

## Ecological Psychology and the Two Visual Systems: Not to Worry!

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Michaels (2000) expressed concerns about the implications of the notion of 2 visual systems (Milner & Goodale, 1995) for ecological psychology. This leads her to suggest a decoupling of perception and action, by which action is separate from perception. It is suggested that although Michaels noted, on the one hand, that Milner and Goodale's approach to perception is a constructivist one, she mistakenly adopts their view that separates vision for perception from vision for action. An alternative position is presented, based on a recent article (Norman, in press), in which the parallels between the 2 visual systems, dorsal and ventral, and the 2 theoretical approaches, ecological and constructivist, are elucidated. According to this dual-process approach to perception, both systems are perceptual systems. The ecological–dorsal system is the system that picks up information about the ambient environment allowing the organism to negotiate it. It is suggested that this type of perception always processes the relevant information for action and that there is no need to sever the perception–action coupling. Ecological psychology and the 2 visual systems are quite compatible, and there is no need for concern.

In her commentary, Michaels (2000) expressed rather grave concerns about the implications for ecological psychology of Milner and Goodale's (1995) findings on the two visual systems, the dorsal and the ventral. Among other things, she noted "that constructivists are even more likely to dismiss ecological psychology as irrelevant because it concerns action" (p. 245) and ends by noting that she does not want to "stand idly by as ecological psychology is relegated to the dorsal stream" (p. 257). These concerns lead Michaels to offer a new account of the interactions between perception

and action. In this account, she suggested a severing of the commonly accepted link between perception and action. Unlike the Gibsonian model, in which perception precedes and accompanies action, she suggested a direct link between information and action. She noted that she found herself “rethinking the relation between perception and action ... and being led (misled?) to a conclusion similar to that expressed by Milner and Goodale (1995)” (p. 246). I will try and show that she was misled, and this is mainly due to her adoption of Milner and Goodale’s definition of perception. In this article, I first look at some definitions of perception, then present my understanding of the implications of the notion of two visual systems to perception, and then return to look at Michaels’s commentary in the light of these.

### PERCEPTION AND THE TWO VISUAL SYSTEMS

It is important to begin by defining just what is meant by *perception*. Clearly, perception means different things to proponents of the two contrasting theoretical approaches, the ecological and the constructivist. Many introductory texts to perception give relatively simple constructivist definitions, such as “the conscious experience of objects and object relations” (Coren & Ward, 1989, p. 13). A more sophisticated definition by an outstanding spokesman for the constructivists is “My view follows Helmholtz’s (1867) that perceptual processing is guided by the effort or search to interpret the proximal stimulus, i.e., the stimulus impinging on the sense organ, in terms of what object or event in the world it represents” (Rock, 1983, p. 16). In contrast, at the beginning of an ecologically oriented introduction to visual perception, Bruce, Green, and Georgeson (1996) wrote

In order for its movement to be regulated by the environment, an animal must be able to detect structures and events in its surroundings. We call this ability *perception*, and it in turn requires that an animal be sensitive to at least one form of energy that can provide information about the environment. (p. 3)

Near the end of his *Ecological Approach*, Gibson (1979/1986) proposed “a redefinition of perception”:

Perceiving is an achievement of the individual, not an appearance in the theater of his consciousness. It is a keeping-in-touch with the world, an experiencing of things rather than a having of experiences. It involves awareness-of instead of just awareness. It may be awareness of something in the environment or something in the observer or both at once, but there is no content of awareness independent of that of which one is aware. (p. 239)

As Michaels (2000) also pointed out (p. 245), Gibson (1979/1986) reminded us that “The term *awareness* is used to imply a direct pickup of information, not necessarily to imply consciousness” (p. 250).

