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COMMENTARY

Information, Perception, and Action: What Should Ecological Psychologists Learn From Milner and Goodale (1995)?

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Two issues motivated the reassessment of a core concept of ecological psychology: the relation between perception and action. The first was Milner and Goodale's (1995) claim, based on neurological and behavioral evidence, that vision for perception is distinct from vision for action. The second was the apparent involvement of lower order, nonspecific optical variables in the control of action as reported by Michaels, Zeinstra, and Oudejans (in press). Perception in the usual ecological sense of the detection of information is obviously needed for action; however, to the extent that perception is defined in terms of explicit knowledge or awareness of environmental properties, including animal-referential ones, a separation was deemed justified. Perception, so construed, together with the ventral stream, was suggested to be about telling rather than acting.

In a book and a series of articles, Milner and Goodale (1995) and their colleagues argued that vision for perception and vision for action are to be understood as separate processes. In this article, this position and supporting evidence are briefly summarized and relevant aspects of the thesis are compared to aspects of the ecological approach to perception and action. I conclude by proposing tentative sepa-

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ration of perception and action for ecological psychology, a proposal that, at least at first sight, goes strongly against a key principle of ecological psychology.

A few caveats are in order before proceeding. First, what follows is not a thorough treatment of the topic. The goal instead is to raise an alert about an emerging theoretical position that has implications both for the ecological approach itself and for the position of the ecological approach in the broader psychological community. This article is intended to stimulate discussion, not to serve as a definitive statement of *the* ecological reaction to Milner and Goodale (1995). Second, and relatedly, I write as if I speak for the ecological community. The plain facts are that no two ecological psychologists agree about everything, nor is there a single statement that would be agreed on by everyone who labels himself or herself an ecological psychologist. We not only disagree about the content of the party line but even on whether there should be a party line. I am among those who think we should strive for a single, clear, ecological position, and my "we–they" terminology simply reflects this wish.

MILNER AND GOODALE'S THESIS

Let us begin with the descriptions of vision for perception and vision for action that Milner and Goodale (1995) employed in their writings. Their characterization of vision for action is benign enough, primarily because they did not describe the principles of their approach to action in detail. Their characterization of vision for perception, however, does make clear some underlying principles, as illustrated in the following quotations. I use italics to highlight aspects that depart from conventional usage among the proponents of the ecological approach. A definition of vision for perception that approximates theirs is, they suggested,

> A process [that] allows one to *assign meaning and significance to* [italics added] external objects and events …. [Perception] carries experiential connotations and tends to be identified with one's *phenomenological experience of the world* [italics added]. (Milner & Goodale, 1995, p. 2)

> Transformations deliver the enduring characteristics of objects and their relations permitting the formation of long-term perceptual *representations. Such representations play an essential role in the identification of objects and [their classification]* [italics added]. (Goodale & Haffenden, 1998, p. 162)

> [Perception, by definition,] *excludes* [italics added] … processing such as that required for the moment-to-moment control of many *skilled actions* [italics added] such as walking or grasping. (Milner & Goodale, 1995, p. 2)

Given these characterizations, Milner and Goodale defined *perception* as a process by which the world is represented and the product of which constitutes conscious experience available for report (verbal or otherwise). It is thought to be carried out in the *ventral stream,* the cortical pathways that connect the primary visual cortex with the inferior temporal lobes. The perception-related role of the ventral stream activity is claimed to be different from the detection of visual information that will serve a role in coordinating or guiding motor activity. This latter activity is thought to be carried out in the *dorsal stream,* the cortical pathways that connect the primary visual cortex with the posterior parietal lobes.

SOME OF THEIR EVIDENCE

From Neurology

Milner and Goodale (1995) described the case of D. F., a woman who developed visual agnosia after carbon monoxide poisoning. She had problems identifying familiar objects and reporting size, shape, and orientation. Nevertheless, her action with respect to such objects and such properties was normal. She could not recognize a spoon as such, but could pick up a spoon and use it to eat. She could not tell the orientation of a mail slot, or even show it with her hand, but she could post a letter into the slot without difficulty. Neurological assessment showed that D. F. had damage in the ventral stream.

There is a corresponding but opposite effect that can be observed with damage to the dorsal cortical stream. Damage to these pathways yields optical ataxia. For example, Milner and Goodale (1995) describe Bálint's syndrome, in which patients are unable to determine the position, relative to themselves, of objects that they claim to have seen distinctly. In the mail-slot problem, for example, they cannot place and orient the hand properly, although they can verbally describe it correctly.

