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COMMENTARIES

On the Apparent Paradox of Learning and Realism

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This article first summarizes how the definition of *perception* as the detection of information follows from the assumption of realism (e.g., Shaw, Turvey, & Mace, 1982). The realist position appears to be inconsistent with the empirical finding that novice perceivers often use nonspecifying variables and converge on the use of information only after practice with feedback (e.g., Michaels & de Vries, 1998). We argue that the appearance of inconsistency is due to the application and evaluation of realist principles beyond the scale of phenomena to which they apply. If the relevant principles are considered at the appropriate scales, convergence on information and realism imply each other. We also argue that the possibility of convergence and the associated use of nonspecifying variables should always be considered in the analyses of experimental results, especially if the information-granting constraints prevailing in the experiment are different from those prevailing in natural ecologies.

The purpose of this article is to relate recent empirical findings on perceptual learning with more traditional philosophical arguments in ecological psychology. The philosophical arguments start from the assumption of realism and conclude that *perception* should be defined as the detection of information. The empirical findings indicate that perceivers converge on the use of information only after practice and thus initially rely on nonspecifying variables. To what extent are the realist arguments and the supposed convergence inconsistent with each other? What is the origin of the apparent inconsistency? And finally, what should we learn from the philosophical studies and what from the empirical ones? Before we

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address these questions we summarize, in turn, both the philosophical arguments and the empirical findings.

THE CONSEQUENCES OF A COMMITMENT TO REALISM

In this section we summarize our understanding of the philosophical position forwarded by Shaw, Turvey, and Mace (1982; cf. Shaw & Bransford, 1977; Turvey, Shaw, Reed, & Mace, 1981), who aimed to derive a theory of perception from the assumption of realism. The position assumes realism, and to appreciate the arguments, one should be willing to accept that the real world exists and that it can be known at least in part. It would be sufficient to admit that one can know, without any doubt, that trivial things, such as this article, exist. The assumption of realism is stated as Principle 1 in Table 1, which, for future reference, also shows the ecological principles to be defended later in this section. Note that it is not our goal to explicate or defend rooting of a perceptual theory in realism. To the contrary, we assume that position as our departure point and present only as much of the position as seems needed to lay a basis for the remainder of our article. We refer the reader to Shaw et al. and Turvey et al. for more extensive treatments of these issues.

It is important for the argument that by *knowing,* more is meant than correct believing; one cannot know something that is not true. Knowing that there is a dictionary on the desk implies that there is a dictionary on the desk. Beliefs, on the other hand, can be true or false. The claim that correct beliefs are all that is possible is, in a way, a form of skepticism. The claim implies that, no matter how much one investigates this journal, one can never know that the article exists, which makes the claim unacceptable from a realist point of view. Surely, correct beliefs exist, but in some cases, one can look for further evidence and perhaps obtain knowledge. We do not believe that this article exists; we know that it exists. Likewise, the assumption is that knowledge is possible, and this assumption is much stronger than the assumption that correct beliefs are possible.

We are aware that no rock-bottom philosophical arguments can be given to persuade a skeptic, who might stubbornly deny knowledge about and the existence of any environmental property. Even at the risk of becoming as stubborn as the skeptic, however, one can choose not to abandon the assumption of realism and, thus, to consider what else must be true if that assumption is true. This means that one

TABLE 1
Ecological Principles

1. The world exists and can be known at least in part
2. The origin of knowledge is perceptual
3. Perception is veridical
4. Ambient energy patterns specify environmental properties
5. Perception is the detection of information

needs some reply to the skeptic who asks how properties of the world can be known; one needs to address the origin of such knowledge. Rationalist solutions to the origin of knowledge include concepts as innate schemata and reason, whereas empiricists argue that the origin of knowledge is perceptual. We agree with the skeptic, and with Shaw et al. (1982), that rationalist solutions beg the question: They presuppose the very knowledge that they seek to explain. The second assumption, therefore, is that perception is the basis of knowledge (Principle 2).

