Concepts for the Study of Information Embodiment

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Abstract

The growing study in information science of the role of the body in human information practice may benefit from the concepts developed around a set of fundamental forms of information previously published by the author. In applying these concepts to the study of human information practice, we see a framework that nicely names and locates the major components of an understanding of information seeking of all types, including that related to the body. We see information in nature, what happens to information when it encounters a nervous system, and how that information is used within nervous systems to both encode and embody the experiences of life. We see information not only in direct encounters with the body but also as it is experienced through extensions of the body, used for both input and output purposes. We also see information in the body in relation to a larger framework of forms of information encompassing both internal and external (exosomatic) information. Finally, a selective review is provided of related research and theory from biology, anthropology, psychology, and philosophy, which supports and deepens our understanding of the approach taken here to information embodiment.

Introduction

I am grateful to the editors of these issues on information and the body for making me aware of the topic, and welcoming my contribution to it. In this article, I initially set out to demonstrate the ready applicability of the several information concepts I had developed in an earlier article (Bates [2006] 2016) to the content of these issues. I had written about information

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with the objective of finding a foundational conceptualization of information that could be used as a basis for theory and thinking in the field (see also Bates 2005). For these *Library Trends* issues, I wrote an initial draft focusing on demonstrating how the concepts I had introduced earlier related to the consideration of information and the body.

My own ideas had been seated in extensive research done at the time of writing the two above-mentioned articles on information. The current editors quite reasonably asked me to enrich the current discussion with an updated review of the available research and thinking in the scientific fields supporting this view. What I discovered was an explosion of fascinating new work being done in biology, anthropology, psychology, philosophy, and information science that provided abundant support for this approach and added many new insights.

The work in these related fields is very much in flux, however. The work is at that early stage in the development of a new area or approach in science, where a profusion of ideas is being produced. It is not fully clear at this point where all the numerous positions of researchers harmonize or conflict, nor how the new understanding can be simplified and rendered internally consistent. There is as yet no simple, pat, description of the new theory that can be dispensed within a few paragraphs. Instead, many researchers are developing approaches that provide new meaning for old questions like "What is consciousness?"; "How is information transferred and stored within and between nervous systems?"; and, of course, the core question of these issues: "What is the role of information in the body, and how does it relate to our traditional understanding of information seeking and information transfer?"

A full survey of all the new developments in these related fields would be book-length or more. Here, instead, I will identify some key papers and themes that demonstrate the exciting work going on in the several fields, and which support the approach taken in this article—and which probably support many of the other articles in these issues as well.

For all these reasons, I have decided to leave the original straightforward exposition of the information concepts as is in part 1 of the paper, to simplify the narrative and promote understanding. Then, in part 2 of the paper, I discuss various of the philosophies and research themes relating to the points made in part 1, in order to deepen understanding, and demonstrate the breadth of support from these other fields for research in our field on information and the body.

Metatheoretical Commitments

The approach taken in this paper largely draws on the conventional understanding that scientific research is fundamentally empirical, inductive, materialist, and rooted in various widely known and long-established techniques ("scientific method") for observing natural phenomena, experimenting with them, conceptualizing relationships and causality within the observed phenomena, and testing and disproving or confirming hypotheses and conclusions developed about them.

Whole libraries have been written about philosophical questions surrounding the underlying metatheory of science. This article does not address these numerous questions, and instead rests on the general scientific methodological approach that is assumed in most scientific writing.

Part 1 of the article, in which concepts from the author's earlier work are applied in the area of information embodiment, only claims value for the information disciplines. Fine-grained theoretical and empirical details from other disciplines are not reviewed. The goal is to build on these other sciences' findings, without engaging deeply in those fields' own scientific disputes and controversies. I want to use their work—in its current unsettled state—to enrich our thinking in information science, not to try to solve those other fields' own debates, for which they alone have the necessary understanding.

The selective review in part 2 of the article pulls out illustrative findings from numerous writings across several disciplines that address embodiment, and reflects on the application of these findings to information science.

Part 1. Concepts

Natural and Represented Information

In writing this article, I set out to interpret the information concepts that I developed in an earlier article, "Fundamental Forms of Information" (Bates [2006] 2016), for the purposes of these issues' topic, information and the body. In the process, I developed insights that go beyond the earlier article, and may advance these issues' topic as well.

These terms are defined for the purposes of the information disciplines; no claims are made beyond these fields. The distinctions made between terms are meaningful for information work. Biologists and neurologists would find some of these terms hopelessly general for their purposes. The objective here has been to define for our own needs, and to do so in a way that does not *conflict* with what is known at those other levels. Information science information terms need to rest upon the lower levels of life correctly, but not be concerned with technical details that are out of the scope of research interests for the information disciplines.

I have defined *information* as the pattern of organization of matter and energy. The patterns made by the shape and movement of sound waves, by the composition of the air, by the structure of a building—these are all information. The baseline for information is *natural information*: all information is natural information in that it exists in the material world of matter and energy. (All definitions are drawn from Bates [2006] 2016, 1036.)

Represented information is an important subclass of natural information: it is natural information that is encoded or embodied. In turn, *encoded information* is natural information that has symbolic, linguistic, and/or signal-based patterns of organization, while *embodied information* is the corporeal expression or manifestation of information previously in encoded form.

Natural information is converted into represented information when it encounters a nervous system or an extension of a nervous system. (I have deliberately used the nonspecific term *encounter* in order to avoid concerning ourselves with the particulars at the cellular level of how nervous systems sense and respond to their environments.) Let us illustrate these concepts with an example. Picture the spider in its web. An insect flies into the web and is snared by the sticky silk of the web. The insect struggles to escape the web, so it is important for the spider to get to the insect and wrap it in more silk quickly to immobilize it.

Now, where is the information in this situation? The patterns of organization of the constituent elements in the spider, the web, the insect—these patterns are all natural information; they exist in the material world of matter and energy. When the insect flies into the web and is caught by it, it disturbs the web; it pulls the web in a certain direction. That tug of the web becomes a sensory signal to the spider, that is, input to the central nervous system of the spider, where it is then linked to the spider's ability to move and direct its actions. Once inside the body of the spider, that signal has become represented information and is transmitted as encoded information. The spider, sitting at the center of the web, feels the tug of the silk, and knows that an insect (or something else) has been snared, and knows what part of the web has captured the insect. The spider now moves in the direction of the tug, and locates the prey. Other instincts about wrapping the prey and repairing the damage to the web kick in, and the spider proceeds with its life.