From Normal Individuals

In addition to neurological findings in the patient population, Milner and Goodale (1995) cited a variety of evidence that suggests dissociations between vision for perception and vision for action in normals. Among these are visual illusions that have been shown to affect judgments of geometrical properties differently from actions toward geometrical properties. For example, Aglioti, Goodale, and DeSouza (1993) demonstrated that judged size of the central disk on the left in Figure 1 is perceived to be bigger than the central disk on the right, but movement recordings of fingers in grasping a (three-dimensional) disk showed that grip size was influenced only by the true size of the disk (however, see Ellis, Flanagan, & Lederman, 1999; Pavani, Boscagli, Benvenuti, Rabuffetti, & Farne, 1999).

A second phenomenon in normal individuals that suggests a separation of vision for perception and vision for action is visual masking, which appears to affect perception but not action. Reaction time to a visual stimulus is not affected by the presence of an aftercoming visual mask, although the visual experience of the stimulus can be prevented by the masking stimulus (e.g., Fehrer & Raab, 1968). More recently, Klotz and

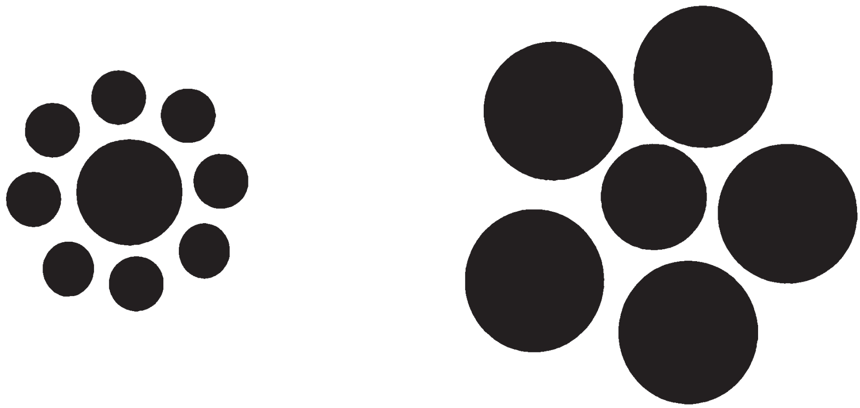

FIGURE 1 The Titchener illusion. Even though one sees the center disk on the left to be larger than the center disk on the right, grasp openings to pick up the disk do not always significantly differ.

Neumann (1999), using a well-controlled cuing-plus-metacontrast paradigm, assembled a compelling empirical case that perceivers are not at all sensitive to the presence of a precue (e.g., a small circle) that, when presented on the same side as the target, will decrease the time taken to respond to the side on which a larger circle appears or, when presented on the contralateral side, will increase response time. Because the contours of the target are in proximity to the contours of the precue, the latter will not be visible because of metacontrast masking. Neumann (1990; Neumann & Klotz, 1994) introduced the concept of *direct parameter specification* to capture a direct processing stream that links "the specification of motor parameters—when and how to respond—to the output of sensory analysis, without passing through the processing stages that produce conscious experience" (Klotz & Neumann, 1999, p. 977). Presumably, the precue directly specifies the response parameters.

A third dissociation of vision for perception and vision for action in normal individuals occurs in cases of saccadic suppression, which although operationally quite different from metacontrast masking may be closely related to it (cf. Breitmeyer & Ganz, 1976). If one displaces a to-be-touched target during a saccadic eye movement, the toucher's hand will move smoothly to the new target, but the person may be completely unaware that the target has been displaced. Action, therefore, reflects the displacement, but perception does not (Bridgeman, Lewis, Heit, & Nagle, 1979).

AN ECOLOGICAL VIEW

Milner and Goodale's (1995) formulation of the relation between perception and action stands in contrast to the formulations used by proponents of the ecological approach. Some of the differences are terminological. For Gibsonians, perception is the detection of information, where something very special is meant by information. Perception in the Gibsonian sense implies awareness but not necessarily conscious awareness. Other terminological issues relate to the domain of action: Gibson (1966) distinguished performatory action from exploratory action. In the broadest terms, *performatory action* refers to activities that bring one closer to a goal, whereas *exploratory actions* are activities that aim to reveal information that can help guide one to a goal. It would seem that Milner and Goodale's vision for action refers to performatory action. Thus, as important as the ideas of imposed versus obtained stimulation and action creating information for its own guidance are to the ecological approach, they do not figure into this discussion. Also, later, action effects on information are sidestepped; the familiar perception–action loop is conspicuously absent.

As to the substantive differences with the ecological perspective, one of the primary ones is the computational and representational view of perception made explicit by Milner and Goodale (1995). Theirs is standard information processing and implies that visual information does not lay a sufficient basis for meaningful perception. Without inherently meaningful inputs, meaning (or significance) must be assigned by the perceiver via memorial or constructive processes. In short, their characterization of what goes in the ventral stream is precisely the sort of Helmholtzian perception against which Gibsonians have argued for decades.

