

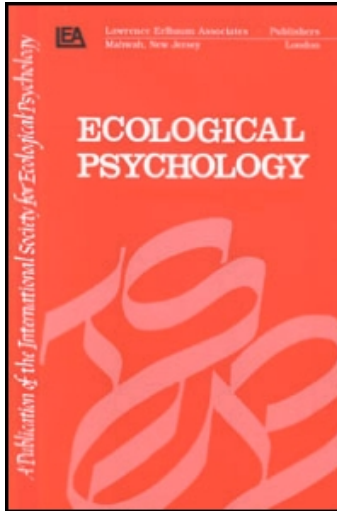
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Ecological Psychology

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t775653640>

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Online publication date: 08 June 2010

To cite this Article Withagen, Rob(2004) 'The Pickup of Nonspecifying Variables Does Not Entail Indirect Perception', *Ecological Psychology*, 16: 3, 237 – 253

To link to this Article: DOI: 10.1207/s15326969eco1603_4

URL: http://dx.doi.org/10.1207/s15326969eco1603_4

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The Pickup of Nonspecifying Variables Does Not Entail Indirect Perception

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A number of recent empirical studies revealed the pickup of nonspecifying variables. This raises the question of whether perception is sometimes indirect. In this article this question is addressed and answered in the negative. First, it is argued that empirical studies are likely to reveal that animals also rely on nonspecifying variables. Probably not every meaningful environmental property is specified by an informational variable. Furthermore, from an evolutionary perspective there is reason to believe that animals also attend to nonspecifying variables, even if specifying information exists. Second, it is argued that the pickup of nonspecifying variables does not entail indirect perception. Gibson's (1959, 1966, 1979/1986) conception of perception as a direct epistemic contact with the environment is adopted. It is suggested that this epistemic contact can be thought of as a continuum—the contact can differ in degree. The strength of the contact is determined by the informational variable exploited. In this framework, the animal is in direct epistemic contact with an environmental property, regardless of whether a specifying or nonspecifying variable is exploited.

One of Gibson's (1966, 1979/1986) major contributions to psychology was his direct perception theory. This perception theory is probably best known for its claim on the nature of the informational variables that animals pick up. At the time Gibson developed his perception theory, it was widely accepted that perceptual systems receive impoverished stimulus information that relates ambiguously to environmental properties (see, e.g., Reed, 1988). Gibson (1959, 1966, 1979/1986) opposed this theory. He asserted that the stimulus information available to the ani-

mal is rich, not impoverished. According to the common interpretation, his theory holds that the informational variables that the animal picks up are “uniquely and invariantly tied to their sources in the environment” (Michaels & Carello, 1981, p. 19). That is, the exploited informational variables are not ambiguous with respect to environmental properties; rather, they are specific to them—they relate one-to-one to environmental properties. “The specification is sought in *invariants*, patterns of stimulation over time and/or space that are left unchanged by certain transformations” (Michaels & Carello, pp. 19–20). And by picking up such invariant, specifying patterns, the animal directly perceives the environmental property that the exploited invariant specifies.

Gibson’s (1966, 1979/1986) direct perception theory has yielded a fruitful experimental program. According to many proponents of the theory (see, e.g., Turvey, 1990; Turvey & Carello, 1995), “Two major experimental goals within Gibson’s program are to discover specificity (1) between properties of the structured energy distributions and properties of the environment, body, and environment–body relations and (2) between perception and properties of structured energy distributions” (Turvey & Carello, 1995, pp. 482–483).

The search for such specificity relations has yielded some interesting discoveries. First, informational variables that are specific to particular environmental properties have been discovered. The optical variable tau, which specifies time to contact of an approaching object (given certain constraints), is one well-known example (e.g., Lee, 1976). Hence, contrary to the assumption of most perception theories, there exists information that specifies certain properties of the environment. Second, a number of studies revealed that animals indeed exploit such specifying information (e.g., Savelsbergh, Whiting, & Bootsma, 1991).