Over hundreds of millions of years, animals have developed the ability to convert interactions with natural information into represented information within their own nervous systems, and, further, to use that represented information to act in and interact with the rest of life.

This is not to claim that the trace that the spider creates in its nervous system is an identical or eidetic representation of what it is encountering. All species have evolved in ways to select and shape inputs for their own purposes. For example, human beings are very social animals, and depend for their survival on the ability to get along with their conspecifics. We have evolved to readily distinguish one person from hundreds by their faces, and we can detect numerous complex emotions by reading the rapidly changing musculature on people's faces as they feel emotion. On the other hand, we are much less good at distinguishing and remembering differences in the appearance of other people's knees, unless, perhaps, we are orthopedic surgeons specializing in knees.

Above, it is said that natural information is converted to represented information when it encounters a nervous system or *an extension of a nervous system.* Note that in this case the insect is not directly captured and eaten by the spider, as happens with many predator/prey situations. Instead, the spider creates an extension of its nervous system by spinning out its web, which it uses to capture prey.

The insect encounters the extension of the spider's nervous system, i.e., its web, which, in turn, through the flexibility and ease of movement of the silk, transmits information—a pattern of organization of matter and energy—down the silk to the center and to the spider. Note also that, through evolution, the spider spins webs that are so thin and difficult to see for other insects' sensory apparatus, that these other insects fail to see the web, and fly into it to their peril. (The web is, shall we say, "under their radar.")

Encoding and Embodiment

We can extend these concepts in countless ways when it comes to thinking about human experience and use of information in relation to the body. A fundamental point to understand is that within a nervous system, information moves in and out of encoding and embodiment constantly.

Human beings are animated by a gigantic and complex nervous system. The encoding that happens in the brain and nerves of the body is converted into embodiment and back into other forms of encoding on a continual basis. Information is encoded in the brain by means of neurons, their thresholds for firing, and their interconnections. When I stand on a cliff overlooking the San Francisco Bay and the Golden Gate Bridge, I "see" the bay, whatever that means. I do not see or feel the neurons firing that create that experience of the bay; I only experience myself as standing on the land experiencing the sight and feel of the bay, along with the scent of the saltwater and the brushing of my skin by the breeze. Somehow, in ways that have been only partially explained to date, human beings experience a site as a view of the site itself, with oneself at the center of our view. We feel our weight on the ground, and have a very good three-dimensional experience of what surrounds us and where we are in relation to everything else. Somehow, our brain is able to take the natural information that is impinging on our body and creating signals in nerves to the brain, and convert that input into a lived picture, an experienced embodiment, of the world around us. It is really quite remarkable! (Compare Metzinger 2009; Westerhoff 2016.)

Thus, those electrical and chemical signals in our bodies—which bear no resemblance whatever to the world they are depicting—nonetheless work together somehow to enable us to feel that we are in fact in the world, and that we can see, hear, smell, touch, and taste it all directly. This is what I have called *experienced information:* the pattern of organization of subjective experience, the feeling of being in life, of an animal.

But to have that lived experience, there is first a great deal of sensing, encoding, and converting from one kind of signal to another that must take place through a complex interplay of many parts of our bodies. Again, we are struck by the remarkable reality that, through the use of processing of sensory inputs into nerve signals, often including the linking of current inputs with previously stored memories and experiences, we are enabled to have the feeling of being in life. We feel that we are experiencing life directly, when in fact that experience is mediated by a multi-billion-cell nervous system that processes the original sensory input through many layers and conversions.

As noted earlier, represented information is information that is encoded or embodied. Within nervous systems, information is moving in and out of encoding and embodiment all the time. Information is encoded in that those neurons and their associated nervous system apparatuses somehow enable us to distinguish the difference between, say, "retrieve" and "reprieve," even though those signals in no way look or sound like retrieving or reprieving, whatever that would look like. In fact, we can experience those words embodied as sounds in our auditory system as we hear, as text when we read them, or even as actions we conduct as we endeavor to retrieve something or reprieve someone. But we cannot experience the underlying nerve signals and processes that make the embodied experience possible. The information that enables us to distinguish the two words is encoded in some kind of neural code that we cannot yet read.

We may not know how our bodies do it, but the fact remains that we experience embodied information all the time. So, within a brain full of encoded information, we somehow create a lived experience of embodiment of our environment and our bodies. A pain in a toe is felt as a pain *right there in the toe,* even though the processing of the associated nerve signals may go on in our brains and in nerves leading to and from the toe. Further, even though the toe might have been bumped hard, we could not be currently feeling any of the pain in that toe unless all that other associated information processing also took place elsewhere in our nervous system.

In that earlier paper (Bates [2006] 2016), I also described *enacted information* and *expressed information.* The former is the pattern of organization of actions of an animal in, and interacting with, its environment, utilizing capabilities and experience from its neural stores, while the latter is the pattern of organization of communicatory scents, calls, gestures, and, ultimately, human spoken language used to communicate among members of a species and between species.

An animal acting in life, say, eating or fighting, is embodying capabilities stored as represented information in the brain, muscles, and other parts of the body. I marvel when I look at a brain surgeon or an airline pilot. They look like you and me, yet have stored within their brains and bodies knowledge and action capabilities that I do not have. Likewise, I have some that they lack. Human beings' large, general-purpose brains can store so many amazing different capabilities. When we use those capabilities, we are enacting (a form of embodiment) information that otherwise remains stored as encoded information.

We can also communicate with other animals through language and other behaviors intended to send meaningful messages. Such expressed information is another form of embodying our encoded information stores.

So, altogether, we embody our neural (encoded) stores of information through experiencing, enacting, and expressing. All of the latter three fit the definition of *embodied information*, i.e., they are the corporeal expression or manifestation of information previously in encoded form.

Embodiment in Relation to Exosomatic Information

In my earlier article (Bates [2006] 2016), I adopted Goonatilake's conceptualization of three information flow lineages—the genetic flow line, the neural-cultural, and the exosomatic (Goonatilake 1991, 118–20). The line that all life has is the genetic. The ability to grow and reproduce, that is, to be a living thing, depends on the transmission to new generations of genetic material. Much of the history of a group of animals or plants is contained within the evolved DNA stored in their genetic information.

Next comes the neural-cultural flow line. Information stored in nervous systems can be taught to the young, as the mother tiger teaches her cub to hunt. The *capacity* to learn to hunt is born with the cub, but that capacity must be shaped by the mother into actual behavioral patterns that fit well with the specific environmental circumstances into which the cub is born. And in advanced species, such as our own, these capacities are embedded in rich cultures of language, practice, and previously made artifacts and structures.