These are, obviously, very different conceptualizations of perception. In very general terms it could be said that the constructivists view perception as a conscious interpretation of the proximal stimulus through a comparison of it with some stored representation. The ecological view, on the other hand, is that perception is the direct pickup of information about the ambient environment, a process that is not necessarily conscious. My contention is that both these views are correct! In a recent article, I (Norman, in press) introduced what I labeled a *dual-process approach* to perception; I suggested that perception, in a broad sense of the term, consists of two synergistic processes, each with quite different purposes but often supporting each other. The roots of this contention lie in a study I carried out many years ago (Norman, 1980). In it, I tried to experimentally determine which explanation of size perception is correct, the ecological or the constructivist, by attempting to determine if distance is or is not taken into account in the perception of size. In retrospect it is clear that that study had a constructivist bias in the paradigm used, but all the same, I found that under certain conditions distance was not involved in the size perception. My suggestion was that both direct and indirect (constructivist) perception of size occurred, and I argued that approach in a belatedly published response (Norman, 1983) to Ullman's (1980) attack on the Gibsonian view.

In my recent article (Norman, in press), I reviewed the neurophysiological, neuropsychological, and psychophysical evidence pointing to the existence of the two visual systems and revealing some of their different attributes. I also attempted to demonstrate the parallels between the ecological approach and the functioning of the dorsal system and between the constructivist approach and the functioning of the ventral system. Finally, I presented some implications of the dual-process approach for explaining a few phenomena in the realm of space perception.

The review of the research on the two visual systems, the dorsal and the ventral, pointed to several distinct differences between them. I briefly describe them here. First, the two systems differ in their anatomical location and input sources. The dorsal system is located in the posterior parietal cortex and other adjacent areas and receives input both from V1 and directly from subcortical inputs via the superior colliculus and pulvinar. The ventral system is located in the inferotemporal cortex and adjacent areas and also includes area V4. Its input is mainly, if not totally, from V1. The ventral system receives its major input from the parvocellular retinocortical pathway but also receives considerable magnocellular input, whereas the dorsal system receives its input only from the magnocellular retinocortical pathway.

Most important, the two systems differ in the functions they perform. The primary function of the ventral system is the recognition and identification of the visual input. Recognition and identification must depend on some comparison with some stored representation. In contrast, the primary function of the dorsal system is analysis of the visual input in order to allow visually guided behavior vis-à-vis the environment and objects in it (e.g., pointing, reaching, grasping, walking toward or

through, climbing, etc.). Although these are the primary functions of the two systems, they also participate in other functions. Thus, for example, the dorsal system appears to be involved in the identification of moving objects, and the ventral system has a capacity for size perception, albeit a somewhat different type of size perception (relative rather than absolute size).

The two visual systems differ with respect to their sensitivities in the spatial and the temporal domains. The ventral system is more sensitive to high spatial frequencies, whereas the dorsal system is more sensitive to high temporal frequencies. In other words, the ventral system is superior at seeing fine details, whereas the dorsal system is better at seeing motion. The dorsal system responds more quickly to visual input than the ventral system does. The two systems differ in their responses to retinal eccentricity: The ventral system is mainly attuned to foveal or parafoveal visual input. Its sensitivity falls off sharply with retinal eccentricity. In contrast, the dorsal system is much less affected by retinal eccentricity. The two visual systems also appear to differ in their ability to cope with a transition from normal binocular vision to monocular vision. Whereas dorsal system function suffers when forced to rely solely on monocular vision (when no motion parallax is available), the ventral system is much less affected. Because the primary function of the ventral system is recognition and identification, it processes the visual input in an object-centered or allocentric frame of reference. The dorsal system, on the other hand, normally has to perform some action on, or in relation to, some object. For this purpose it needs the dimensions of the object in body-centered terms, that is, it must use an egocentric frame of reference.