However, the pickup of specifying variables has not always been found. A number of recent ecologically motivated experimental studies have revealed the pickup of informational variables that relate ambiguously to the to-be-perceived environmental feature. The reliance on such nonspecifying variables has been found not only in artificial tasks, such as the perception of the relative mass of two colliding balls (Jacobs, Runeson, & Michaels, 2001) or the perception of the pulling force of a stick figure (Michaels & de Vries, 1998), but also in ecologically natural tasks. It appears that animals sometimes exploit nonspecifying variables to perceive or realize affordances (e.g., Michaels, 2000; Michaels, Zeinstra, & Oudejans, 2001; Solomon & Turvey, 1988; Turvey & Carello, 1995). The perception of the distance reachable with a hand-held rod via dynamic touch is an instance of such an affordance perception. As has been demonstrated extensively, people have a definite impression of the distance reachable with a hand-held rod when wielding it (e.g., Solomon & Turvey, 1988). A number of studies revealed that this perception is informed by the rod’s moments of inertia, the rod’s resistances to angular acceleration (e.g., Solomon & Turvey, 1988; Turvey & Carello, 1995). A moment of inertia is a function of the rod’s mass distribution and, therefore, is related ambiguously to the distance reachable with the rod. As Carello, Fitzpatrick, Domaniewicz, Chan, and Turvey (1992) put it, “Given a moment of inertia of $41,666.7 \text{ g} \cdot \text{cm}^2$, one could suppose that the object in question was

2g/250 cm, or 150g/28.9 cm, or 10g/111.8 cm, or 500g/15.8 cm, and so on" (p. 291). The same value of the moment of inertia occurs with rods of different lengths, and equal-length rods can occur with different values of the moment of inertia. Nevertheless, "perceived distance reachable with a rod is a single valued function of moment of inertia, that is, people feel a given rotational inertia as a single well-defined extent and not as multiple possible extents" (Carello et al., p. 291). Thus, perceived distance reachable is specific to an informational variable, but the exploited informational variable is not specific to the actual distance reachable.

What does the demonstration that animals sometimes rely on nonspecifying variables mean? Does it reject Gibson's (1966, 1979/1986) direct perception theory? A number of ecological psychologists have suggested that the pickup of specifying information is a necessary condition for perception to be direct. Vicente (2003), for instance, stated, "Perception can be direct only if there is a one-to-one relation between an invariant and an affordance. In other words, the invariant (a higher order property of the stimulus array) must directly specify the affordance" (p. 249). And Michaels and Carello (1981) argued that, "The viability of a theory of direct perception depends on a demonstration that the energy pattern stimulating the senses contain a specification of the environment" (p. 19). Thus, the demonstration that an animal exploits a nonspecifying variable seems inconsistent with the direct perception theory. Instead, the demonstration seems to provide evidence for the more traditional indirect perception theory that Gibson (1959, 1966, 1979/1986) opposed. Broadly speaking, this theory holds that the pickup of stimulus information that is ambiguous with respect to its source implies that perceptual processes are inferential: Because the stimulus does not specify its source, the perceiver has to infer what causes the stimulus in order to gain knowledge about the environment. The result of the inferential processes is a representation of the world, and this representation is the object of perception. Hence, the animal does not perceive the environment directly, but indirectly, that is, via a representation. For instance, in *Cognitive Psychology*, Neisser (1967) stated:

We have no direct, *immediate* access to the world, nor to any of its properties. ... Whatever we know about reality has been *mediated*, not only by the organs of sense but by complex systems which interpret and reinterpret sensory information. ... [The] patterns of light at the retina are the so-called "proximal stimuli." ... One-sided in their perspective, shifting radically several times each second, unique and novel at every moment, the proximal stimuli bear little resemblance to either the real object that gave rise to them or to the object of experience that the perceiver will construct as a result.

Visual cognition, then, deals with the processes by which a perceived, remembered, and thought-about world is brought into being from as unpromising a beginning as the retinal patterns. (pp. 3–4)

Although this indirect perception theory has been criticized—in particular by ecological psychologists (e.g., Gibson, 1966, 1979/1986; Michaels & Carello, 1981; Shaw, Turvey, & Mace, 1982), its premise that the pickup of nonspecifying vari-

ables entails a representational conception of perception is hardly ever questioned. Both indirect-perception theorists and direct-perception theorists appear to consider the premise as beyond dispute (see Michaels & de Vries, 1998, for an exception). Ecological psychologists generally argue that the environment is directly perceived *because* animals pick up specifying variables. Hence, the finding that animals also rely on nonspecifying variables seems to imply that animals sometimes perceive their environments indirectly, that is, via a representation.