Implicit in the preceding paragraph is a first concern about the possible fallout of the Milner and Goodale (1995) theory: It is a quick, obvious, and, I believe, erroneous step from the notion of a Helmholtzian ventral stream to the proposition that ecological psychology is about the dorsal stream and constructivism is about the ventral stream. A distinction along these lines releases cognitive psychology from having to worry about action. Constructivism thereby inherits new apparent legitimacy for its tired (but still booming) enterprise of erecting barriers between animals and environments and then packing the animal with borrowed intelligence to help it overcome the barriers (Shaw, Turvey, & Mace, 1982). The new danger lurking in the ventral–dorsal distinction is that constructivists are even more likely to dismiss ecological psychology as irrelevant because it concerns action. They can then carry on their business-as-usual computationalism. This is a mistake; key concepts of ecological psychology such as information, direct perception, smart perceptual devices, and so on are essential for explaining "plain" perception. Chiding researchers to study action (e.g., Michaels & Beek, 1995; Turvey, 1977, 1990) should not discourage those who study plain perception from adopting an ecological approach. In the 50 years since the publication of Gibson's (1950) *The Perception of the Visual World,* most ecological psychologists have concentrated their energies on such perception—of shape, distance, age, biological motion, physical motion (e.g., pendula, colliding balls), pictures, and heading, just to name a few. Much work remains to be done.

The second criticism of the Milner and Goodale (1995) position to be expected is for the very separation it endorses between perception and action. A central tenet of the ecological approach is that one perceives to act and acts to perceive

(Gibson, 1966) and that a separation of the scientific investigations of perception and action will fail to illuminate either (Turvey, 1977). Over the years, proponents of the ecological approach have assembled strong logical and empirical cases for a conjoint treatment of perception and action. However, to simply dismiss the Milner and Goodale thesis on principle would be a mistake. We should not look the other way; several theorists have already been seduced by the division along the lines of dorsal–ecological and ventral–cognitive. In that regard, many psychologists persist in behaving like the poor cousins of neuroscience, waiting for and overvaluing its handouts and ignoring the extent to which neuroscientific research itself can rest on very poor, if tacit, folk psychology.

A healthy suspicion of the psychology behind neuroscience or neurology can be taken too far if one refuses to ask whether the distinctions they foster might offer useful constraints on theory. So, are there ways in which ecological psychologists can and perhaps should accept a certain separation along the lines suggested by Milner and Goodale (1995)? We now turn to some recent results that suggest how this might be answered.

INFORMATION FOR ACTION

I have found myself rethinking the relation between perception and action in the context of a particular finding in a recent experiment and being led (misled?) to a conclusion similar to that expressed by Milner and Goodale (1995). As a backdrop for this finding, let me review some basic ideas about direct perception and the importance of specificity to direct perception and action.

Direct Perception and Specificity

Direct perception depends on two specificities. The first is a 1:1 relation between values of a detectable variable (e.g., an optical variable) and a to-be-perceived property of the environment.[1] As an example, consider the relation between degree of cardioidal strain and age, as studied by Pittenger and Shaw (1975). Let us assume, for the sake of argument, that degree of strain (i.e., a particular level of a transformation of the cranium) and age are uniquely related; values of strain map uniquely and continuously onto values of age. Let us also assume that research has shown that when one detects a certain degree of strain, one sees the person to be of a particular age. Together, these two unique relations (property to invariant and invariant to perceived property) express what ecological psychologists mean by the terms *information* and *perception.* These two relations define cardioidal strain as information about age and permit us to say that age is perceived. The term *information* in an ecological usage means that the variable in question has been shown to specify the to-

[1]To call something a property of the environment is not to divorce it from the animal. Stair height, whether measured in meters or by leg lengths is still a property of the environment.

be-perceived property and it has been shown to be picked up by a perceiver who is perceiving the property. If the second of these requirements is not met, then the variable is just an invariant. And, of course, by perceived is meant directly perceived; there is no other kind.[2]

In principle, we expect similar specification relations to hold for action. Again we presume a 1:1 mapping between an optical variable and environmental property. Again, for sake of argument, let us assume that this relation holds for Lee's (1976) optical variable tau and time to contact (TTC) and that a 1:1 relation has been shown to hold between tau and an appropriate metric of an action. Say, for example, that initiation of elbow flexion in punching a falling ball is shown to be a function of tau (Lee, Young, Reddish, Lough, & Clayton, 1983). We conclude that tau is information relevant to the control of the action and it is exploited in the action. It would also be customary to say that TTC is perceived and acted on. To anticipate, a key thesis of this article hinges on this last conclusion: Should we or should not we take this type of statement literally? Does one need to perceive an environmental property to act effectively?