The neural-cultural tool extraordinaire of human beings is, of course, language, which enables people to describe things and situations that are not present. Our large brains enable the storage of a huge amount of material, and, through the use of language and observation, others can learn that same material with relative ease. However, the neural-cultural line of transmission requires that the receiver be in the physical presence of the sender. That transmission is still limited by the capacity of the human brain, and to the coexistence in the same place of the teacher and student.

Finally, in addition to the use of language in the neural-cultural lineage, human beings developed their own distinctive information flow lineage—exosomatic storage. *Exosomatic information* is information stored in durable form external to the body. This ability was precociously expressed in wall paintings in caves tens of thousands of years ago but did not become common in carvings, statues, and, finally, writing, until more recent times. Once we figured out that we could record information on objects external to ourselves, we were no longer limited to the size of our brain capacity for storage, nor to the need to have sender and receiver present together at the same time. Previously, we could communicate through expressed information. However, such information, whether spoken, sung, or danced, is ephemeral. It exists only in the moment it is expressed and then disappears. Once we could record information on something durable, we could keep it and refer to it indefinitely; we could hand it down to later generations. In contrast to the ephemerality of expressed information, *recorded information* is communicatory or memorial information preserved in a durable medium.

Recall what was said earlier—that when natural information encounters a nervous system, (some of) that information is converted to represented information and stored in encoded or embodied form in the brain. The same thing can be said of exosomatic information. When encountered by an understanding nervous system, it can be converted into stored information in the brain.

Recall also that it was said that when natural information encountered a nervous system or *an extension of a nervous system,* it could also be converted into represented information. In the last several hundred years, human beings have developed a myriad of forms of extensions of nervous systems, designed both to take in information and to communicate it outward. To better see the information, we developed microscopes and telescopes to enlarge the sight being observed. To capture information, we invented microphones, still and moving cameras, and numerous other information technologies. To send it out, we invented the telegraph, telephone, radio, film, television, and all the other information technologies we use daily.

Once this information is captured into some kind of durable exosomatic form, it, too, can be manipulated in countless ways to achieve human goals of usability and understandability. We see information being converted back and forth between encoded and embodied forms within our storage and transmission technologies constantly. For example, the television signal that comes in over my cable connection is, like so many of the signals in human brains, in a form that in no way resembles the final product. It comes into my television as *encoded* electronic pulses, and the technology in the television then converts it to an *embodied* image, which is understandable and interpretable by us humans. This transformation by the technology enables us to have our own embodied experience of the content of the television program.

The embodiment on the television screen is not complete. We do not receive a physical human being sitting at a newscaster's desk in our living room. Rather, we see instead a two-dimensional image of that broadcaster, enclosed within the limits of the dimensions of our television screen. But the appearance of that person looks very much like the appearance of that person *would* look if we were both in the same physical place. So, this two-dimensional version of the embodied image is a good approximation to the full experience of mutual presence in the same studio, i.e., full embodiment.

Once we found a way to represent language in writing, we then had the capacity to record and retain linguistic material for an indefinitely long time. For much of human history since the invention of writing, recorded information in the form of written language was the primary means of communicating through the generations. In the last couple of centuries, we have invented many other technologies that supplement, and in some cases, are beginning to replace written language. Instead of writing a note to a friend, one now sends a photo from a smart phone. Instead of studying the written text of a play, a student watches a performance of the play on the internet. All these information technologies are extensions of nervous systems, both on the sending and receiving ends, and involve both encoded and embodied information in the information technology and in the human being.

Implications for the Study of Information Behavior/Practice

The relative popularity of various different technologies for retaining and displaying recorded information varies through time and with the invention of ever-newer means of retention and transmission. But the overall pattern for human beings is one of capturing and using information, of storing and sending information, of the several types described in this article. (Note: Two other forms of information described in Bates [(2006) 2016, 1036], *embedded information* and *trace information*, will not be discussed here, but fit within the overall framework.)

The human being is awash in information. This information comes from within the body and from the bodies of others. It comes through our sensorium, and, since the development of the vast range of information technologies we use today, it comes through these various extensions of nervous systems as well. We process and use all these forms of information. These uses include the integration of experience with memories and new thoughts.

It is all one giant information ecology. Failure to recognize and study any one important element of that ecology is to fail to some degree in the overall challenge of understanding information behavior. Embodied information has been underrecognized in information research to date. That this situation is changing rapidly is evidenced by the writing in these issues of *Library Trends*, building on a number of recent papers in this topic area. We are well on the way to filling out our understanding of all the many sources of information that people draw upon to conduct their lives.

On the other hand, information researchers are not studying the entirety of human life and actions! Instead, we identify what I have called the "red thread" of information that weaves its way through the activities of life (Bates [1999] 2016, 1048). Information seeking and use is a part of all the other activities we engage in during our lives. Research in information studies seeks to develop an understanding of this crucial thread in our lives. We want, ultimately, to understand where and how information fits within the broader texture of human life.

Part 2. Theoretical Background

Having laid out in part 1 a way to use my earlier information concepts in the context of information and embodiment, in this section I will take up three themes to illustrate and deepen the understanding of part 1. These themes are *information, embodiment,* and *extension.* But first, a bit more needs to be said about the nature of the literature available in relevant parts of biology, anthropology, cognitive science, psychology, and information science.

There is a very large shift—or perhaps it should be described as a "contested shift"—from earlier models of the relationship between mind and body and between perception and the brain to new models. This shift has been happening in a number of different specialties and along different, but related, streams of thought and research.

I had been aware of some of this literature, but when I reopened my background search on this material for this article a dozen years after writing the information papers, I found a vast body of research and theorizing extending across specialties variously known as ecological psychology, cognitive biology, grounded cognition, embodied cognition, and the cognitive nonconscious.

One article (A. D. Wilson and Golonka 2013) mentions a book reviewing three distinct theoretical and research-based conceptualizations of embodied cognition (Shapiro 2011), then notes that another author in a respected journal reports six such models (M. Wilson 2002).

Or consider two books, each titled *Cognitive Biology,* one published in 2009 (Tommasi, Peterson, and Nadel) and the other in 2011 (Auletta). The latter book is a monster—a large format 850-page treatise. Its reference list is 110 pages long; a sampling estimate yields a number of about 2,750 references in the list. The former book is a collection of papers by a total of thirty-two authors. As a test, I looked up all thirty-two Tommasi, Peterson, and Nadel authors in Auletta's reference list. Only seven out of the thirty-two authors appear there. Furthermore, in the introduction, the Tommasi, Peterson, and Nadel book explicitly eschews any relationship to a 1980 article by Boden and Khin Zaw titled "The Case for a Cognitive Biology" (Tommasi, Nadel, and Peterson 2009, 11). Auletta (2011) also does not cite Boden and Khin Zaw (1980).