This article addresses the question of whether the pickup of nonspecifying variables entails a representational conception of perception. The article consists of two parts. In the first part, it is argued that ecologically motivated studies are likely to reveal that animals also pick up informational variables that relate ambiguously to the to-be-perceived property. Probably not every meaningful environmental property is specified by an informational variable. Furthermore, from an evolutionary perspective there is reason to believe that animals also attend to informational variables that relate ambiguously to environmental properties, even if specifying information exists. In the second and main part of the article, the question of whether the pickup of nonspecifying variables entails indirect perception is addressed and answered in the negative. Gibson's (1959, 1966, 1979/1986) conception of perception as a direct epistemic contact with the environment is adopted. It is suggested that this epistemic contact can be thought of as a continuum—the contact with a particular environmental property can differ in degree. The strength of the contact is determined by the informational variable exploited. In this framework, the animal is in direct epistemic contact with a particular environmental property, regardless of whether a specifying or nonspecifying variable is exploited.

ANIMALS ALSO PICK UP NONSPECIFYING VARIABLES

There are several reasons why ecologically motivated studies are likely to reveal the pickup of informational variables that relate ambiguously to the to-be-perceived property. I will give two.

Probably Not Every Environmental Property Is Specified by an Informational Variable

Some ecological psychologists (e.g., Jacobs, 2001; Vicente, 2003) have suggested that probably not every environmental property is specified by an informational variable. Vicente, for instance, argued that

there are many situations where it seems clear that information, in the Gibsonian sense, does not exist. An obvious example is the behavior of the stock market. As far as anyone knows, there are no deterministic rules or laws that govern changes in the

prices of stocks. This is a prototypical example of the type of situation that cannot be captured by direct perception. ... (p. 260)

And Jacobs (2001) wrote

I hesitate to accept the argument commonly made by ecological psychologists that relevant environmental properties must be specified by ambient energy patterns merely because such patterns are generated lawfully. For instance, although not very likely in natural situations, it is physically possible that different combinations of forces result in the same net force and thus generate the same movement, which is to say, despite their lawful generation, movement patterns do not necessarily specify the underlying forces. Likewise, the mere fact that ambient arrays are a function of environmental properties does not prove that such functions always have an inverse. (p. 199)

As Runeson (1988) argued, specificity is contingent on constraints. That is, it is by virtue of physical laws and ecological constraints that informational variables are related one-to-one to environmental properties. Consider, for instance, the KSD-principle. KSD stands for *kinematic specification of dynamics*—it entails that dynamic properties are specified by kinematic patterns (e.g., Runeson, 1995; Runeson, Juslin, & Olsson, 2000). This principle is illustrated by the collision of balls, showing that the relative mass of the balls is specified by “the relative amount of motion change incurred by the colliding objects” (Runeson et al., p. 527). This specificity relation between the dynamical property (relative mass) and the kinematic pattern (changes in velocity) exists because of the conservation of momentum, rendering the momentum before collision equal to the momentum after collision. This physical law grants the relative amount of motion change to be specific to the relative mass of the balls.

The fact that the specificity relation between informational variables and environmental properties is contingent on physical laws and ecological constraints means that it might be that not every meaningful environmental property is related uniquely to an informational variable. As Turvey and Carello (1995) put it, “Structured arrays can only be as specific to their sources as the laws of physics allow” (p. 483). Hence, given the physical laws and ecological constraints in the animal’s natural habitat, certain meaningful environmental properties might not be specified by informational variables. This would mean that animals have no option but to pick up nonspecifying variables to perceive those properties.

Evolution Does Not Yield Animals That Rely Exclusively on Specifying Information

But if specifying information is present in the ambient arrays, then will the animal pick it up? From an evolutionary perspective there is reason to believe that