At this point it is crucial to recall that we are searching a source of knowledge, and not a source of true belief. This means that if knowledge exists, its origin must establish beyond any doubt that what is known does in fact exist. Because, by assumption, knowledge is possible, one must conclude that perception can be trusted. This conclusion might appear at odds with the large literatures on illusions and perceptual errors. The question, however, is the following: Should one prefer a theory tailored to realism, which must be twisted to explain perceptual errors, or a theory tailored to perceptual errors, which must be twisted to explain realism? In our view, the practical success of animals is far more impressive than the exceptional cases in which perception appears to be in error. Still following Shaw et al. (1982), we therefore prefer a theory to consider the reliability of knowledge before it addresses apparent misperceptions.[1] This first-things-first attitude forces us to continue the argument and to accept that, because some knowledge is possible, perception must be veridical (Principle 3).

The veridicality of perception might become more intuitively appealing if one realizes that it equates the logic of perceiving to the logic of, say, reading. Reading a book is an act that implies a reader, a book, and a certain relation between the two. Reading is veridical in the sense that reading something, without a single exception, implies the existence of the thing that is read. Likewise, perceiving is an act that implies a perceiver, something that is perceived, and a certain epistemic relation between the two. Thus far it has merely been established that it is not possible to perceive something, or to know something, if that something does not, in fact, exist.

The claim that perception is veridical means that perception is specific to the environmental properties that are perceived, which is to say that it is related one-to-one to those properties. If actual and perceived properties are related one to one, a one-to-one relation must be preserved throughout the act of perceiving. Consider a well-studied example, such as the perception of the weight lifted by another person (Runeson & Frykholm, 1981, 1983). If this weight is indeed perceived veridically, a one-to-one relation must be preserved at each step in the chain from the actual weight, to the kinematics of the lift, to the operative optical flow, to the operative sensory flow, and finally to the perceived weight. Vice versa the chain must remain unbroken from the intention to perceive weight, to the operative sensory flow, to the operative optical flow, to the kinematics, to the actual weight. Be-

[1]Extensive treatments of the ecological interpretation of illusions and apparent perceptual errors can be found, for instance, in Michaels and Carello (1981) and in Shaw et al. (1982).

cause patterns in ambient energy arrays are a necessary link in this chain, perception must be related one to one to ambient energy patterns, and such patterns must likewise be related to the perceived properties (Principles 4 and 5).

These final principles bring us back to J. J. Gibson (1950, 1966, 1979/1986), who arrived at the same conclusions using different arguments. J. J. Gibson used the term *information* to refer to ambient energy patterns that specify environmental properties. Furthermore, he defined *perception* as the detection of information. The arguments summarized in this section seem to indicate that this definition is logically implied by the assumption of realism.

CONSTRAINTS AS GRANTORS OF INFORMATION

We now briefly address a line of argument in the debate concerning Principle 4 that is relevant to the following sections. Runeson (1988) argued that constraints are grantors of information. Constraints are regularities that hold in to-be-considered ecologies. Such regularities can be natural laws that hold universally, but also regularities that hold only in more restricted ecologies. In the by now well-known example of an approaching object, the optical variable tau specifies the physical variable distance divided by speed given, among others, the constraint that the size of the object remains constant. If, in addition, the speed of the approaching object remains constant, tau also specifies time to contact (e.g., Bootsma, Fayt, Zaal, & Laurent, 1997; Lee & Reddish, 1981; Savelsbergh, Whiting, & Bootsma, 1991). Thus, in this example, the constraints of constant size and speed grant specificity between tau and time to contact. More generally, Principle 4, which asserts the existence of information in a specificational sense, can often be defended only if relevant constraints are considered.