Katherine Hayles (2016), on the other hand, who has written extensively on literature, computers, and the digital world, relies throughout her article about "the cognitive nonconscious" on Ladislav Kováč's article

"Fundamental Principles of Cognitive Biology" (2000). Nothing by Kováč is to be found in either Auletta (2011) or Tommasi, Peterson, and Nadel (2009). This all would suggest that the concept of cognitive biology has not yet converged on a single accepted model any more than embodied cognition has.

All this is by way of saying that these more body-based theories about animal living and information inputs/processing/outputs has generated a vast literature, and that these ideas are still very much in flux and hotly contested among biologists, cognitive scientists, and neuroscientists. So, how can we use them in information science?

First, we have the advantage that these other fields are not our own; we can leave the actual experimenting and theorizing about cognition and the body to them. Our purpose is to expand our understanding of information seeking and use to include a richer and more extensive vision of all the influences on the human relationship to information. The fundamental lesson we learn from all this literature is that any model of information practice that does not include the body and the nonconscious processing that accompanies the conscious information work is incomplete. We need to build our own models of people in relation to information in ways that incorporate at least a general understanding of this new view of information that is being developed in the natural sciences, without attempting to resolve the still unresolved differences among the theories of embodiment in those fields.

In this review, I approach that challenge by discussing several broad themes that can be found in this literature, and show how they relate to part 1 of this article and to the theme of these *Library Trends* issues on information and the body. These themes are information, embodiment, and extension.

Information

Information and Survival

The noted ethologist, Konrad Lorenz, wrote:

> Life is an eminently active enterprise aimed at acquiring both a fund of energy and a stock of knowledge, the possession of one being instrumental to the acquisition of the other. (Lorenz 1977, as cited in Kováč 2007, 70)

All animals use information to get around safely in the world. For example, because we can see, we do not bump in a chair when we walk into a room. It is important to understand, however, that this pattern of using information to protect and support successful living holds true all up and down the line, from the smallest to the largest animals.

Every animal has what biologist J. von Uexküll ([1934] 2010) called an "umwelt," that is, a surrounding perceptual life-world that is distinctive to that animal's experience. This umwelt is associated with whatever senses the animal has, and its size and relationship to the surrounding world. The world as experienced by each species (and sometimes, especially among humans, by each individual within a species) is dramatically different from one to another. To take a simple example: Eagles have much greater resolving power in their eyes than we do, and consequently can see small mice and voles running around on the ground from very far up in the air—from distances that human beings could not possibly make out. Indeed, an eagle is said to be able to spot a rabbit 3.2 km away (Wikipedia 2017). It is fair to say that the world looks very different to an eagle than it does to us humans.

Information gathering and processing will happen differently with each species and individual, but, by Lorenz's principle, all living species need energy to live, and they need information to find energy. They use both in order to do all the other things, such as evade predators and reproduce, that animals do to survive.

Ladislav Kováč, in his "Fundamental Principles of Cognitive Biology" (2000), has worded it somewhat differently:

> There is a universal characteristic of any living system to sense relevant features of its surroundings and to react appropriately upon them in order to preserve its own permanence, its *onticity* (54).
>
> Hence, life from its very beginning is a cognitive system: the self-copying molecule, pursuing its onticity in the world . . . is already a *subject* facing the world as an object. (59)

Hoffmeyer (1997) demonstrates how the quest for energy and information operates in the behavior of even the lowly Escherichia coli bacterium. Coli bacteria move in the direction that offers more nutrient molecules rather than less. They do this by measuring the saturation of their chemoreceptor sites while moving. Hoffmeyer spends two pages describing how the bacterium does this, and then notes that he has just scratched the surface of this "highly complex system." I bring it up only to show the role of information and energy in this bacterium's behavior.

The e. coli gets the necessary information, as noted above, by measuring the nutrient saturation in its umwelt. Now, how can it move in the more nutrient-rich direction? Basically, these bacteria have developed the capacity to do two particular things. The flagella, the thread-like structures that it uses to swim, may rotate either clockwise or counterclockwise. Counterclockwise rotation leads to linear movement, and clockwise rotation makes the bacterium tumble around itself. When the saturation is good, the bacterium goes in the linear direction toward the richer resources. When the saturation is poor or declining, the bacterium tumbles around itself, lands randomly pointed in another direction, then again measures saturation. It does this repeatedly until it lands in a direction where the saturation is improving.

The bacterium samples the environment for the relevant information, then can either move toward the nutrients or randomly tumble itself in another direction, in an effort to find the desired nutrients. Hoffmeyer's story elegantly demonstrates Lorenz's point that all living things are questing for energy and information.

The Law of Requisite Variety

Putting all of this in still more general terms, W. R. Ashby developed what he called the Law of Requisite Variety. This law holds that for a system (whether machine or organism) to function successfully, it must generate as much variety in its responses to the environment as the environment generates as input to the system (Ashby 1973, 202–12), with the exception of the cases where the same response can be used for more than one type of disturbance. Variety may come in the form of a physical disturbance or of information.

Let us imagine a physician who responds to most nighttime telephone calls from his patients by saying, "Take two aspirin and call me in the morning." This may suffice for many conditions being reported by the patients, but suppose that in one case the patient goes on to have a heart attack and dies. The patient's family sues the doctor for malpractice, the doctor loses, and subsequently loses his license to practice. In order to make a living, the doctor goes to work in a remote jungle town in another country, but he makes little money and is subject to many exotic diseases. We can fairly say that the failure to respond adequately to the patient's "disturbance" has led to a much lower quality of life for the doctor and a higher likelihood of dying early.

Humans, possessing our large, general-purpose brains, have a lot of flexibility and choice, but all animals, including us, are subject to certain limits imposed by our genetic makeup. There is no guarantee that any species will always have a suitable response to a disturbance (Kováč 2000, 63). If global warming produces conditions beyond what a given species of animal is capable of responding to, then the animal, and possibly the whole species, will die off.

A lot of research in information science has been about what are, in effect, optional information-searching activities: scholars doing research for a book, hobbyists finding out how to carry out a hobby, etc. But at another level, information seeking is vital to survival—finding the right specialist to treat a newly diagnosed condition, for example. Walter (1994) has described the information needs of children. These needs are not only about finding a favorite picture book in the library. They are also about, say, learning to look both ways before crossing a street. A child living in a chaotic household with drug-addicted parents, who is seldom even fed regularly, needs to learn about how to cross a street, for the sake of survival, because no one is teaching her.