Michaels, Zeinstra, and Oudejans (in press)

This experiment attempted to replicate Lee et al. (1983). The important finding, for purposes of this discussion, is that expansion velocity emerged as the variable that punchers exploited in coordinating the preparatory, flexion phase of the action. Initiation and rate of elbow flexion in punching a falling ball depended on $\dot{r}$. I am convinced that this is so, but I invite the doubtful reader to follow along, treating it as a thought experiment.

What is $\dot{r}$? First, r, the image size of the ball on a plane at a unit distance from the projection point, is approximately equal to the diameter of the ball (R) divided by its distance (d). Differentiating with respect to time yields

$$\dot{r} = -\frac{\dot{d} \cdot R}{d^2} \qquad (1)$$

[2]There is a dual pair of specification relations with which to be contended. It is less frequently cited by ecological psychologists and the subject of the debate about direct versus directed perception. The second specification relations are the duals of the first, according to Shaw and McIntyre (1974). To reiterate the text, because of the working of natural law, the presence of environmental Property Y implies the existence of Information I, and because pickup is direct, the perceived Property Y follows from detection of I. The second pair works in the opposite direction from the world–information–perception: Because perception is Y, the information is I, and because the information is I, the world is Y_e, what the information specifies. The key consequence is that perception of a particular property relies (uniquely) on detection of particular information. Some do not subscribe to this principle and alternative views are sometimes called *multiple specification* (although this usage confuses specification with perception) or *directed perception* (Cutting, 1986, 1991). The common theme of these latter views is the claim that nominally different variables can all lead to the same perception.

Obviously, a momentary value of $\dot{r}$ is ambiguous with respect to the distance of the ball, its size, its velocity, and its time to arrival. Thus, the answer to the question of what the optical quantity of, say, $\dot{r} = -.01$ specifies is nothing, really. There is no property, as it were, to be perceived.

One could say that with experience and learning, an $\dot{r}$ of –.01 comes to specify the initiation of elbow flexion. This is what we concluded: $\dot{r}$ comes to specify the moment to flex the elbow (and even the rate to do so; Michaels et al., in press). However, again we must ask what is the environmental property that is specified? One might argue that "it is time to flex the elbow" is, in fact, a property of the animal–environment system, much like "this stair is climbable" in Warren's (1984) paradigm. This is very appealing and may be one way to pass through the horns of the dilemma raised by the apparent usage of $\dot{r}$. Although affordances are surely related not only to geometric properties of the body, but also to kinematic and kinetic properties (cf. Oudejans, Michaels, & Bakker, 1997; Oudejans, Michaels, van Dort, & Frissen, 1996), an $\dot{r}$ of .01 specifying its time to flex seems to have an aboutness that refers only to the animal. Granted that during locomotion, for example, optical flow variables can also be said to specify needed action (see, e.g., Warren, 1988, for an overview), in that case the optics already bear a lawful relation to the action by virtue of how they are generated. In any event, I believe that minimally we need more carefully articulated theory about how variables evolve into information as one learns a skill (cf. Oyama's, 1985, analysis of the ontogeny of information during development). Such theory might find deeper relations between the nature, detection, and use of information that have immediate consequences for action and the information that does not.

Michaels et al. (in press) were led to the conclusion that for the punching task, the optical variable $\dot{r}$ was information for action rather than information for perception. Such a conclusion appears to fit well with Milner and Goodale's (1995) thesis that there is vision for perception and vision for action. The general issue is whether the actor needs to perceive an environmental property, for example, to be aware that the ball has been dropped (to emphasize the environmental side) or that it is time to flex (to emphasize the action side), or if the detected information can simply guide the action, as seems to be implied by the concept of direct parameter specification. Both the second and third of these alternatives might constitute a version of action without perception of an environmental property that an ecological psychologist might be able to accept.

Notice that the lawfulness of the generation of optical properties is still of relevance to information for action, because it still ensures the regularity of the invariant. However, the lawfulness captured under the heading of ecological optics does not in this case lead to a specification of object properties. Instead, it simply constitutes a boundary condition making the optical pattern regular and, thus, a possibly useful variable for action.

In either case, one does not need to perceive that the ball is on its way for the action to be initiated. One might even argue that such an experience would be just the kind of intervening cognitive event that Gibson and his followers tried to expunge, along with sensations, constructions, inferences, representations, calculations, comparisons, and so on. In the perception case, these barriers to realism have been termed "between things" (Shaw et al., 1982).

