Information for Perception and Information Processing

ANTHONY CHEMERO
Scientific and Philosophical Studies of Mind Program, Franklin and Marshall College, Lancaster, PA 17603, USA; E-mail: tony.chemero@fandm.edu

Abstract. Do psychologists and computer/cognitive scientists mean the same thing by the term 'information'? In this essay, I answer this question by comparing information as understood by Gibsonian, ecological psychologists with information as understood in Barwise and Perry's situation semantics. I argue that, with suitable massaging, these views of information can be brought into line. I end by discussing some issues in (the philosophy of) cognitive science and artificial intelligence.

Key words: Barwise, Gibson, information, perception, situation semantics

Introduction (Very Brief)

Interdisciplinary endeavors are fraught with terminological perils. This is especially true in the cognitive and computational sciences where, as Brian Cantwell Smith (forthcoming) points out, the same dozen or so words are used in a proprietary way by each of the participating disciplines. This often leads to minor misunderstandings, but can also lead to more serious problems. Many of us can name books that are flawed at their core because authors in, say, philosophy assume that researchers from another field, say computer science, use a term in the same way that philosophers typically do.[1] The issue for this paper, one that ought to trouble philosophers of information, is whether and to what extent the term 'information' maintains the same sense across disciplinary boundaries. In particular, I will focus on whether perceptual psychologists interested in information are talking about the same thing that logicians and theoretical computer scientists are talking about. That is, is the information picked up in perception the same thing as the information that is processed? It is not hard to see that the answer to this question opens an enormous can of worms in the philosophy of artificial intelligence, from the viability of computational models of perception to the very possibility of artificial intelligence. In this short paper I will mostly just open the can, leaving the untangling of worms to the reader.

1. More introduction: 'Information' in Psychology and Philosophy

Generally, the understanding of information that plays the greatest role in psychology is due to James J. Gibson. Although most psychologists are unwilling to buy

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into Gibson's full theory of perception (1966, 1979; see Section 2), they typically agree with him about what information is. Indeed, even Marr (1982) who criticizes Gibson's approach explicitly and lays out a strikingly non-Gibsonian view of what visual perception is, one that is the model for all of cognitive science, seems to agree with Gibson's views of the nature of information. It is information-*processing*, he says, that Gibson doesn't get (1982, pp. 29–31). Many of the philosophers of mind and language who have written on information also owe a great debt to Gibson. For example, Evans (1982) claims explicitly that he uses the term in Gibson's sense[2]; Barwise and Perry (1981, Footnote 1) claim that their situation semantics is inspired by Gibsonian views of information. Millikan (2000) and Dretske (1981) were also influenced by Gibson's views. In addition to philosophers and psychologists who have taken on Gibson's view of information while rejecting his views on perception and action, many proponents of so-called embodied cognition are (perhaps unwitting) Gibsonians. To take just one example, in largely favorable critique David Kirsh (1991) argues that the robotic research of the most influential of the embodied cognitive scientists Rodney Brooks (see Brooks, 1999) just is a robotic implementation of Gibson's theory of action.

This all points to the fact that Gibson's views on information have been influential in psychology, philosophy and cognitive science. Indeed, his views on information have been much more influential than his views on perception more generally. The key thing to notice here, though, is that with the exception of Marr, all those mentioned above would deny that perception or cognition are information-processing. So this leaves us with a potentially pressing question: to what extent is the information that philosophers of mind, psychologists, and roboticists are interested in the same information that is processed in computers? To answer this question, I will sketch Gibson's view of information, and see how well it fits with a view of information that has currency in (the philosophy of) computer science, Barwise and Perry's situation semantics (1981, 1983).

2. Gibson on Perception and Information

Gibson's posthumous *magnum opus*, *The Ecological Approach to Visual Perception* (1979) is perhaps alone among books about perception in devoting nearly 50% of its pages to discussion of the nature of the environment that animals perceive. This half of the book is a description of Gibson's theory of the information available for vision, which goes hand-in-hand with his theory of visual perception. There are two main points to Gibson's theory of perception. First, Gibson disagreed with the tradition that took the purpose of visual perception to be the internal reconstruction of the three-dimensional environment from two-dimensional inputs. Instead, the function of perception is the guidance of adaptive action. Second, Gibson (1966, 1979) rejected classical views of perception in which perception results from the addition of information in the mind to physically caused sensation.