animals also attend to nonspecifying variables, even if specifying information exists. First, it might be that particular specifying information is not exploited because the system that is required for its pickup could not evolve. As has been argued extensively over the last 40 years by many evolutionary biologists (e.g., Andrews, Gangestad, & Matthews, in press; Cartwright, 2000; Clark, 1989; Dawkins, 1982; Gould, 1997; Gould & Lewontin, 1978; Jacob, 1977; Kauffman, 1995; Sober, 1993), and appreciated by some ecological psychologists (e.g., Johnston & Turvey, 1980; Reed, 1996), evolution by natural selection does not work as an optimizing agent, yielding optimally designed systems that are perfectly adapted to their environments.¹ Organic form and behavior are the result not only of natural selection but also of numerous developmental, phyletic, and historical constraints that influence the path of evolution to a considerable degree. Animals are integrated wholes, Gould and Lewontin (1978) asserted, “with *Baupläne* so constrained by phyletic heritage, pathways of development, and general architecture that the constraints themselves become more interesting and more important in delimiting pathways of change than the selective force that may mediate change when it occurs” (p. 581). The constraints can restrict paths and modes of change in such a way that certain systems are unlikely to evolve (see, e.g., Dawkins, 1982). Hence, it might be that particular specifying information is not picked up because the constraints restrict the evolutionary processes in such a way that the system required for the detection of this specifying information, the so-called smart perceptual device (Runeson, 1977), could not evolve.

Second, natural selection is not so powerful that animals that also pick up nonspecifying variables cannot survive. Nonspecifying variables are not necessarily useless variables—their pickup does not necessarily yield perception that is fundamentally in error. A nonspecifying variable can be quite informative about an environmental property. Again, consider the relation between the rod’s length and its moment of inertia around one of its ends. The moment of inertia is determined by how far the rod’s constituent masses are from its end—that is, it is partly determined by the rod’s linear dimensions. This means that the rod’s moment of inertia is “informative about its linear dimensions, but not perfectly so” (Turvey & Carello, 1995, p. 483). Hence, an animal that picks up this variable can have a fairly accurate perception of the distance reachable with the hand-held rod. Granted, the pickup of this nonspecifying information yields certain errors—rods that are of different lengths are sometimes perceived as being of the same length, and equal-length rods are sometimes perceived as being of

¹According to Reed (1996), many ecological psychologists (implicitly) assume that evolution works as an optimizing agent. “[M]uch current thinking about the use of information by animals is unfortunately overly adaptationist in the sense criticized by Gould and Lewontin. It is too frequently *assumed* that information exists and that some sort of optimal information is available to the organism” (p. 48).

different lengths, but its detection does not necessarily result in perception that is fundamentally in error (cf. Carello et al., 1992).

Evolution is likely to yield animals that also pick up such nonspecifying, moderately informative variables. In the course of evolution, animals with perception and action accurate enough to survive and reproduce were selected. In many cases this means that a considerable degree of perceptual inaccuracy is allowed. For instance, a human being who intercepts 70% of the balls thrown at him or her because he or she exploits a nonspecifying, moderately informative variable will not die because of that. The selection pressures are not that strong that an animal that also picks up nonspecifying but useful variables cannot survive. Relatedly, natural selection is in many cases relative: The animals that survive are the ones that do better than their competitors. This does not, however, imply that the animal that survives exploits the specifying variable; rather, it implies, at least if the accuracy of perception was the determining factor for survival, that the animal picks up a more useful variable than its competitor, but this might be a nonspecifying variable. In sum, there is reason to believe that animals exploit specifying as well as nonspecifying variables. Hence, ecologically motivated studies are likely to reveal that animals also pick up informational variables that relate ambiguously to the to-be-perceived property.

DIRECT AND INDIRECT PERCEPTION?

As touched on in the introduction, the finding that animals pick up nonspecifying variables raises the question of whether perception of the environment is always direct. It seems to imply that animals perceive their environments indirectly, that is, via a representation. Recently, Runeson et al. (2000) argued that the pickup of nonspecifying variables indeed implies that the environment is not directly perceived. They studied the process of how people learn to visually perceive the relative mass of two colliding balls. As Gibson (1966) asserted, the process of perceptual learning is a process of differentiation: The animal discovers the to-be-attended-to pattern in the ambient array or arrays. That is, the animal learns to exploit the informational variable that is specific to the to-be-perceived property. Gibson (1966) referred to this process as *the education of attention*.² In their study, Runeson et al. found evidence for this process. Many participants initially relied on a nonspecifying variable and converged on the specifying variable after feedback.

²Recently, Jacobs and Michaels (2002) argued that because this process of convergence on the specifying variable is a short-term process, animals pick up only specifying variables in the long term. However, if the previously mentioned evolutionary arguments are right, it is unlikely that the process of convergence always results in the pickup of specifying variables, especially on the short timescale that Jacobs and Michaels suggested.