Sensations, Perception, and Action

Dispensing with perception as a step in action, a step wherein the perceiver is aware of an environmental property, is in some ways analogous to the step Gibson (1963/1982) laid out in his landmark paper, "The Useful Dimensions of Sensitivity." One key distinction he drew in that paper was between sensations and perceptions; moreover, he claimed that perceptions are not based on sensations:

> There are two kinds of seeing, I argue, one resulting in the experience of a visual field and the other in the experience of a visual world (Gibson, 1950). The sensations of the visual field shift with every movement of the head. But, the perception of the [world] remains constant throughout. (Gibson, 1963/1982, p. 352)

Gibson went on in his paper to consider the nature of sensations from a variety of perspectives, including that sensations are the subjective pole of experience. Examples of sensations would include pressure on the hand, a salty taste, angle on the retina, and so forth. Perception, on the other hand, referred to the objective pole of experience. Perceptual parallels to these examples of sensation would be feeling weight, tasting salt, and seeing the orientation of the mail slot.

The distinction between sensations and perceptions was a cornerstone of Gibson's (1966) book *The Senses Considered as Perceptual Systems:* "In this book I will distinguish the input to the nervous system that evokes conscious sensation from the input that evokes perception" (p. 2). In making perception not dependent on sensation, Gibson broke from the Helmholtzian tradition. Sensations and perceptions were also related to different aspects of the stimulation. Sensations were associated with lower order variables or variants (e.g., retinal image size), whereas perceptions were associated with higher order variables—invariants (e.g., optical flow variables). Sensations and perceptions were also associated with different anatomical levels; the former being the province of receptors and organs, and the latter being the province of perceptual systems.

The Helmholtzian and Gibsonian models are presented in Figure 2, together with a model that would further divide action from the perception of the environment. The upper diagram represents the Helmholtzian theory that Gibson argued against, with sensations as the starting point for perception. In later versions of the Helmholtzian tradition, features, cues, and so forth took over from sensations, but, as were sensations, these lower level responses to lower order variables were seen as

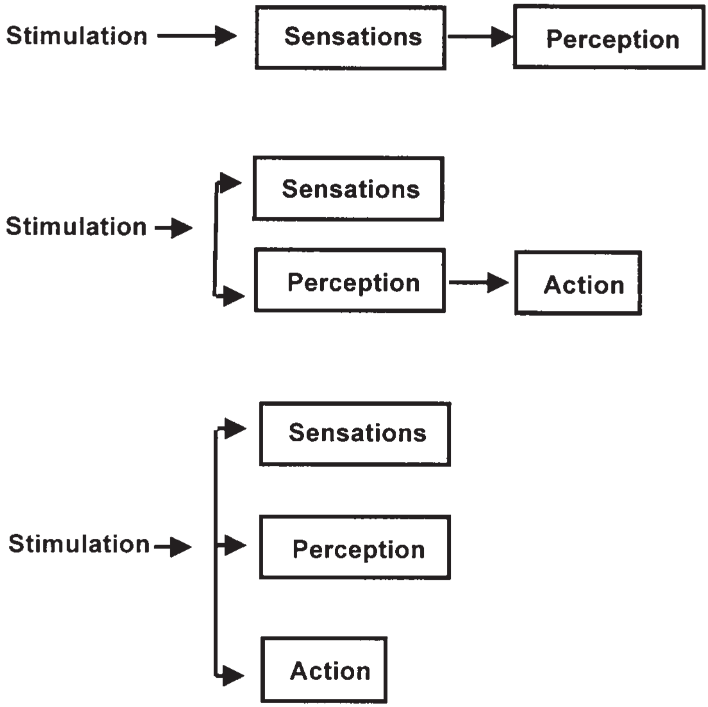

FIGURE 2 The top diagram conveys the Helmholtzian theory where perceptions are built from sensations. The middle diagram is Gibson's view of information and the theory of direct perception. The bottom diagram takes Gibson's distinction a step further and separates perception and action.

providing the elements on the basis of which perceivers unconsciously inferred, deduced, calculated, constructed—pick your era—or connected reality.

The middle part of Figure 2 represents the thrust of Gibson's view of information and the theory of direct perception. There are lower order variables of stimulation and attention can be called to them (e.g., being aware of two fingers when only one finger is held up and fixation is to a distant point, being aware that the top of a cup may have an elliptical image shape). Gibson argued that the lower order variables and the sensations that may accompany them, however, were incidental to perception, not the basis for it. Perception, Gibson claimed, was a function of other variables of stimulation that specified their sources in the environment. Ultimately included among the properties of the environment that were specified and picked up were affordances (mentioned in Gibson, 1966). Perception of these environmental properties, in turn, might or might not be followed by action.

Often sensations and perceptions can be simultaneously present, as in the two earlier parenthetical examples. It is also possible to have either without the other:

Pressure phosphenes, the visual sensations that occur when one presses on one's eyeballs, have no perceptual correlates. Similarly, perceptions can be without correlates in sensations. For example, when one perceives the location of a heard event, one does not have access to sensations of interaural intensity differences or interaural delay.