The ventral system is based on long-term memory, using stored representations to recognize and identify objects and events. In contrast, the dorsal system appears not to have a long-term storage of information but only very short-term storage allowing the execution of some immediate behavior. (It should be mentioned that there must be some storage of dorsal system interactions with the environment in a procedural memory system. Otherwise we could not account for perceptual learning of perceptuo-motor tasks.) As far as consciousness is concerned, one is normally much more conscious of ventral system functioning than of dorsal system functioning. It would seem that the dorsal system can function quite adequately without consciousness. This is most clearly seen in the many studies on patient DF, who sustained brain damage that has left her without a functioning ventral system. She has been shown to be capable of performing various actions vis-à-vis objects in her environment, such as inserting a card into a rotatable slit, matching her grasp size to that of the object to be picked up, or avoiding obstacles in her path. She performs all these tasks without evidencing any conscious apprehension of the task in question. In a word, DF is capable of picking up the affordances of the objects in her environment but incapable of reporting on them.

The parallels between the functions of the dorsal system and Gibson's (1979) descriptions of perception should be apparent to readers of this journal. Very briefly, these parallels include the emphasis on an active perceiver, one who is not

necessarily conscious of the information picked up. Gibson maintained that perception functions without recourse to memory and that the dorsal system is virtually memoryless. The parallels between the functions of the ventral system and the constructivist view are also quite obvious. As can be seen in the quote from Rock (1983) presented earlier, the constructivists see perception as an interpretation of the proximal stimulus, an effort at identifying the objects or events in question. It is the ventral system that interprets and identifies the visual input by comparing it with some representation in memory. Both the constructivist view and the ventral system are totally dependent on memory.

The idea being suggested here—the dual-process view—is that perception in its entirety consists of two processes: one seen to parallel known functions of the dorsal system and one seen to parallel those of the ventral system. Gibson was aware of the existence of such two types of perception. In one of his *Purple Perils* (1976) entitled “What Is It to Perceive?” he wrote

The verb *to perceive* has two meanings, one being that of ordinary usage and the other coming from a puzzle in philosophy and psychology:

1. To perceive X means simply to be in touch with it, to be able to cope with it, or to be aware of it in the environment.
2. To perceive X means to have an *experience* corresponding to X, or *percept* of it, or a content of awareness, or of consciousness. This implies that there is a *mental X* besides the actual X. The second meaning is troublesome.

The two meanings need to be kept separate in the investigation of perceiving. The act of a perceiver and the content of his mind should not be confused.

Gibson’s interests, of course, focused on the first of the two meanings, but I suggest that by incorporating both definitions into a broader theory many phenomena and perplexing experimental findings will be better understood.

It should be stressed that although the two systems ostensibly have quite different functions, they function synergistically, and there is cross-talk between them. For example, the dorsal system has only a very short-term memory that basically allows actions to be carried out only online (a “use-it-or-lose-it” system, as Michaels, 2000, p. 254, suggested), and it has been shown that the ventral system memory can serve to bridge longer time gaps. The motor actions carried out under these conditions are not quite as efficient and accurate as when there is no time gap, and this can be interpreted as indicating that they are at least partially under the control of the ventral system. In other words, the ventral system can carry out functions that are normally dorsal, albeit not as efficiently. The dorsal system can carry out functions that at first might be seen as belonging to the ventral domain. For example, neurophysiological studies on monkeys (Sakata, Taira, Kusunoki, Murata, & Tanaka, 1997) and positron emission tomography studies on humans (Baker,

Frith, Frackowiak, & Dolan, 1996) have indicated that the dorsal system is sensitive to three-dimensional features of objects, such as shape, orientation, and size. Of course, these features are important not only for the recognition and identification of objects but also for their motor manipulation, and they are presumably coded in an egocentric frame of reference in the dorsal system.