This information processing way of understanding perception, Gibson thought, puts an unbridgeable gap in place between the mind (where the information is added, and the perception happens) and the world (where the merely physical light causally interacts with the retina). Instead, Gibson argued, perception is a direct — non-inferential, non-computational — process, in which information is gathered or picked-up from the environment.

Combined, these two theses give rise to Gibson's most well-known contribution, his theory of affordances (1979). If perception is direct, no information is added in the mind; if perception also guides behavior, the environment must contain sufficient information for the animal to guide its behavior. That is, the environment must contain information specifying opportunities for behavior. In other words, the environment must contain information specifying affordances. These views place significant constraints on the theory of information that Gibson can offer. First, because it is used in non-inferential perception, information must be both ubiquitous in the environment and largely unambiguous; second, because perception also guides behavior, the information in the environment must specify opportunities for behavior, which is to say it must specify affordances. Although the theory of information outlined in Gibson (1979) does meet these criteria quite nicely, it is spelled out in too plainspoken a manner to be convincing to most philosophically inclined readers.[3] I will try to do better here.

The first thing to know about what Gibson meant when he used the word 'information' is that he was not talking about information as described by Shannon and Weaver. ("The information for perception, unhappily, cannot be defined and measured as Claude Shannon's information can be." 1979, p. 243). The best first pass at an understanding of what Gibson *did* mean by 'information' is his distinction between stimulation and stimulus information. To see the difference, consider standing in a uniformly bright, densely fog-filled room. In such a room, your retinal cells are stimulated. The light in the room enters your eye and excites the rods and cones. But there is no information carried by the light that stimulates your retina. This is the case because the uniform white light that converges on the eye from the various parts of the room and is focused by the eye's lens does not specify the structure of the room. So stimulation, the excitement of sensory cells, is not in itself information and is, therefore, not sufficient for perception. The differences between the normal environment and the fog-filled room are instructive. In the fog-filled room, the light that converges on any point that could be occupied by an observer's head and eyes has been scattered by the fog. Thus, when it reaches the observer it has not come directly from any surface in the room, and hence cannot inform the subject about the surfaces in the room. In the more typical, non-foggy situation, the light that reaches any point in the room has been reflected off the room's surfaces. The chemical makeup, texture, and overall shape of the surfaces off which the light reflects determine the characteristics of the light. Since surfaces are interfaces of substances with the air in the room, the nature of the surfaces is, in turn, determined by the substances that make them up. This set of facts is what

allows the light that converges at any point to carry information. It also allows animals whose heads occupy the point to learn about its environment by sampling the light.[4]

This story allows us to understand what it is for light (or other energy) to carry information, but says nothing about what sort of thing information is. When Gibson and his followers claim that information is ubiquitous, are they saying that in addition to the substances, objects and energies in the room, there is extra stuff, the information? Yes and no. Yes: information is a real, unproblematic aspect of the environment. But as is evident from the quotation from Gibson above, information it is not a kind of measurable, quantifiable stuff that exists alongside the objects or substances in the environment. Instead, information is a relational feature of the environment. In particular, the light converging on some point of observation is in a particular relationship to the surfaces in the room, that of having bounced off those surfaces and passed through a relatively transparent medium before arriving at the point. The information in the light *just is* this relation between the light and the environment.[5]

A few quick points about this. First, note that information relation between the light and the surfaces does not hold in the case of a fog-filled room. So the light in this case bears no information about layout of the environment. Second, it is worth noting that this way of understanding information allows it to be ubiquitous in the environment. Light reflected from surfaces in the environment converges at every point in the environment. Third, the information in the environment is more or less complete: the light converging at every point has reflected off *all* of the non-obstructed surfaces. Fourth, and most importantly for Gibson's project, is that the light can contain information specifying affordances. To see this, a little needs to be said about affordances.