THE CHALLENGE OF PERCEPTUAL LEARNING

Empirical research motivated by the principles discussed in the previous sections can be crudely divided into two approaches. The first approach starts by carefully considering the situation in which perception takes place. Relevant constraints prevailing in that situation are evaluated for their information-granting potential, and ideally, patterns specifying the to-be-perceived property are identified. Experiments then aim to test whether the identified patterns can account for the perceptual or motor output of the human or animal under study. If not, the search continues to find other patterns that might also specify the to-be-perceived environmental property or perhaps closely related properties. This approach can be termed *affirmative* or *principled* because it does not consider possible violations of the previously described principles; rather, the principles are used to guide the research. A prime example of such principled research is the early research on interceptive timing, which meant to affirm that observers and actors rely on the time-specifying variable tau (e.g., Lee & Reddish, 1981; Lee, Young, Reddish, Lough, & Clayton, 1983; cf. Bootsma & Peper, 1992).

A second empirical approach might be termed the *falsificationalist* or *shotgun* approach. As with the affirmative approach, this approach attempts to identify ambient energy patterns that specify relevant environmental properties, but it also considers other variables that might not specify such properties in any obvious way. It aims to determine which of a large number of specifying and nonspecifying variables best explains the observed performance. In the extreme, one might say that the approach shoots as many variables from the hip as possible and tests all of them. To the extent that the philosophical arguments in the previous section are viable, one would expect that the predictive value of specifying variables is higher than the predictive value of nonspecifying variables. Examples of the falsificationalist or shotgun approach are the later studies on interceptive timing (e.g., van der Kamp, 1999; van der Kamp, Savelsbergh, & Smeets, 1997) and the perceptual learning studies considered in the next paragraphs.

Recently, ecologically motivated research has addressed perceptual learning with many dependent measures, including verbal reports (Michaels & de Vries, 1998), ratio estimates entered electronically (Jacobs, Michaels, & Runeson, 2000; Jacobs, Runeson, & Michaels, 2001), and the timing of button presses (Smith, Flach, Dittman, & Stanard, 2001). Three findings of such learning studies are especially relevant to the present purpose. First, novice perceivers differ from each other in which variables they use, and they often use nonspecifying variables. Second, after a limited amount of practice with feedback, perceivers converge on more useful nonspecifying variables or even on variables that specify to-be-perceived properties. This convergence is what we understand J. J. Gibson (1966; cf. E. J. Gibson, 1969) to have meant by *the education of attention.* Third, less change in variable use is observed if the variable with which perceivers start already allows accurate performance in practice, and more change is observed if that variable does not at all allow accurate performance in practice.

Let us briefly illustrate the first two of these findings with an example. In several colliding-balls experiments (e.g., Jacobs et al., 2001), participants were shown two simulated balls approaching each other at some angles and speeds, colliding, and separating at new angles and speeds. Perceivers were asked to judge the relative mass of the colliding balls. Before practice, participants' judgments often correlated highly with the speed difference of the balls after the moment of impact. This speed difference does not specify relative mass, and its apparent use, therefore, led to less-than-optimal performance. After a practice phase with feedback, however, the judgments often correlated more highly with the relative amount of motion change—a variable that does specify relative mass—and the apparent use of such a specifying variable went together with more accurate performance.

Such learning results, most notably the use of nonspecifying variables by novice perceivers, seem to be inconsistent with the philosophical arguments presented in the previous sections. If perceivers sometimes rely on nonspecifying variables, perception is not always related one to one to the property to be perceived, implying that perception cannot be the origin of true knowledge. Thus, it seems that either the philosophical assumptions or arguments are invalid or the empirical findings should be interpreted otherwise. It would, of course, be unfortunate if a minimally constrained empirical approach would force us to abandon potentially valuable principles. Given this, and our intuitive trust in realism, we dedicate the next two sections to the search for alternative interpretations of the empirical findings. More precisely, we consider whether the apparent use of nonspecifying variables can be reinterpreted as the detection of information.

PERCEPTION VERSUS JUDGMENTS

Perhaps the apparent use of nonspecifying variables merely indicates that the dependent measures used in the experiments, which we refer to as judgments, reflect inferences or beliefs rather than perception. Participants might have perceived environmental properties that were not of primary interest to the tasks at hand. Being asked to report properties that they did not perceive, participants might have been pressed to infer those properties. This would be in agreement with the previously described consequences of realism, because it liberates perception from the errors that follow from the apparent use of nonspecifying variables. In this view, the errors arise between perception and judgments, rather than between the environment and perception.