The bottom panel of Figure 2 extends the argument. It makes perception of environmental properties incidental to action in the same way that sensations are incidental to perception. One view would be that sensations and perceptions are both *epiphenomena,* by-products of learning to coordinate activity in the face of environmental contingencies. Later, I address their possible functionality apart from action, but, to quote Milner and Goodale (1995), "[Natural selection] cares little about how well an animal 'sees' the world" (p. 11).

If a sensation is subjective—it is about how stimulation affects the body—and perception is objective—it is about objects and events in the world—then does action have an experiential domain, analogous to the subjective and objective poles of experience? Milner and Goodale (1995) suggested that, at least in the case of cortical blindness, there is no visual awareness at all accompanying action, either bodily experiences (visual sensations) or experiences of the objects and events in the world. Are we unconscious robots when (only) acting?

Definition Club, a group of graduate students and staff at the Vrije Universiteit, has come up with the following as its working definition of action:

> An action is a temporally bounded, observable, goal-directed movement (or non-movement) that entails intention, the detection of information, and a lawful relation between that information and the movement. An action can be composed of actions and can be part of other actions.

The experiential domain of action is arguably the intention, where intention defines the beginning and end of the action and reflects both the actor (his or her wants, needs, and capabilities) and what the environment has to offer. It is more than available affordances and effectivities; it is particularized by the occasion. I intend to punch this ball when it falls; I am punching it; I succeeded in punching it. Moreover, the expectation is that the intentions may be accompanied by perceptions (experiences that reference the world) and by sensations (experiences that reference the body) but do not have to be. One can lift a weight without feeling how heavy it is or without feeling pressure on the hands; one (D. F.) can post a letter without seeing the orientation of the mail slot.

DIFFERENCES BETWEEN VISION FOR PERCEPTION AND VISION FOR ACTION

Continuing with Milner and Goodale's (1995) terminology for now, what are the ways in which vision for perception and vision for action might be different? Milner and Goodale emphasized processing differences—the same visual input is subject to different processing (e.g., visuomotor transformations, special coding strategies, such as for faces, and attentional mechanisms). In what follows, I enumerate some other explicit possibilities more in the spirit of the ecological approach. I have not tried to weed out redundancies, nor do I presume to be exhaustive.

First, the information is likely to be different; the properties relevant to the control and coordination of activity and the informational variables that specify them may be different from the properties and associated variables that are detected when one merely perceives objects and events.

Second, the phenomenological experiences may be different; for example, awareness of the environment versus awareness of an intention and how far along one is in achieving it.

Third, the principles of learning might be different. Perceptual differentiation and the education of attention give a start on understanding learning to perceive. Learning to use visual information in action may present different challenges. An issue addressed earlier concerns how a variable becomes information when one learns to coordinate an act. Additionally, one must solve the problem of how and when to tap optical variables in the coordination of action.

Fourth, the mechanisms of information detection might be different, even if the information itself is the same. Two observations hint that this might be so. First, Stins and Michaels (2000) examined stimulus–response compatibility effects in two tasks with identical stimuli but different responses. In one condition, the participant had to perform more of a judgment task—to choose a hand to press a button. In the other task, they had to reach to touch a place with one of the two hands. The compatibility effects were different in the judgment task and the reaching task.[3] Less subject to the argument that the information might have been different (e.g., specifying position of the stimulus light relative to the response location), Frank Zaal and I found another such effect in an experiment with more impoverished optics, a circle of light rising on a wall in a dark room. To test for the use of optical acceleration in locomotion for catching, we asked participants to press buttons to signal whether "the ball" would land in front of them or behind in one condition or if they had to take a step forward or backward to intercept the ball in the other condition. The optical patterns were the same in both conditions, but when the instructions were to catch, the head tracked the ball, whereas the head remained dead level when the task was judging.

Fifth, they may operate on different time scales. Vision for action may be essentially online; its "aboutness" as regards the action system may be only in the here and now (even though it can be prospective). Information for perception can pre-

[3]Pushing a button is considered here to be a perceptual task, whereas reaching is considered an action task. Note that this is at odds with the reaction time studies previously cited. Klotz and Neumann's (1999) button pressing, as a beneficiary of direct parameter specification, was considered to be action. It seems to me that their concept of direct parameter specification is too good to waste on button pressing.

sumably point further into the past or future. The state of the chessboard may inform about moves well into the past and well into the future; fossils inform about the long-distant past. There can also be a certain timelessness to perception. I see the statue in the park from time to time and thereby am aware of its persistence. Exactly when I see it or for how long is not important because I am sampling enduring properties of the optic array. Action, on the other hand, seems to imply a temporal viewpoint.