Affordances are opportunities for behavior. Because different animals have different abilities, affordances are relative to the behavioral abilities of the animals that perceive them. In some cases, these abilities are importantly related to an animal's height. To take just two examples, Warren (1984) has established a relationship between leg length and stair climbing affordances and Jiang and Mark (1994) have established a relationship between eye height and the perception of gap crossing affordances.[6] Given the relationship between height and some affordances, information about height is also (partial) information about affordances. Remember that at every point in the environment reflected light converges from the surfaces in the environment. Among these surfaces is the ground, so one relatively obvious source of information concerning height is the light reflected from the ground beneath the point of observation. A less obvious source of information is pointed out by Sedgewick (1973): the horizon cuts across objects at a height that is equal to the height of the point of observation. That is, whenever light is reflected to some point in the environment from the horizon and also from some object between that point and the horizon, the light will contain information about the height of the point of observation relative to the height of the object. Of course, information

about the height of a point of observation is also information about the height of an animal. So, at least for the types of affordances that have some relationship to an animal's height (stair climbing, gap crossing), there is information in the light about the affordances. More generally, this means that information in light is not just about the things the light bounces off. It is also information about the perceiver and the relation between the perceiver and the environment.

The following are the key points of this brief description of Gibson's theory of the information available in the environment for perception.

1. Information for perception is not Shannon-Weaver information.
2. Ontologically speaking, information is a relation between energy in the environment (light, vibrations, etc.) and the substances and surfaces in the environment.
3. Along with the substances and surfaces of the environment, the energy in the environment also contains information about animals that perceive it and about what is afforded to these animals.
4. Because of (3), information can be used by animals to guide behavior directly. That is, information about affordances can guide behavior without intervening inferences or computations.

The question before us now is whether these four points are consistent with the way the word 'information' is used in (philosophy of) computer science.

3. Situation Semantics and Information

It turns out that there is a theory of information that has considerable currency in computer science and cognitive science that is consistent with Gibsonian information: Barwise and Perry's (1981, 1983) *situation semantics*, and the extensions of it by Israel and Perry (1990), Devlin (1991), and Barwise and Seligman (1997). Situation semantics is a good candidate here because, as noted above, Barwise and Perry's realism about information was directly influenced by Gibson. It has, therefore, a better chance than other contemporary theories of information from the philosophy of computer science (e.g., Floridi, to appear a, b) to be compatible with information as psychologists who study perception view it. Thus this section will contain a brief outline of situation semantics and the theory of information that follows from it. Note that this discussion will be neither a complete nor a rigorous account of the work it summarizes.

Barwise and Perry (1981, 1983) developed situation semantics in order to, as they said, bring ontology back to semantics. That is, they were interested in a semantics based on how the world is, and not on minds, knowledge, mental representations, or anything else epistemic in character. Information according to this view is a part of the natural world, there to be exploited by animals, though it exists whether or not any animals actually do exploit it. According to situation semantics, information exists in *situations*, which are roughly local, incomplete

possible worlds. Suppose we have situation token s1 which is of type S1 and situation token s2 which is of type S2. Then situation token s1 carries information about situation token s2 just in case there is some *constraint* linking the type S2 to the type S1. Constraints are connections between situation types. To use the classic situation semantics example (Barwise and Perry, 1983; Israel and Perry, 1990; Barwise and Seligman, 1994), consider the set of all situations of type X, in which there is an X-ray with a pattern of type P. Because patterns of type P on X-rays are caused by veterinarians taking X-rays of dogs with broken legs, there will be a constraint connecting situations of type X with situations of type D, those in which there is a dog with a broken leg that visits a veterinarian. Given this, the fact that a situation x is of type X carries the information that there is a situation d (possibly identical to x) of type D in which some dog has a broken leg.