We can use the colliding-balls example that was described in the previous section to illustrate this view. In that example, the judgments of novices often correlated highly with the speed difference of the balls after the moment of impact, which led us to conclude that the relative-mass perception of novices is often based on this speed difference, a variable that does not specify relative mass. Instead of concluding that the perception of relative mass was based on this nonspecifying variable and, thus, that the perception of relative mass was nonveridical, one could also conclude that the novices veridically perceived the considered speed difference and that they mistakenly based the relative mass judgments on the veridical speed perception.

Unfortunately, accepting this use of the distinction between judgments and perception implies sacrificing the seemingly parsimonious understanding of learning. The claim that the errors in judgments arise between perception and judgments suggests that explanations for the improvement of judgments should also be sought at the level of inferences from perception to judgments.[2] The view that one learns

[2]Note that this is not necessarily the case. Yet another possibility is that judgments reflect inferences in an inferential mode of apprehension and perceptions in a perceptual mode (Runeson, Juslin, & Olsson, 2000). In this view, the improvement of judgments can be explained by a transition from the inferential to the perceptual mode. We have argued elsewhere, however, that the education of attention might also occur within such a perceptual mode (Jacobs, Michaels, Zaal, & Runeson, 2001). Although this is consistent with the mode transition as such, it makes the transition less appealing as a solution of the present issue.

to make better judgments on the basis of the same perception, in turn, is inconsistent with the claim that learning is the convergence on the more useful energy patterns because, in this view, the judgments are not based on energy patterns. Portraying the improvement in judgments as coming to rely on the more useful nonspecifying perceptions seems hopelessly unparsimonious. In addition, it reveals a second and probably more severe problem of the suggested separation of perception and judgments.

Because the use of apparently nonspecifying variables has been reported with a wide variety of dependent measures, one would need to distinguish perception from many if not all possible outputs that can be observed in experiments. This would turn perception into an inaccessible entity. Claims about the relation between perception as inaccessible entity and the environment or ambient energy patterns are largely unfalsifiable as long as empirical findings can also be attributed to the relation between perception and the measured output. In short, emphasizing the distinction between perception and judgments might make the learning studies in agreement with the philosophical arguments but only at the expense of the proposed explanation of learning, the falsifiability of the core ecological principles, and the parsimony of our understanding of judgments. It would therefore be preferable if we could find a realist interpretation of the learning studies that does not rely on the distinction between perception and judgments.

EDUCATION OF ATTENTION VERSUS EDUCATION OF INTENTION

If judgments indeed reflect perception, and perception is indeed veridical, an apparent change in variable use must reflect a change in which property is perceived. Such an interpretation of the convergence would redefine the task of scientists: Their task would now be to determine what property is specified by the variable that appears to be detected and, thereby, investigate what property is perceived. The apparent use of nonspecifying variables would mean that the scientist has not yet identified the property that participants intend to perceive, and a change in variable use would imply a change in the property that the perceiver intends to perceive. In this view, learning could be referred to as the education of intention instead of, or as well as, the education of attention.

The viability of the education-of-intention approach rests on the assumption that all variables that appear to be detected specify some environmental property. Elsewhere (Michaels, Withagen, Jacobs, Zaal, & Bongers, 2001) we argued that each pattern in ambient energy arrays probably specifies some environmental property, which need not be a property that is relevant to the control of action or that corresponds in any obvious manner to variables typically used in physics. Similarly, one could assume that a perceiver can intend to perceive any property of the environment. This means that if perceivers appear to detect a particular variable, the experimenter might always be able to find a property that is specified by that variable and conclude that the perceiver intended to perceive that property.