However, Runeson et al. (2000) argued that during this process a transition from an indirect to a direct mode of apprehension takes place. If the perceiver picks up a nonspecifying variable (as at the start of the learning process), he or she is in the indirect mode; that is, the perceiver is in a mode of apprehension in which the nonspecifying variable is enriched through inferential processes. If, on the other hand, a specifying variable is exploited (as at the end of the learning process), the environment is directly perceived. This theory of mode transition follows if the nature of the informational variable exploited is taken to be the distinguishing feature of the two perception theories: The theory of indirect perception holds that nonspecifying perceptual variables are exploited; the theory of direct perception states that specifying variables are picked up.

It is, however, questionable whether the nature of the perceptual variables exploited is the quintessence of direct perception. A more central tenet of the direct perception theory, I think, is the claim on the object of perception (see also Heft, 2001; Mace, 2002). As is described in more detail in the next section, Gibson's (1966, 1979/1986) ecological psychology is rooted in the realist approach to perception (see, e.g., Heft, 2001; Lombardo, 1987; Reed, 1988). This approach states that the environment is the object of perception. Perception is conceived of as a direct epistemic contact with the environment.

By asserting that the environment is perceived, Gibson (1959, 1966, 1979/1986) rejected a central tenet of the indirect perception theory, namely that a mental representation of the environment is the perceived object. Stemming from the Cartesian tradition, the indirect perception theory treats perception as a subjective mental state, more or less isolated from the environment (e.g., see Fodor, 1980). The basic idea is as follows: A stimulus impinges on a sense organ and gives rise to a sensation, an awareness of the state of the receptors. Only this sensation is directly apprehended. Because the sensation is ambiguous with respect to its source, the animal must deduce what causes the sensation in order to gain knowledge about the environment. The inferential processes result in a representation of the environment, and this representation is perceived. Thus, the animal does not perceive the environment, but a representation of it. In this framework, perception resides in the animal and is more or less detached from the environment. Although in different forms, this idea dominated perception theories from Descartes to Müller and Helmholtz and is the basic assumption in many recent cognitive theories of perception (e.g., see Meijering, 1989; Reed, 1982).

The representational conception of perception runs the risk of introducing a homunculus, a little person inside the head that looks at the mental representation. Thereby, the indirect perception theory would take a "loan of intelligence" (Dennett, 1978) and lead to an infinite regress (who perceives the mental representation of the homunculus ...) (e.g., Dennett, 1991; Shaw et al., 1982). However, it is not clear that the pickup of nonspecifying variables logically implies a representational conception of perception. In the remainder of the article this thesis is

addressed and rejected. It is suggested that animals are in direct epistemic contact with their environments, regardless of whether a specifying or nonspecifying variable is picked up.

Perception as an Epistemic Relation With the Environment

Although highly revolutionary, Gibson's (1966, 1979/1986) ecological approach did not come out of nowhere. It is, as stated earlier, rooted in the realist tradition of perception that can be traced back to Aristotle (see Lombardo, 1987). The realist approach of Gibson was influenced most directly by that of Edwin B. Holt, his graduate school mentor at Princeton and a former student of William James (Heft, 2001).³ Holt's approach attempted to circumvent the problems of psychologies based on the Cartesian dualisms of mind and matter, and animal and environment. It holds that mental phenomena do not reside in the animal, but in the dynamic relation of the animal and its environment. As Holt (1914/1973) pointed out, "consciousness or mind is not inside the skull nor secreted anywhere within the nervous system; but all the objects that one perceives, including the so-called 'secondary qualities,' are 'out there' just where and as they seem to be" (p. 181). But how can the environment be the object of perception? In his essays on cognition and response, Holt (1915a, 1915b) paid considerable attention to conceptualizing behavior. He argued that

The behaving organism, whether plant, fellow man, or one's own self, is always doing something, and the fairly *accurate description* of this activity will invariably reveal a law (or laws) whereby this activity is shown to be a constant function of some aspect of the objective world. (1915a, p. 370)

The collection of these aspects form what Holt called a "cross-section," a concept that refers to a part of a manifold that is defined by a law unrelated to this manifold. Holt (1914/1973) illustrated this concept as follows:

A navigator exploring his course at night with the help of a searchlight, illuminates a considerable expanse of wave and cloud, occasionally the bow and forward mast of his ship, and the hither side of other ships and buoys, lighthouses, and other objects that lie above the horizon. Now the sum total of all surfaces thus illuminated in the course, say, of an entire night is a cross-section of the region in question that has rather interesting characteristics. It is defined, of course, by the contours and surface composition of the region, including such changes as take place in these (specially on

