and the philosophy of biology, I propose that we broaden our consideration of what it is to "perceive" by thinking about perception in terms of information flow from the environment to the organism and the general characteristics of environmentally directed information processing systems that have evolved across species over the history of life. I believe that this information-centric conception of perception can be helpful for thinking about how living systems in general handle and act on information made available to them by the environment. To end, some food for thought: In the broadest sense, perception may just be a term that we have attached to the ability to process and act on information for the purpose of enhancing fitness and increasing the chances of successful reproduction. Is this the distinguishing feature that separates the living world from the non-living world?

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