Information Literacy

Information literacy, in library parlance, has traditionally meant knowing how to find information, and knowing how to evaluate that information once found. This term, however, has recently begun to be used in a much broader sense.

Annemaree Lloyd (2010) formalizes her definition of the term as follows:

> Knowledge of information sources within an environment and an understanding of how these sources and the activities used to access them is constructed through discourse. Information literacy is constituted through the connections that exist between people, artifacts, texts and bodily experience that enable individuals to develop both subjective and intersubjective positions. (26)

Lloyd goes on to describe in much more detail the various elements of this broader understanding, including, for example, knowing how information is situated in a landscape, what forms of information are valued, how to locate information appropriate to a task, and having the capacity to move beyond context and seek information that will enhance practice (27–28). Here, in effect, information literacy is knowing how to secure the information to cope with and succeed in any environment one enters. This is a much richer and fuller understanding of information literacy than has traditionally obtained, and addresses the fuller demands of one's whole life.

This section started with the need for all life to secure energy and information. It has ended with a fuller understanding of how information seeking and use can enrich human life and enhance life success.

Embodiment

Now that we have a somewhat broader and more biologically based understanding of the role of information in animal and human life, let us consider the role of the body in that information seeking and use.

Cognitive science was dominated for many years by a computational metaphor—the brain as computer, processing inputs through the body's sensorium, storing the results in short or long-term memory, and outputting the results of further processing (Horst 1999, 170). Aside from being an input/output channel, the body apart from the brain was not much discussed. Experiments were commonly done wherein, for example, the head might be held in a fixed position and the eye's response to pinpoints of light in a darkened room studied. The idea was to hold all other variables constant while studying just the action and responses of the eye.

After a while, several streams of criticism of this analytical approach developed. These criticisms take various approaches, but they all argue for more attention to the body and for a more unified conception of brain and body working together in their interaction with their environment. Hutchins (2010, 428) states it as follows:

> Embodiment is the premise that the particular bodies we have influence how we think. . . . According to the embodied perspective, cognition is situated in the interaction of body and world, dynamic bodily processes such as motor activity can be part of reasoning processes, and offline cognition is body-based too. Finally, embodiment assumes that cognition evolved for action, and because of this, perception and action are not separate systems, but are inextricably linked to each other and to cognition.

Below, several related streams of research and theory regarding embodiment will be discussed: ecological psychology, the new unconscious and the cognitive nonconscious, and grounded and embodied cognition.

Ecological Psychology

One of the earliest such critics was James Gibson, who developed a new theory of how perception works (1950, 1966, [1979] 2015). He mainly studied vision, but examined all the other senses as well. This theory is subtle, but has huge implications for psychology and neuroscience. While its originality is widely recognized, the theory goes counter to so much in classical cognitive science that it has still not taken a dominating role in the psychology of vision (Mace 2015).

Gibson's work has many applications, though, to information studies. For starters, he argued that the traditional fixed-head-in-a-dark-room sort of experiments, while they provided some information of use, were not at all reflective of how people really see, and how animals move through life seeing things around them. He called his last book *The Ecological Approach to Visual Perception*. There followed an International Society for Ecological Psychology, and a journal named *Ecological Psychology* (Mace 2015). His emphasis on the person in a real-world environment is very appropriate to the concerns of a field such as ours. We are dealing with people needing information in real-life contexts, so an ecological approach suits well. Further, I would argue that most computer-search interfaces do *not* harmonize well with the way people interact with information as they move through life. (This is the subject of another paper I am working on.)

So, what was Gibson's theory? Most understanding of vision assumes that the sense receptors in the eye take in images, which are sent to the brain and processed, then the person can act on these perceptions. Gibson argued that that is not the way we see at all. Instead, the eyes are just one part of several larger systems that process visual information, each system working on distinctive aspects of vision. "The perceptual capacities of the organism . . . lie in systems with nested functions" (Gibson [1979] 2015, 195).

People see through eyes that each have their own vision capabilities (1st system), that are in a larger system of muscles that direct and move the eyes (2nd system), that are in a binocular system of two eyes, each sensing information (3rd system), that are in a head that moves (4th system), that, in turn, is in a body that moves (5th system), and all parts of this system function together to achieve vision (Gibson [1979] 2015, 234). For example, proprioceptive cues for location of body and parts of the body play a key role in helping vision succeed. The senses "are all more or less subordinated to an overall orienting system" (234).

Further, the information taken in during seeing should not be thought of as being like a movie recording countless individual images that flow together to be processed by the brain. That would actually be a very inefficient way of taking in information, and nature rarely wastes energy where it does not need to. (Remember, for most species most of the time, energy to support perceptual or cognitive activity is precious and hard to get.)

Gibson said that, instead, our visual system(s) look for invariances in the "ambient optical array," i.e., what is available to the eye to see, in a real context, with a surface below, objects in a field of vision, and light surrounding an individual. Further, we look for what he called "affordances." "The *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill" ([1979] 2015, 119).

According to Barrett (2011), "The concept of affordance means that what goes on in an animal's head . . . cannot be separated from how it moves its body about in the world" (98). "For a human, of a certain size, with two legs that bend in the middle and a squashy bottom, a chair affords the possibility of sitting, as does a tree stump, but such objects do not afford sitting to a giraffe or a cow" (98). She notes that the nature of exploratory behavior means that perception and motor action necessarily "work together to detect and exploit affordances" (98). In turn, different animals, having different relationships to their environments, i.e., different umwelts, will see the world as providing different affordances.

So, rather than vision being the taking in of an undifferentiated continuous movie that is sent to the brain for processing, we, in effect, establish through vision an understanding of what the world *affords* us. We are aware of surfaces and the medium in which we live. In other words, it could be said that we establish what is "out there" in terms of surfaces, medium, and affordances, then process only the changes that we detect.

As Gibson ([1979] 2015, 299) says:

> My description of the environment . . . and of the changes that can occur in it . . . implies that places, attached objects, objects, and substances are what are mainly perceived, together with events, which are changes of these things. To see these things is to perceive what they afford. This is very different from the accepted categories of what there is to perceive as described in the textbooks. Color, form, location, space,

> time, and motion—these are the chapter headings that have been handed down through the centuries, but they are not what is perceived.

Compare the differences in energy use and processing effort between, on the one hand, taking in the sight of the entire world around you on a continuous movie-like basis, followed by continuous processing to extract meaning from the input, and, on the other hand, establishing what is "out there" and then simply monitoring for changes in it. The latter requires much less effort.