For our purposes here, there are two things to note about this example. First, the constraint between the situation types is doing all the work. That is, the information that exists in the environment exists because of the constraint, and for some animal to use the information the animal must be aware of the constraint. This feature is true not just of the example of the unfortunate dog, but holds generally of information in situation semantics. The second point is that the constraint in the example holds because of a causal regularity that holds among dog bones, X-ray machines and X-rays. That is, the particular X-ray bears the information about the particular dog's leg because, given the laws of nature and the way X-ray machines are designed, broken dog legs *cause* X-rays with patterns of type P. This feature of the example does *not* hold more generally of information in situation semantics. That is, constraints that hold between situation types are not just law-governed, causal connections. Constraints can hold because of natural laws, conventions, and other regularities. So, a situation with smoke of a particular type can bear information about the existence of fire by natural law, but it can also bear information about the decisions of tribal elders by conventions governing the semantics of smoke signals.

Even given this very sketchy description of the nature of information in situation semantics, we can see that this view of information can capture the kind of information that Gibson was interested in. We can see this via an example. Imagine that there is a beer can on a table in a room that is brightly lit from an overhead source. Light from the source will reflect off the beer can (some directly from the overhead source, some that has already been reflected of other surfaces in the room). At any point in the room at which there is an uninterrupted path from the beer can, there will be light that has reflected off the beer can. Because of the natural laws governing the reflection of light off surfaces of particular textures, colors and chemical makeup, the light at any such point will be structured in a very particular way by its having reflected off the beer can. In situation s1, the light at point p has structure a of type A. Given the laws just mentioned, there is a constraint connecting the situations with light-structure type A to the beer-can-present situations of type B. So, the structured light at point p contains information about situation about token beer-can-presence b (of type B). Notice too that, because of

conventional constraints governing the relationship between cans and their contents, beer-can-presence b being of type B carries information about beer-presence c of type C. Furthermore, the light at any point in the room from which the beer can is visible will contain information about the beer can's affordances. Take some point p, which is at my eye height. The light structure available at this point will contain not just information about the beer can and the beer, but also about the distance the point is from the ground, the relationship between that distance and the distance the beer can is from the ground, hence the reachability of the beer can and drinkability of the beer for a person with eyes at that height.

This example also points to an important feature that distinguishes this view of information from Dretske's classic probability-based theory of information (1981). Because constraints that connect situations are not limited to law-like connections but can also be cultural or conventional in nature, the fact that some situation token contains information about some other token does not necessarily entail that the second situation token is factual. For example, the light at my point of observation contains information about the beer can and the beer can contains information about beer being present. If it's possible that, because of some error at the bottling plant that caused the can to be filled with water, there is no beer in the can, the beer can presence can still carry information about beer presence. But according to Dretske's view, for one state of affairs A to carry information about another B, the probability of B, given A, must be 1. This is the case, Dretske argues, because the connection between the states of affairs must be governed by natural law. (Note that this claim is echoed by some Gibsonians, e.g., Turvey, 1992; Turvey and Carello, 1986; but not by Gibson himself (1979) who would have accepted a broader conception of constraints.) So according to Dretske's view, beer can presences don't carry information about beer presences, this is because the beer can is not connected by natural law with the presence of beer. This feature of Dretske's theory has long been thought to be problematic, and has been criticized from many quarters.[7] Situation theorists have typically argued that constraints need not be necessary connections between situation types. Barwise and Seligman (1994, 1997) for example have argued that the regularities that allow the flow of information must be reliable, but must also allow for exceptions. Millikan (2000) makes a similar point. She distinguishes between informationL (information carried in virtue of natural law) and informationC (information carried in virtue of correlation).

We've seen in this section that an ecological approach to information matches up reasonably well with the situation semantics view of information, but not with Dretske's theory. This means that at least one of the current ways that information is thought of in computer science can perhaps be applied to perceived information.