This attempt to interpret the convergence on the more useful variables from a realist perspective is thus largely unfalsifiable. Nevertheless, the main problem of the approach is larger than that. In the real world, intentions are not free to vary with the information that an animal happens to detect. Whether they succeed or not, fielders intend to catch balls and predators intend to catch prey. If the predator misses the prey, and one claims that the animal therefore intended to miss its prey, one needs to introduce another concept to explain why the animal shows behavior such as approaching and chasing its prey—the job that intention in its original meaning was supposed to do. In its original meaning, intentions serve to constrain task situations and thereby define the problems that perception and action are supposed to solve. Given intentions, some variables can be said to be information in a specificational sense and others cannot.

We readily admit that ecological studies do not typically articulate how intention does what it does, but ecological studies are usually clear in the job that intention is supposed to do. In the case of experimental studies, the assumption is that perceivers follow instructions and, therefore, intend to perceive the property that the experimenter asks them to perceive. This is not to deny that there might be some discrepancy between the instructions and the intention of perceivers, but to abuse this possibility and to make intention follow the particular variable that is detected in an ad hoc manner is to throw out the baby with the bath water. How should a theorist explain that missing the prey is somehow a failure if he or she has already used the concept of intention to rescue the realist argument?

THE APPARENT PARADOX OF LEARNING AND REALISM

In sum, our attempts to redefine the use of apparently nonspecifying variables as the detection of information required us to strip the ecological principles of their theoretical relevance, to a large extent, by using them as ad hoc concepts. It seems, to us at least, that there is no alternative than to accept the empirical finding that perceivers converge on the use of information and, thus, that novices sometimes rely on nonspecifying variables. An additional argument in favor of the convergence is that it seems to be implied by the detection of information. Have animals always relied on information? If not, how did they perceive and survive before they detected information? The most reasonable assumption seems to be that, by learning or evolution, they converged from the more useful nonspecifying variables to the use of information.

Does this mean that, from here, the entire approach described in the first section tumbles down? That is, does the convergence and the associated use of nonspecifying variables mean that perception is not always the detection of information and, therefore, that perception is not necessarily veridical, which implies that perception can be, at most, the origin of true belief and, thus, that we cannot uphold the assumption of realism? In our view, if one agrees to evaluate the ecological principles with respect to the convergence, it does. However, in the act of destruction, the convergence reconstructs the very same principles from the opposite side.

The additional assumption required for the reconstruction is that the convergence is arbitrarily fast compared to changes in information-granting constraints. If that is the case, one can assume that information remains constant with respect to the convergence. A perceptual system that continuously converges on information can thereby be assumed to approximate the detection of information to an arbitrary extent sooner or later. Because the changes in variable use are assumed to be fast with respect to the changes in constraints, situations in which the detection of information is not approximated are necessarily short with respect to larger time scales. If the use of nonspecifying variables does not last over the minimal time units relevant to phenomena under study, in our case realism, one can define perception, with respect to those phenomena, as the detection of information.

From here, the arguments described in the first section can be rolled off the other way around. Because perception is the detection of information, and information is related one to one to the properties to be perceived, perception is veridical. Veridical perception can be the source of true knowledge. Thus, because we veridically perceive properties of our environments, we can know such properties. In sum, we have argued that the convergence is inconsistent with realism, but that, at the same time, the notions appear to imply each other. This is what we call *the apparent paradox of learning and realism.* The next section considers a possible solution of the paradox which, as hinted in the previous paragraphs, lies in the scale dependence of theoretical principles.

THE SCALE OF ECOLOGICAL PRINCIPLES

This section argues that theoretical principles that explain phenomena at one scale of analysis do not necessarily apply to phenomena at other scales. The argument is introduced with an analogy. Imagine a biologist who studies how cats manage to attain an upright posture during free fall, and another biologist who studies home-finding behavior in cats and bases his or her theory on the apparent truth that cats live and displace themselves on the ground. The theories of these biologists appear incompatible because animals and other objects that are assumed to be on the ground cannot engage in free fall. The theories are compatible, however, and they even support each other, if the relevant principles are applied only at the scale of the phenomena that they are supposed to explain. Cats can be assumed to be on the ground on the long term precisely because they fall on the short term, and they must fall on the short term because they live on the ground on the long term.