Sixth, they may differ as to the importance of spatial viewpoint. Successful action with respect to an object or event usually implies and requires an egocentric spatial viewpoint. Changing the perspective between the eyes and hands can make coordinated action very difficult, as when the camera is moved during video surgery (Holden, Flach, & Donchin, 1999). Recognizing a friend, identifying a plane as a Boeing 747, or detecting an affordance seems more object centered than ego centered. Vision for perception seems to be viewpoint free.

Seventh, vision for action and vision for perception may be, respectively, tacit and explicit. The knowledge that is expressed in action does not seem to be expressible in language, whereas perceptual knowledge (perhaps by definition) can be verbalized.

A NOTE ON AFFORDANCES AND PERCEPTION–ACTION COUPLING

If we separate perception of environmental properties from vision for action, the place of two important concepts in the ecological approach would shift somewhat. One is affordances. Are affordances perceived or acted on? One can obviously perceive the affordances of objects and events without engaging in the afforded action, suggesting that affordances can be perceived as properties. D. F., however, with her damaged ventral stream, clearly picked up the affordances of the mail slot. The differences enumerated in the previous section do not provide an unequivocal answer to whether affordances should be viewed as a ventral-stream or dorsal-stream activity. Some affordances are dependent on viewpoint (e.g., reachableness), whereas others seem viewpoint free (e.g., the climbableness of stairs does not change as one gets closer). Part of the problem in trying to determine where affordances belong is the absence of principles defining the upper and lower limits on the scale of affordances. As affordances get very big or very small, they seem to look less like affordances (e.g., could academia be said to afford career building for Person X, or could a piece of chalk be said to afford grasping while using Muscles a and b for Person Y).

A second concept that we may want to rethink is perception–action coupling. First, a key thesis is that if perception is construed in terms of awareness of environmental properties, then it is arguably not coupling with action. However, even if perception is construed as the detection of information, there are other arguments against perception–action coupling. My colleague P. Beek (personal communication, June 1993) reminds us that it is not perception and action that get coupled, or even information and action, but rather information and (the control of) movement. The definition of action presented earlier conveys the gist of the problem: the term *action* is already intentional, informational, perceptual (i.e., detectional), and motoric. From this perspective, it is a category mistake (Ryle, 1949) to speak of the coupling of perception and action; two things cannot couple if one is part of the other.

THE PURPOSE OF VISION FOR PERCEPTION

As functionalists (and insofar as the by-product theory is deemed unpalatable), Gibsonians should also concern themselves with the function of vision for perception or what I have generalized to perception of environmental properties.[4] Milner and Goodale (1995) mentioned a few functions associated with the ventral stream, but they all ring hollow from an ecological perspective. At the beginning of this article, I criticized the three functions cited by Milner and Goodale: identification, recognition, and representation. As to the first two of these functions, one might well ask what the value of identification or recognition is if it does not affect action in one way or another sooner or later. For the third, to say that the ventral stream is there to make representations seems to lose sight of the fact that mental (or neural) representations are hypothetical constructs invented to account for a collection of phenomena. From an ecological perspective, then, this putative function is to provide an embodiment of that which can explain cognitive phenomena or that which pays back loans of intelligence. Perhaps this is unfair to Milner and Goodale; in some ways, their distinction emphasizes that there is a dorsal stream concerned with action, in addition to the information-processing stream, the existence of which requires no advocacy among cognitive psychologists. Nevertheless, it is hard to accept the claim that the function of a system is to create a structure, if one thinks the utility and workability of the structure remain to be explained. Put another way, making representations is not a function.

What are other possible functions for a visual system besides the online guidance associated with the dorsal stream? Two possible functional roles for ventral stream processing come to mind. First, processes in the ventral stream may provide control for activity over a longer time frame than a couple of seconds. Indeed, D. F. exhibited considerable difficulty when she had to delay her actions; the dorsal stream seems to be very much a use-it-or-lose-it system.

A second and perhaps more interesting function for the ventral stream is related to communication and, thus, to language. One of the most important actions we perform is telling; we tell other people about places, objects, and events in the envi-

[4]D. Jacobs (personal communication, September 1999) raised the question of the functionality of sensation: Should one attribute functionality to perception of environmental properties but not to bodily sensations?

ronment. Knowledge that is exclusively in the form of capabilities to direct attention to Invariant A, rather than Invariant B, or to constrain or inform the assembly of elements of the motor system into a functional unit can only be communicated by showing. However, for members of our species, who must learn so much secondhand (or more) from the experiences of others, the premium shifts to telling. Our capacity to tell (and be told), along with the various other psychological functions that make telling possible (speech, language, classification, remembering,[5] etc.) is arguably what distinguishes us from other animals. It may be that assembly of a sentence will be understandable using the same principles and concepts as assembly of an action; there are obvious parallels. If so, telling may just be a special case of acting. However, aspects of communication seem to index objects and events by the sensations and perceptions that exposure to them gives rise to (e.g., color, size, position with respect to other things). And, as argued earlier, these properties do not, in and of themselves, have action consequences.[6]