³In the beginning of his career, Gibson was a proponent of Holt's motor theory of consciousness and conducted some experiments to test the theory (e.g., Gibson & Hudson, 1935; Gibson, Jack, & Raffel, 1932). By the 1960s Gibson had rejected this theory but retained Holt's idea of perception as an epistemic relation between the animal and its environment (see Reed, 1988).

the surface of the waves) and by the searchlight and its movement, and by the progress of the ship. (p. 171)

The cross-section is relational: It is determined by the ship relative to the environment, namely the part of the environment through which the ship is passing. In like fashion, the animal's environment constitutes a cross-section. "It is to certain features, and not to others, of its environment that the living organism responds, and the group of things to which it thus reacts constitutes a cross-section manifold ... " (Holt, 1914/1973, p. 172). The collection of environmental objects that form the cross-section is defined by the animal's sensitivity, but exist independent of it; the objects are aspects of the objective world. Holt stated that these objects are perceived. "I know not what distinction can be drawn between the object of consciousness and the object of behavior" (Holt, 1915b, pp. 393–394). In other words, the environment is the object of perception: "This neutral cross-section as defined by the specific reaction of reflex-arcs is the psychic realm:—it is the manifold of our sensations, perception and ideas:—it is consciousness" (Holt, 1914/1973, p. 182).

In this framework, perception does not reside in the animal; it is not localized in the brain or some other piece of anatomy.⁴ Instead, perception is conceived of as a relation between the animal and its environment—it is an ecological phenomenon. Just as reading a book is a relation between the reader and the book, perception is a relation between the perceiver and the perceived. More precisely, perception is an epistemic relation between the animal and its environment—a being in contact with the environment, which is achieved by the pickup of perceptual information (e.g., Heft, 2001; Holt, 1914/1973; Lombardo, 1987; Shaw et al., 1982).

Epistemic Contact With the Environment as a Continuum

Gibson (1959, 1966, 1979/1986) adopted the previously mentioned conception of perception. In his essay *Perception as a Function of Stimulation*, he started by stating, "The word *perception* in this essay means the process by which an individual maintains contact with his environment" (1959, p. 457). Gibson (1959, 1966, 1979/1986) aimed at explaining how this epistemic relation of the animal with its environment—in his terminology the *keeping-in-touch with the world*—is established, and he introduced the concept of *information as specification*. Gibson (1959) argued that the pickup of an informational variable that specifies an environmental property is a necessary condition for being in epistemic contact with that property. There is, Gibson (1959) asserted, a one-to-one relation between an environmental property and a pattern in the ambient array, and between this

⁴This is not to say that the brain is not of importance in perception. In this conceptualization, the brain is conceived as an organ that provides the causal support for establishing an epistemic relation between the animal and its environment. As Lombardo (1987) stated, "Animals perceive with their perceptual systems; it is not the perceptual systems that perceive" (p. 330).

pattern and the perception (cf. Turvey, 1990). To be in touch with an environmental property, Gibson (1959) argued, this chain should remain unbroken. “*There is no other avenue for contact with or knowledge of the environment*” (Gibson, 1959, p. 464).

In these statements about the keeping-in-touch with an environmental property, the epistemic contact is thought of as all or nothing: The animal is in direct touch with a certain environmental property if and only if it picks up an informational variable that is specific to that property. But is the epistemic contact with an environmental property all or nothing? Is the keeping-in-touch with an environmental property achieved if and only if a specifying variable is picked up, and not if a nonspecifying but moderately informative variable is exploited? It might be more constructive to think of the keeping-in-touch with the environment as a continuum—the epistemic contact with an environmental property can differ in degree. That is, an animal that picks up a nonspecifying variable is not deprived of direct epistemic contact with an environmental property, perceiving that property via a representation. Rather, that animal’s epistemic contact with the environmental property is not as strong as that of an animal that exploits a specifying variable. Consider, for instance, a dynamic touch experiment in which participants are to position a planar surface at the distance reachable with a hand-held, unseen rod.⁵ Let us, for the sake of argument, assume that a participant picks up an informational variable that is specific to the distance reachable. Such a participant is in perfect touch with the distance reachable—any change in the length of the hand-held rod is reflected by a change in the position of the planar surface. A weaker epistemic touch with the distance reachable is established if the participant picks up a nonspecifying, moderately informative variable, such as moment of inertia. Being not in perfect touch with the distance reachable, that participant’s positioning of the planar surface is not as firmly tied to the lengths of the rods. Equal-length rods can occur with different positions of the surface, and rods of different lengths can occur with the same position of the surface. The epistemic contact with the distance reachable with the hand-held rod is weaker and, thus, the response-panel position less accurate, if the exploited informational variable is less informative about the distance reachable.⁶