We look for affordances all the time, because we use affordances to help us live. In my 2006 article (Bates [2006] 2016), where I developed different concepts of information, I discussed the work of Edwin Hutchins in his book *Cognition in the Wild* (1995). He was interested in studying how cognition works "in the wild," that is, in real life, rather than in a laboratory. I saw his study as a work on information seeking and use as well. He studied the crew of a U.S. Navy vessel, as they successfully navigated their ship into port.

> The very layout of the ship and the design of the bridge promoted the smooth flow of information from the exterior of the ship to the crew and among the crewmembers. Each crewmember took on a distinct, but coordinated, role. Critical information was posted at just the right locations for use. Likewise, navigation practices required that not one, but two crewmembers have certain crucial pieces of information at the same time to reduce the likelihood of error. . . . Even the format design of the forms the crew filled out made it easier for them to complete their work successfully. (Bates [2006] 2016, 1042–43)

Though I did not use the word, notice how affordances are operating throughout this description—the affordances of ship design, of information location, of coordinated crew actions (social affordances), and so on. In working together, people, ship design, and information design all created a successful act of navigation. These techniques are all a part of the toolkit of animals operating in a world of possible affordances. In sum, in Gibson's argument, perception is fundamentally a part of a *whole-body* process interacting with the world as it is.

The concept of affordances is very important to user-centered design of information systems, human-computer interaction research, information architecture, and user experience design. See, for example, Hinton's (2015) book on context and design, which draws on Gibson.

The New Unconscious and the Cognitive Nonconscious

For most of the twentieth century, the concept "unconscious" was captured largely by the Freudian understanding of the unconscious, as being the part of the psyche holding emotional drives and needs that were often repressed out of awareness. The unconscious came to be seen as a force countering the sweet reason of conscious rationality, and which engaged in a continual war with our conscious choices and preferred self-image.

More recently, a new conceptualization of the unconscious has developed. Uleman (2005, 5) attributes the start of this new movement to John Kihlstrom's 1987 article, "The Cognitive Unconscious," which looked at a lot of forms of processing that are not conscious. Kihlstrom noted: "Research on perceptual-cognitive and motoric skills indicates that they are automatized through experience, and thus rendered unconscious" (1987, 1445). The "new unconscious is much more concerned with affect, motivation, and even control and metacognition than was the old cognitive unconscious. Goals, motives, and self-regulation are prominent, without the conflict and drama of the psychoanalytical unconscious" (Uleman 2005, 6). The new discussion is not about unconscious drives, but rather about the many ways we process information out of awareness and use it in real time, sometimes melded with conscious decisions, and sometimes not (Hassin, Uleman, and Bargh 2005).

Developing a slightly difference conception of the "nonconscious," in recent articles (2014; 2016), and in a newly-published book (2017), Katherine Hayles argues that "nonconscious cognition" cannot be brought into awareness but is nonetheless necessary to effective conscious functioning. Among other things, nonconscious cognition processes information faster than can consciousness, recognizes patterns too complex and subtle for consciousness to discern, and draws inferences that influence behavior and help to determine priorities (2017, 10). She argues that we can see important roles for nonconscious cognition not only in human beings but also in other life forms, and in sophisticated technical systems as well, and, further, that we should aim to develop a unified theory for the role and nature of such cognition across these several domains.

Grounded and Embodied Cognition

Lawrence Barsalou's review article, "Grounded Cognition" (2008), comprehensively reviews the research on whether cognition is operating purely as abstract thought or else is grounded in other forms of awareness, particularly, as simulations.

> Simulation is the reenactment of perceptual, motor, and introspective states acquired during experience with the world, body, and mind. As an experience occurs (e.g., easing into a chair), the brain captures states across the modalities [input channels] and integrates them with a multimodal representation stored in memory (e.g., how a chair looks and feels, the action of sitting, introspections of comfort and relaxation). (Barsalou 2008, 618)

For example, among the many research studies Barsalou reports are these:

> Bub et al. (2007) showed that a perceived object (or object name) automatically triggers simulations of both grasping and functional actions. . . .

> Researchers increasingly extend these original findings in creative ways. In Bosbach et al. (2005), accurately judging the weight of an object lifted by another agent requires simulating the lifting action in one's own motor and somatosensory systems. (Barsalou 2008, 624)

Thus, it is commonly the case that thoughts and ideas experienced in the conscious mind also have simultaneous processing correlates elsewhere in the body; we simulate an experience throughout the body, not just in the conscious mind.

Barsalou distinguishes *grounded cognition* from *embodied cognition* by saying that the latter phrase "produces the mistaken assumption that all researchers in this community believe that bodily states are necessary for cognition and that these researchers focus exclusively on bodily states in their investigations" (2008, 619). For the remainder, I will nonetheless use the term *embodied cognition*, because it is more widely used (according to *Web of Science* and *Psycinfo*), and with the understanding that the embodied-cognition approach both recognizes and incorporates bodily states, but is not limited to them in its thinking.

Another stream of research that emphasizes embodiment is that by George Lakoff and Mark Johnson (1980, 1999). Lakoff and Johnson argue that our use of metaphor in language is pervasive and is rooted in bodily and physical life experience. We are constantly describing love as a journey, good as up and bad as down, and so on. These usages are so common that they often are not recognized as metaphors at all. Here are some example sentences:

> *Love as a journey*
> Look how far we've come.
> It's been a long, bumpy road.
> We're at a crossroads.
> We may have to go our separate ways. (Lakoff and Johnson 1999, 64)
>
> *Conscious is up, unconscious is down*
> Get up. Wake up.
> He fell asleep. He sank into a coma. (Lakoff and Johnson 1980, 15)
>
> *Good as up; bad as down*
> Things are looking up!
> Things are at an all-time low. (Lakoff and Johnson 1980, 16)

However, Lakoff and Johnson's analysis is not limited to everyday quotidian activities. Johnson (2007) and Lakoff and Nuñez (2000) argue that much abstract thought is rooted in the same embodied experiences as described in the above colloquial examples. Johnson (2007, 177) states, "The most sweeping claim of conceptual metaphor theory is that what we call abstract concepts are defined by systematic mappings from body-based, sensorimotor source domains onto abstract target domains." He then develops the example of "the common conceptual metaphor CATEGORIES ARE CONTAINERS" (180). He notes that we say that the category "human" is *contained* in the category "animals" and the category "animals" is *contained* in the category "living things." We are drawing on our physical experience of putting one thing inside another to describe the entirely abstract idea of categorizing concepts.