4. A Unified Theory of Information?

The discussion of the last section holds up the hope that the (Gibson-inspired) situation semantics theory of information can be a unified theory of information, one which can account for both the information used in perception and the information that is processed in computers. These results should reassure those who believe that perception (perhaps all of cognition) is computation: the information in the environment can pass into the animal for processing. But there is also reason to think such reassurance is illusory. Despite all the ways in which the Barwise and Perry view of information can capture the ecological notion of information, there is a remaining issue that might lead us to conclude the Gibsonian information is not the information that is processed in computers. This is the fact that, according to Gibson, the information for perception is information about affordances. And the whole point of affordances is that they underwrite direct (that is, non-inferential, processing-free) perception. To see that this is a problem, consider the way vision is explained in traditional (non-direct) theories, e.g., Marr (1982). First, light reflected off objects in the environment hits the eyes. This light is focused into a pair of two-dimensional images of the environment at the retina of each. The information in these images is combined and processed, through various stages during which information is added, to yield a language-like representation of the environment. This language-like representation is then used, in combination with other representations, to determine a course of action. Affordances, by design, obviate the need for all internal processing of information. The animal simply *uses* the information that is in the light to control its behavior. This kind of information, information specifying affordances, is not processed.

There is, therefore, apparently an important difference between ecological information and information in computers. The question is whether this apparent difference ruins the possible détente just sketched. There are two separate issues here, actually. First, can the theory of information just sketched be an account of the information processed in computers, the kind of information that is processed in computationalist theories of perception? Second, is internal computation the right model or metaphor to understand the ways in which animals use information about affordances? The first question is whether Gibsonian view information is of use to computer and cognitive scientists. The second question concerns whether artificial intelligence and computational modeling are of use to those interested in affordances.

On the first question, whether information as understood in situation semantics can be processed, the answer is clearly 'yes'. Although Gibson was interested in the perception of affordances and therefore was very concerned to argue that there is information specifying affordances in the world, he never claimed that there is not also information specifying substances, surfaces, objects, properties, relations, events and the like. And indeed, despite the claims of some Gibsonian strict constructionists (e.g., Stoffregen, 2000), there is no reason to think that Gibson would

have denied that we can and sometimes do perceive substances, surfaces, objects, properties, relations, events and the like. This is of course also true of information as understood in situation semantics. So the fact that situation semanticists believe there is information about things other than affordances is no hindrance to a unification of their view of information with Gibson's. Furthermore, it is no hindrance to the use of this unified theory of information to account for the information about substances, surfaces, objects, properties, relations, events and the like that is processed in computers. So far, so good.

The answer to the second question, whether information about affordances is compatible with internal computation, is less definitive. The first reason to think that it is not is that, as noted, information about affordances need not be processed to lead to action. This, however, is not necessarily the final word, because information about affordances must certainly be *used* by the animal to guide its action, and that use might be amenable to a computational modeling; indeed, the use might actually be computation. To see how this could work, consider the internalization of affordances embodied in Ruth Millikan's notion of pushmi-pullyu representations (1996) (see also Clark, 1997). Pushmi-pullyu representations (PPRs) are simultaneously descriptions of how the world is and directives about how one ought to behave, without being simply conjunctions of descriptions and directives. Millikan conceived them specifically as internal entities that could guide behavior without complicated inferential processes. PPRs just are representations of affordances. The very idea of an internalized affordance shows that it is (logically) possible for information about affordances to be not just in the environment but also inside organisms.[8] Furthermore, PPRs are ubiquitous in models used in cognitive science, even those that claim to not use representations at all (see Chemero, 2000).

Does this mean that information about affordances is processed? It need not. To see why, consider an early AI model that implements something like the perception and use of affordances: Agre and Chapman's Pengi (1987). Pengi is a simulated agent that plays the video game Pengo. Pengi plays without forming an explicit plan of what to do, and without keeping track of any particular things in its environment. Instead, Pengi reacts directly to its surroundings, and deals with what is going on directly in its immediate vicinity. Rather than planning its actions, it reacts to its situation. Pengi accomplishes this by perceiving and reacting to *indexical-functional entities*. Indexical-functional entities are defined only in terms of Pengi and what he does; that is, they are entities understood in terms of their affordances for Pengi. For example, Pengi guides its behavior in terms of representations of "the-bee-that's-chasing-me" or "the-corridor-I'm-running-along" rather than representations of "bee-37" or "north-south-corridor-3". Using indexical-functional entities avoids needing to make lots of inferences. Pengi avoids the-bee-that's-chasing-me, without having to realize that bee-37 is chasing him and therefore he needs to avoid bee-37. Playing this way, by improvising and reacting to affordances, Pengi plays Pengo as well as most humans who have played for a few hours. And it does so by using internally represented affordances, and without processing

information. How does this happen? Pengi's behavior is controlled by a set of rules that go directly from affordances to action, without any intervention. Pengi's rules might be something like