IMPLICATIONS

What does a hypothesized separation between action and perceiving properties of the world boil down to? How would ecological psychologists behave differently if we subscribe to the sorts of distinctions that have been suggested here? One implication is clear and bears on how one goes about establishing what information is used to control movement in reactive situations (recall that this article explicitly sidesteps actions that create information for their own guidance). In the normal course of things, one would derive a list of candidate variables and attempt to establish which of these variables constrains the control of movement, where the list of candidates are invariants that specify environmental properties. Based on current arguments, the control of action might be expected to glom onto a variable irrespective of whether it specifies an environmental property. Thus, we should expand our array of candidate variables that might inform the control of movement. Most certainly, we should not derive a variable that specifies an environmental property and then design experiments to see if it works in controlling action.

[5]By remembering, I mean being able to (in part) reexperience events in the past. I remember catching the big trout in the pool at Hockanum; I remember putting banana on my cereal this morning. These experiences are more than just being able to utter the sentence; I could answer a number of other questions about these events. I believe that remembering is a uniquely human function that evolved together with and in the service of language. Although we are accustomed in everyday speech to saying things such as "Fido the dog remembers where he buried the bone" or "He remembers he was spanked for chewing on the slipper," the events to be explained by these constructions admit to far simpler explanations. Fido smells the bone and has learned to avoid the slipper.

[6]Whether the variables on which they are based may have some role in development or learning is also a possibility (see Michaels & de Vries, 1998, for a consideration of the possible role of lower order variables in the development of smart perceptual devices).

Another implication involves posing new questions such as the following: In analogous situations, do judgments, verbal responses, and movements all rely on the same variables? How does the structure of an action dissolve over time if the action has to be delayed? How does perceptual psychophysics differ from conceptual psychophysics? What of the other senses? Presumably the same sorts of distinctions can be drawn for perceptual systems other than vision.

What are the dangers implicit in a separation of perception and action? Are there slippery slopes away from realism, serious science, and toward a boundless multiplication of entities? Two points should be made in this regard. The first is that the possible differences between vision for telling and vision for acting are empirical; they can be decided by experiments addressing the preceding questions. The second issue is whether it is worth our while to pose them and how far we should go. One thing is clear: The cognitive science of fancy phenomena such as language has more to learn from the study of action than the other way around. Just as the evolution of telling must have been parasitic upon the evolution of acting, the science of telling will inherit its key concepts from the science of acting. The hope is that a pursuit of the distinctions between vision for telling and vision for action will, in fact, illuminate action.

SUMMARY

Based on neurological findings and a collection of phenomena in normal individuals, Milner and Goodale (1995) argued for a separation of perception and action. These were claimed to be separate psychological functions carried out by parallel cortical streams. In this article, Milner and Goodale's position has been assessed from an ecological perspective. Of particular interest was what could be made of their thesis given the ecological precept that perception and action are intimately related.

From the outset, it was clear that Milner and Goodale's (1995) idea of perception was very different from the Gibsonian idea. Milner and Goodale's definitions are off-the-shelf constructivist definitions: Perception is a representational process of enrichment whereby an input gains meaning. For ecological psychologists, perception is seen as the detection of information that, by definition, specifies significant aspects of the perceiver's world. Despite this definitional gulf, I asked whether there is an understanding of perception for which ecological psychologists might find a separation of perception and action useful. The chosen definition was perception as awareness of an environmental property.

I argued that the online control of action does not depend on the awareness of an environmental property. More particularly, the coordination of activity does not entail the awareness of an environmental property specified by information. This conclusion was motivated by an empirical finding by Michaels et al. (in press) that an aspect of action coordination seemed to be tied to an optical variable that, although useful in the experimental task, was arguably a lower order variable—a variant and not specific to a property of the environment.

The claim that perception in this sense is not regarded as a necessary step on the way to action was compared to Gibson's removing sensation as a step in perception. A number of possible differences between these construals of perception and action were enumerated: information, mechanisms of information detection, principles of learning, phenomenological experiences, time scales, the relative importance of spatial viewpoint, and whether knowledge is explicit. All of these issues are empirical, and we can ask ourselves whether trying to answer them is worth our effort. The political issue is, as usual, trickier, but I, for one, do not want to abandon plain perception (without action) or stand idly by as ecological psychology is relegated to the dorsal stream. If the hypothesized distinctions prove groundless, all the better, but if they do not, we should be ready.

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