In information science, in recent years, there has been a surge of interest in information and embodiment. A group of researchers has been pursuing the implications of embodiment for research in information practice and information literacy. Annemaree Lloyd's study (2009) of people learning to be paramedics in Australia demonstrated the role of the body in both learning how to do the work through observation of experienced paramedics in action, and in "reading" the bodies of people being picked up for hospital transport. Cox (2013) argues for an "information in social practice" approach to studying what was formerly named "information behavior." He emphasizes, among other things, the materiality and embodiment of information activities, using personal photography as an example. See also Lueg's (2015) argument for more attention to embodiment in information behavior research.

A collection of articles on the importance of bodily experience in information practice has recently appeared, titled *Information Experience* (Bruce et al. 2014). Olsson (2016) and Olsson and Lloyd (2017) take this approach into the study of the work of archaeologists, drawing particular attention to the haptic forms of information pick-up. Hartel, Cox, and Griffin (2016) and Cox, Griffin, and Hartel (2017) amply demonstrate the importance of the body in several kinds of serious leisure activities.

Finally, we cannot leave this section without noting two foundational books that have long provided a philosophical and theoretical grounding within cognitive science for the embodied approach. I will make no attempt to review the detailed theoretical issues within cognitive science theory that are addressed by these books. For our purposes, it is enough to cite their titles: *The Embodied Mind: Cognitive Science and Human Experience* (Varela, Thompson, and Rosch 1991) and *Being There: Putting Brain, Body, and World Together Again* (Clark 1997). We will return to Clark in the next section.

Extension

The concept of extension appears in several related senses in this discussion.

The Extended Phenotype

First, let us note the spider's use of an extension—its web. The spider and its web is the very example chosen by Richard Dawkins (1982) for his concept of the "extended phenotype." (The genotype is the genetic inheritance of an animal; the phenotype is the genetically and environmentally determined embodiment of a genotype, i.e., the animal itself.)

Dawkins argued that the "houses" and other structures that animals manufacture outside their bodies can be considered extensions of their bodies, extensions that are really due to the genetic inheritance that produces the animal phenotype. These extensions, arguably, are a part of the animal, as they are crucially defining of the animal, and are associated with what leads to the success or failure of the animal in evolutionary terms.

> Now consider a spider sitting at the centre of her web. . . . In a very real sense her web is a temporary functional extension of her body, a huge extension of the effective catchment area of her predatory organs. (Dawkins 1982, 198)

Catching prey in webs is so fundamental to the nature of the spider, and is so surely a major part of what enables the spider to survive and thrive, that we cannot seriously study spiders without including webs as a part of the study of the spider as a functioning animal. So, the extended phenotype of the spider consists of the spider itself, plus its web. It is the whole package, spider plus web, that either succeeds or fails evolutionarily. Likewise, if we want to study human beings, we must surely incorporate an understanding that humans cover their hairless bodies with clothing in the cold, and build lean-tos/huts/houses to protect themselves from extreme climate and predation.

In a more recent book, Clark (2008) makes an extended theoretical and philosophical argument for exactly how he thinks cognitive scientists should think about bodily extensions and the body's relation to the surrounding environment:

> Finally, the body, by being the immediate locus of willed action, is also the gateway to intelligent offloading. The body . . . is the primary tool enabling the intelligent use of environmental structure. It acts as the mobile bridge that allows us to exploit the external world in ways that simplify and transform internal problem solving. The body is thus the go-between that links these two different (internal and external) sets of key information-processing resources. Hence, the body's role in such cases is that of a bridging instrument enabling the repeated emergence of new kinds of distributed information-processing organization. (207)

When we need to multiply 3102 by 425, it is certainly easier to do so if we employ a piece of paper and pencil, or a calculator, to do it. For most of us, figuring out the answer to that problem in our heads is very challenging and subject to error. We *need* the extension of paper and pencil to carry out this mental operation successfully. Likewise, if we can consult a book or website to find out the population of Turkey, our use of these forms of external assistance makes possible what would otherwise require an extensive and possibly fruitless search to find the answer among bureaucrats in Turkey. By recording and collecting vast amounts of information, and developing structures—from the bookshelf to the digital library, from the catalog to the online database—to make it available, we have multiplied our information power astronomically. A full understanding of information seeking, acquisition, and use requires us to see how these extensions of our phenotypes enable us to succeed in the information tasks that confront us.

Diane Mizrachi studied how college students contended with the array of challenges facing students in today's rich media and technology environment (Mizrachi and Bates 2013). Currently, we are moving among a number of rapidly changing communication patterns and information technologies. Students had their own preferences among the numerous devices that are available, from smartphones to laptops to portable listening devices, and their professors had their own mix of preferences as well—required text, online information store, class handouts, and so on. Each student used a different mix of these abundant possibilities, depending on personal preferences and the types of classes being taken. This *academic information management* is not a trivial challenge, and success in handling this challenge can affect student success in college.

The authors summarize the extensive methods used by students in managing their academic information:

> Cognitive and physical interactions with academic information include reviewing, reading, writing, copying, sorting, piling, filing, discarding, deleting, archiving, placing (purposefully setting information within the environment for accessibility, visibility, and reminding), shifting . . . and prioritizing (by urgency or importance). (Mizrachi and Bates 2013, 1600)

Niche Construction

One of the most recent manifestations of Dawkins's theme of the extended phenotype occurs in an area of biology called "niche construction" (Odling-Smee, Laland, and Feldman 2003). Researchers in this area argue that

> the evolution of organisms is co-directed by both natural selection and niche construction. *While genetic variation is subject to natural selection through differential survival and reproductive success, the selective environments themselves are partly determined by modifications made by niche-constructing organisms.* . . . Evolution entails networks of causation and feedback in which previously selected organisms drive environmental changes, and organism-modified environments subsequently select for changes in organisms. (italics added) (Kendal, Tehrani, and Odling-Smee 2011, 785)

Beavers build wooden lodges on rivers and streams to dam up the water flow in order to provide safe and warm housing within the lodge for themselves, their offspring, and food storage. This inborn set of behaviors provides considerable protection from extreme weather and predators for the living beavers. As the above authors argue, this niche construction behavior, in turn, affects natural selection, so that there is a reciprocal relationship between the usual model of natural selection and natural selection as affected by the niche construction efforts of animals.