> RULE: IF the-block-I'm-going-to-kick-is-next-to-me, THEN kick-the-block-I'm-going-to-kick.

Compare this to the way other AI models, those that process information in complex ways and do not represent affordances, would solve the same problem. Such a system would need a set of rules, used in a series of inferences to accomplish the same task as:

> RULE: IF [(Goal = kick-blockX) AND (Adjacent(blockX))] THEN [Do (kick-blockX)]. To actually kick the block, the agent would need to also have the following bits of information about its environment:
>
> Goal = kick-block-21;
> Location(Block-21) = 421;
> Location(me) = 532;
> Spot 421 is adjacent to 532, etc.

These would have to be combined in a series of inferences, to finally yield the motor command Do (kick-block-21). Pengi, on the other hand, takes just one step, a mapping from a representation that a block affords kicking to the motor command to kick the block.

So there can be information about affordances represented and used in artificial intelligence models that are of interest to ecological psychologists, without those models implying that using affordances requires complex computational processes. This means that situation semantics can provide a formal theory of information for both perception of the environment and for processing in computers.

5. Conclusion

I began this essay by noting the terminological perils that plague interdisciplinary endeavors such as artificial intelligence, cognitive science, and the philosophy of information. I have not shown that the term 'information' is not a term that is used in multiple ways by people who think they are communicating. Instead, I have shown that there is a sense of 'information' that could be used for effective interdisciplinary communication by psychologists, philosophers and computer scientists. It is perhaps too much to hope that from now on we will all use the term as I (following Gibson, Barwise, and Perry) have suggested, ending confusion from now on.

There is a result of this that might have more of an effect. I have shown that there is nothing about information that makes ecological psychology inconsistent with computational views of perception. This is a rather modest accomplishment. But it

does open the possibility that the very same creatures might use the information in the environment in a way that is consistent with ecological psychology sometimes and with information-processing models of the mind at others. In particular, I hope to have made space for the possibility that the bulk of human perception is perception of affordances and that the bulk of human action is computation-free use of affordances, without simultaneously making it impossible that we occasionally perform just the sort of complex inferences that computationalists think form the basis for all of human behavior.

Notes

[1] It would, of course, be impolitic to name names here. But one might begin the list with those outside philosophy who take philosophical work on intentionality to be about purposiveness.

[2]Millikan (2000) points out that Evans is simply wrong that he uses the term the way Gibson does.

[3]Reed (1996) also tries to give a philosophically-sound account of Gibson's theory of information and affordances. This essay is an attempt to improve on Reed's work. See also Chemero (2003).

[4]Note that there is still stimulation of retinal cells in this case. Stimulation is necessary, but not sufficient for perception.

[5]Fodor and Pylyshyn (1981) agree with this point about the relational nature of information as Gibson understands it. They disagree with more or less everything else in Gibson (1979).

[6]The exact nature of the relationship between height and other aspects of body scale and affordances is a matter of dispute. See Chemero (2003).

[7]In *Knowledge and the Flow of Information*, Dretske tries to solve this problem by making information flow depend on channel conditions, surrounding conditions which, if present, would make the probability of beer, given beer can, equal to 1. For this to be of any help in understanding the information used in perception, situations must also carry information that all necessary channel conditions are present. Typically, they do not. See Millikan (2000).

[8]I am assuming that PPRs carry information about affordances in a format that is usable by organisms. Ecological psychologists, who are typically unfriendly to mental representations of any kind, might question this assumption, suggesting instead that only information in light is usable by organisms. Thanks, Deniz Dagci

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