⁵One might argue that this artificial experimental setup is not representative of the natural situation, for the participant is deprived of visual information about the length of the hand-held rod. However, this example is used just to illustrate the idea of a continuum of contact.

⁶Note that this idea of a continuum of contact refers to the epistemic contact with an environmental property. The idea is not related to the ecological conception of nesting and the allied concept of differentiation. Mace (2002) illustrated these concepts as follows: “A real world is distinct from a surrogate world by virtue of its nested structure at all scales. When one looks closely at the skin of a person, one ultimately gets to cells. When one gets closer to the painting of a face, one gets to the paint and grain of canvas, not cells and skin tissue” (p. 111). The continuum idea that I present in this article does not relate to this process by which an animal gets in touch with more properties or details of an environmental object. Rather, the continuum idea refers to the epistemic touch with an environmental property, say, a particular affordance.

In this conceptualization, the difference between an animal that exploits a specifying variable and an animal that picks up a nonspecifying variable is not the difference between directly and indirectly perceiving an affordance; rather, the animals differ in the strength of the epistemic contact with the affordance, the animal picking up the specifying variable being in better touch with the affordance than the animal that attends to the nonspecifying variable. In other words, the idea of a continuum of contact entails that an animal is in direct epistemic contact with a particular affordance, regardless of whether a specifying or nonspecifying variable is exploited.

What are the implications of this continuum idea for the ecological approach to perception?

First, the continuum idea recognizes the pickup of nonspecifying variables and preserves the realist conception of perception. It holds that the animal is in direct epistemic contact with its environment also when a nonspecifying variable is picked up. Hence, the idea is consonant with the *sine qua non* of the realist approach to perception in which Gibson's (1959, 1966, 1979/1986) psychology is rooted: Perception is an epistemic relation between the animal and its environment.

Second, the continuum idea provides a way of conceptualizing perceptual learning. As stated earlier, Gibson (1966) conceived of perceptual learning as a process by which the animal learns to discover the informational variable that is specific to the to-be-perceived affordance. According to the continuum idea, the process by which animals converge on the variable yields a better epistemic contact with an environmental property. Thus, if animals converge on the specifying variables to perceive or realize the affordances—either at the timescale of phylogeny, ontogeny, or learning—the strength of the epistemic contact with these affordances increases.

Third, the continuum idea provides a way of conceptualizing perceptual mistakes. Despite Gibson's (1966) elucidation of misperceptions (see also Michaels & Carello, 1981; Shaw et al., 1982), an often-heard critique of his direct perception theory is that it cannot account for perceptual errors. In cognitive theory, these errors are generally conceptualized as errors of correspondence between the perception and the actual environmental state of affairs. A theory of direct perception cannot accept such a conceptualization (Heft, 2001; Shaw et al., 1982; see also Holt, 1914/1973). After all, this conceptualization is based on an animal–environmental dualism: The perception resides inside the animal and does or does not correspond to the environmental state outside. The definition of perception as an epistemic relation between the animal and its environment abandons this dualism. As an alternative conceptualization, some ecological psychologists, following Holt, conceived of perceptual errors as “a lack of coherence or consistency within perceptual experience” (Heft, 2001, p. 80; see also Shaw et al., 1982, on “possible-worlds semantics”). That is, the perceptual experiences of the same object might differ under different conditions. To use an example of

Holt (see Heft, 2001), a stick appears bent when viewed in water but not when viewed out of water. The perceptual error, it is argued, does not consist in an error of correspondence between the appearance and the reality, but in the lack of consistency between appearances under different viewing conditions (see Heft, 2001). The continuum idea provides an alternative to this ecological conceptualization: If keeping-in-touch with the environment is a continuum, perceptual errors can be conceived as a weak epistemic contact between the animal and an environmental property; that is, the animal is not in full epistemic contact with the property.