Analogously, perceptual learning and realism appear inconsistent with each other only if the relevant principles are applied beyond the appropriate scales. In our view, the assumption of realism cannot be maintained if one considers short-scale phenomena. Similarly, perceptual systems cannot be said to exploit nonspecifying variables if the minimal time units are taken with respect to the longer scale of realism.[3] If, in contrast, one applies the principles to the appropriate time scales, learning and realism imply each other. That is, short-term convergence guarantees that information will be detected on the long term, and the assumption of realism implies that perceptual systems must somehow converge on information on the short term. To come back to the analogy, the convergence continuously pushes perceptual systems to the use of information, like gravity that continuously attracts cats and other objects to the surface of the earth.

It might be helpful to note the similarity between these arguments and the enslaving principle and circular causality that feature in dynamical systems theory (e.g., Haken, 1977, 1997). In that theory, the time scale of microscopic components is often supposed to be arbitrarily small with regard to the time scale of macroscopic behavior that is generated by these components, which is to say that the microscopic processes are arbitrarily quick with regard to the macroscopic processes. In part because of this scale difference, the microscopic processes can often be said to adapt instantaneously to changes in the macroscopic patterns. That is, the macroscopic patterns impose their structure on (or enslave) the generating microscopic components. A widely appreciated consequence of this enslaving is that the study of macroscopic behavior does not necessarily require an understanding of the generating microscopic processes (e.g., Beek, Jacobs, Daffertshofer, & Huys, 2001). Similarly, we argue that ecological psychologists might justifiably disregard principles at the (microscopic) scale of convergence but only if the phenomena under study reside at the (macroscopic) scale of realism.

Further intuitive support for the claim that the ecological principles should not always be evaluated at smaller event scales can be derived from the intractable multitude of ambient energy patterns. An endless number of variables can be defined that do not specify a particular to-be-perceived property. Many of the nonspecifying variables might approximate specifying variables to an arbitrary degree and could thus lead to highly accurate perception. Minimal noise in perceptual systems, say at the neural level, can be expected to lead to minimal change in whichever of the many variables are detected. Given the multitude of perhaps

[3]Our arguments do not necessarily imply that a perceiver must perceive, say, a book on a desk for a period relevant to the longer time scale to know that there is indeed a book on the desk. What is implied is that the perceiver or his or her ancestors must have perceived objects such as books and desks for sufficiently long periods so that perceptual systems can be said to rely on information. If so, even perception considered as a short-scale phenomenon might be veridical. More important, however, such short-scale perception is not necessarily veridical, and one can therefore accept short-scale perception as the basis of knowledge only if one explains how—or assumes that—perceptual systems are sensitive to the sufficiency of the convergence.

highly useful nonspecifying variables, such change can further be expected to lead to the detection of nonspecifying variables, at least in some cases. Therefore, if considered seriously, such minimal noise can lead to the rejection of the principle that perception is the detection of information (Principle 5 in Table 1). It seems intuitively clear, however, that this scale of analysis (i.e., the scale of change in variable use because of minimal neural noise) should not always be considered seriously with respect to the ecological principles.

CONCLUSIONS

If, as defended in this article, different principles should be evaluated and applied at different scales, generally accepted principles might not apply to all phenomena under study. This means that, before scientists apply any principles, they should carefully compare the scales of the relevant principles and phenomena. We have argued that the principles derived from realism might apply to perception in situations in which information-granting constraints remain constant relative to the convergence on information because, if the constraints remain constant, the continuous presence of the convergence guarantees the detection of information. For everyday environments, such a constancy of constraints seems reasonable to assume. Experimental tasks, on the other hand, often entail abrupt changes in information-granting constraints and, thus, in the available information. This implies that the principles derived from realism might not be suited to study perception in such situations. Moreover, empirical learning studies seem to indicate that the principles of convergence can often be useful to study experimental tasks. Therefore, in our view, experimenters should not lightly reject the principles of convergence on information and the associated use of nonspecifying variables in favor of the traditional ecological principles.

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