Here is an example of evolution affected by niche construction that has been discovered in humans: First, humans figured out how to domesticate pastoral animals, and thus bring a great deal of valuable, high-energy meat and milk under our control. However, most humans were not able to digest milk after about the age of two, when nursing ends. Eventually, a mutation came along that enabled people to continue to digest the lactose in milk for the rest of their lives. This mutation greatly increased the nourishment available to human beings in the colder areas of Europe, where it became most dominant. This beneficial mutation consequently spread very rapidly, and is still possessed by people of European origin and a few other places. Most people in other regions did not acquire the mutation. Thus, modern humans are a mix of people who can comfortably drink milk and those who are lactose intolerant (Gerbault et al. 2011).

The human niche construction ability that led to our domesticating farm animals enabled us to have ready access to large amounts of high-energy nourishment. Members of our species who happened to have the mutation for lactose tolerance thrived better amid a growing population, so natural selection benefited them, and the mutation spread rapidly in the population. Thus, niche construction played a major role in the evolved nature of the organism that we are today.

Looking back on the history of human beings, the moment we figured out how to farm, in addition to hunting and gathering, we were enabled to feed a much larger population and build long-lasting, strong, and protective housing. When people made farming innovations, the prior development of language enabled us to communicate the techniques used for farming and building to the next generation, and so continue a powerful mode of niche construction that greatly promoted and improved our survival. Once we developed the capacity to create such extensive exosomatic structure to support our cognition and reproduction, we gained considerable capacity to ease the dangers faced by prior generations of hominins.

Indeed, Kim Sterelny (2011, 809), also a supporter of the niche construction model, argues that

> humans became behaviorally modern when they could reliably transmit accumulated informational capital to the next generation, and transmit it with sufficient precision for innovations to be preserved and accumulated. In turn, the reliable accumulation of culture depends on the construction of learning environments, not just intrinsic cognitive machinery.

Our large, general-purpose brain has enabled us to create an extraordinarily rich and extensive niche on the planet. Our capacities have enabled us to adapt to and live in all the surface environments of the planet. The development of language and large memories enabled us to store vast amounts of knowledge for later generations. Once we figured out how to *record* that knowledge on durable exosomatic storage devices, such as tablets and books, we experienced a veritable explosion of stored knowledge, which we could, in turn, use for further niche development.

Niche construction even shows itself in the literal sense when we organize our informational environments. The dormitory rooms of the students Mizrachi studied were small and housed two or three students each. The desks of the students were each distinctly organized according to whatever practices were most effective for each student. Indeed, this is true for most offices. Most of us could justify why each stack of books or papers must be exactly where it is in our own offices. The generic term for this kind of organization is *personal information management,* or PIM (Jones and Teevan 2007). The large research literature on PIM will not be reviewed here, but note that the *capacity* to engage in PIM is a capability for a particular kind of niche construction, a capacity that humans have in abundance.

Cognitive Assemblages

The latest and most sophisticated form of human niche construction is what Hayles calls "cognitive assemblages" (2017). These are the giant combinations of human beings, material resources, computers, and intellectual and physical systems that we have created to manage people and resources for our benefit. Examples are the internet, traffic-management systems, and financial markets. The Automated Traffic Surveillance and Control system in Los Angeles, for example, manages the 7,000 miles of roads in the area from a central command center (Hayles 2017, 121ff). It is a mix of managers, specialized computer algorithms, cameras, road sensors, and drivers who call in local conditions. Timing of stop-light changes and other roadway factors can be modified centrally in real time, based on inputs from the sensors and human beings. Hayles:

> The most transformative technologies of the later twentieth century have been cognitive assemblages. . . . While many modern technologies also had immense effects—the steam engine, railroads, antibiotics, nuclear weapons and energy—cognitive assemblages are distinct because their transformative potentials are enabled, extended, and supported by flows of information, and consequently cognitions between humans and technical participants. Hybrid by nature, they raise questions about how agency is distributed among cognizers, how and in what ways actors contribute to system dynamics, and consequently how responsibilities—technical, social, legal, ethical—should be apportioned. (2017, 119)

So, we have moved from the extended phenotype of the individual animal, to individual and collective niche construction, to human cognitive assemblages. These are all protections against risks and threats to survival. Obviously, with the amazing flexibility and vast extent of human niche construction and cognitive assemblages, we are able to protect ourselves from many of the threats and contingencies of life, though the possibility always remains that we can also be fooled or misled by our own devices.

Conclusion

In this article, I have presented an understanding of human information seeking and use that is intended to incorporate not only the conventional uses of recorded information that are discussed and researched in information science but also all the much broader and more varied kinds of information that people absorb in their lives through and with their bodies, and through and with the use of a vast array of bodily extensions. I have applied vocabulary terms developed in earlier articles (Bates 2005, [2006] 2016) to the concepts herein—namely, natural and represented information; embodied and encoded information; and experienced, enacted, expressed, and recorded information. These terms are all useful within the broader context of information and embodiment, as discussed in these *Library Trends* issues. Furthermore, a broad and necessarily selective review of relevant literature in biology, anthropology, psychology, philosophy, and information science has been presented by way of supporting the body-emphasis of the first part of the paper.

We saw how fundamental information is to life. We saw that all life needs information and energy to survive, and that this is as true of a five-year old child as it is of a bacterium. We came to recognize that a great deal of information processing is done out of awareness and is essential to conscious thought. Our language and thought are rooted in our physical bodies, and the seeking and absorption of information cannot be fully understood without including an awareness of this bodily basis of information processing.

We learned that animals absorb information from the world in different and more efficient ways than is normally assumed, and that we use many extensions of our bodies in the world to help us gain information and process it effectively and fast. We saw how we humans, particularly, create niches that protect and support us against the threats that are common to all forms of life.

Based on this review, I believe it is evident that there is much support for a fuller view of information seeking and use. To gain that understanding, it is necessary to recognize the many ways in which perception and cognition are bodily based, and the ways in which we use countless extensions to expand our processing, understanding, and utilization of resources.

I end this discussion with a graceful quotation from Katherine Hayles:

> I want to . . . sketch in broad terms my vision of how a member of the Homo sapiens species encounters the world. Alert and responsive, she is capable of using reason and abstraction but is not trapped wholly within them; embedded in her environment, she is aware that she processes

> information from many sources, including internal body systems and emotional and affectual nonconscious processes. She is open to and curious about the interpretive capacities of nonhuman others, including biological life-forms and technical systems; she respects and interacts with material forces, recognizing them as the foundations from which life springs; most of all, she wants to use her capabilities, conscious and nonconscious, to preserve, enhance, and evolve the planetary cognitive ecology as it continues to transform, grow, and flourish. (2017, 63–64)

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