Fourth, a prerequisite of the continuum idea is that an animal can be in epistemic contact with an environmental property by attending to an informational variable that does not specify that property. This conflicts with a thesis defended by some ecological psychologists. As stated earlier, Gibson (1959), for instance, argued that an animal can establish an epistemic contact with an environmental property only through the pickup of an informational variable that is specific to that property. "*There is no other avenue for contact with or knowledge of the environment*" (Gibson, 1959, p. 464). However, this thesis is inconsistent with some experimental findings. Again, consider the perception of the distance reachable with a hand-held rod via dynamic touch. As stated earlier, humans have a definite impression of the distance reachable, but the informational variable that informs their perception does not specify it (e.g., Solomon & Turvey, 1988; Turvey & Carello, 1995; Withagen & Michaels, 2001). Thus, it seems that the prerequisite for the continuum idea is met: An epistemic relation with an environmental property can be established by picking up an informational variable that does not relate one-to-one to that property.

Fifth, the continuum idea requires a new definition of information. In ecological theory, the concept of information refers to the one-to-one relation between a pattern in the ambient array or arrays and a to-be-perceived environmental property (see, e.g., Michaels, 2000; Vicente, 2003).

[T]he invariant (a higher order property of the stimulus array) must directly specify the affordance (a goal-relevant distal property of the environment). This one-to-one mapping is referred to as *information*, a theoretical construct that has a unique and important meaning in Gibsonian ecological psychology that differs from the normal usage of the term. (Vicente, pp. 249–250)

However, the continuum idea implies that animals are sometimes *informed* about an environmental property by variables that do not specify it. That is, animals are informed by variables that are not qualified as information according to the previously mentioned ecological conception. Thus, as Chemero (2003) recently argued, it seems that ecological psychology is in need of a new concept of information. What is called for is a conception that does not require a one-to-one relation between a pattern in the ambient array and an environmental property.

In the philosophy of information, such a conception has been (recently) developed. Millikan (2000), for instance, introduced the concept of information_C, where C stands for correlation.

Natural signs bearing information_C are, as such, instances of types that are correlated with what they sign, there being a reason, grounded in natural necessity, why this correlation extends through a period of time or from one part of a locale to another. (p. 237)

However, the correlation, Millikan (2000) argued, can be weak.

For example, a particular instance of a small shadow moving across the ground is a natural sign carrying information_C that a flying predator is overhead if it is actually caused by a flying predator, but the correlation that supports this natural signing, though it persists for good reason, may not be particularly strong. (Millikan, p. 237)

In the prey's natural habitat there is no one-to-one relation between the shadow and the flying predator overhead. On a cloudy day, the flying predator does not yield a shadow moving across the ground—thus, no shadow does not necessarily imply no predator. And a nonpredator of the same shape as the predator could have produced the same shadow—thus, a shadow does not necessarily imply a predator. Therefore, the shadow is informative about a flying predator overhead, but not perfectly so. The Gibsonian ecological approach is in need of a conception of information that captures this information bearing of such nonspecifying variables.

CONCLUSION

In this article it was argued that ecologically motivated studies are likely to reveal the pickup of information variables that relate ambiguously to the to-be-perceived property. Probably not every environmental property is specified by an informational variable. Furthermore, from an evolutionary perspective there is reason to believe that animals also attend to informational variables that relate ambiguously to environmental properties, even if specifying information exists. This raises the question of whether animals also perceive indirectly. I have argued that the pickup of nonspecifying variables does not entail a representational conception of perception. I adopted Gibson's (1959, 1966, 1979/1986) conception of perception as a direct epistemic contact with the environment and suggested that this "keeping-in-touch with the world" (Gibson, 1979/1986) can be thought of as a continuum—the epistemic contact of the animal with an affordance can differ in degree. The strength of this contact is determined by the informational variable exploited. If the specifying variable is picked up, the animal is in full contact with the affordance; the contact is weaker if the informational variable exploited is less informative. In this framework,

the animal is in direct epistemic contact with an affordance, regardless of whether a specifying or nonspecifying variable is exploited.

ACKNOWLEDGMENTS

I am grateful to Sacha Bem, Raoul Bongers, Tony Chemero, Harry Heft, John van der Kamp, Rolf van de Langenberg, Bill Mace, Claire Michaels, Suzanne Noog, and Frank Zaal for helpful discussions and comments on earlier drafts of this article.

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