The interactions between the two systems also become apparent when the perceptual task at hand is one that would normally be carried out by the dorsal system but the pick up of information is impeded. This might occur if that information is impoverished or conflicting, and in such cases it is suggested that the ventral system is turned to for help (see Norman, 1980, 1983). Another instance in which similar perceptual tasks can be seen to be tackled by both systems is when the observer learns a new task. It is suggested that in the novice it is the ventral system that comes into play, and only with practice does the dorsal system take over the task. An example of this can be found in Runeson, Juslin, and Olsson's (2000) study of the visual perception of dynamic properties. Their observers initially evidenced what they called an "inferential" mode of processing (which I would call *ventral*) and with practice transferred to a "direct-perceptual" mode of processing. Of special interest is their report on one of their observers (No. 13), who did quite poorly on the task until,

In the course of the posttest, with no more feedback, she "felt there was no use trying any more and started to just look and respond, to get it over with." She expected an even poorer score and was surprised when told that it had in fact improved greatly. (p. 547)

Three points relating to this quote should be mentioned. First, in many tasks performance is superior when the task induces dorsal processing rather than ventral processing (see review in Norman, in press). Second, the complexities of the relations between dorsal system processing and consciousness come to the fore. The participants in Runeson et al.'s (2000) study shifted to a dorsal processing mode with practice. However, if dorsal processing is unconscious, how were they capable of producing the required responses? The answer would seem to be that either not all dorsal processing is unconscious or that there is a transfer of information from the dorsal system to the ventral system following the required perception. The fact that when Observer 13 decided "to just look and respond" she did much better also points to a special relation between consciousness (or attention) and dorsal system processing. The dorsal system is best engaged not when the observer makes a conscious effort to do well, but when the observer moves into what might be called an "automatic mode." Finally, it should be noted that the task Runeson et al. used did not require an "action" but only a judgment of which of two colliding circles was the heavier. In spite of the fact that making judgments would seem to be a ventral-type task, the authors showed that the practiced observers' superior performance was due to dorsal/direct processing. The dorsal system is the system that

processes motion information, and the trained observer uses its more appropriate mechanism, but with less conscious feedback leading to the surprise at learning that performance is so good. It is important to reiterate the final point: The dorsal system is a *perceptual* system, which often picks up information for the control of actions but also at times functions as a purely perceptual system.

### COMMENTS ON MICHAELS (2000)

Milner and Goodale's (1995) research has led to important insights about the functioning of the visual system, and the impact of their findings abound in many subdisciplines of cognitive science. All the same, however, their interpretation of their findings as indicating that one visual system—the ventral system—deals with perception, whereas the second system—the dorsal system—deals with action, is very problematic. As Michaels (2000) correctly noted, “Milner and Goodale’s definitions are off-the-shelf constructivist definitions: Perception is a representational process of enrichment whereby an input gains meaning” (p. 256). It is because of this constructivist stance that Milner and Goodale chose to refer to the functions of the ventral system, the conscious system, as perceptual and to those of the dorsal system, the unconscious system, as action and not perception. If one were to accept this definitional scheme one would have to conclude that most, if not all, of the phenomena studied by Gibson and other ecologically oriented researchers are not perception! As I claimed earlier, the dorsal system is a perceptual system, which among other things is active not only in the visual control of movement but also in other perceptual activities, such as the pickup of object movements and their interactions. Because it is the system that continuously allows one to engage one’s environment with relatively few mishaps, it is a perceptual system of great import.

The central problem of Michaels’s (2000) commentary is that she appears to adopt Milner and Goodale’s (1995) constructivist stand and follows their bifurcation of perception and action. At first she wrote “The second criticism of the Milner and Goodale (1995) position to be expected is for the very separation it endorses between perception and action” (p. 245), and one cannot but agree with her. However, then she seems to change course and totally adopt their definitions of perception and action. She did this in several instances in her commentary. For example, one of her subheadings is “Differences Between Vision for Perception and Vision for Action.” In light of what I have written earlier in this article, I would suggest that all vision is for perception, and it is perception that can be split into perception for action (and a little more) and into perception for recognition (and a little more).

Michaels (2000) appeared to have opted for the Milner and Goodale (1995) definitions partially in the light of the results of a recent study (Michaels, Zeinstra, & Oudejans, 2001) in which participants’ ability to punch a falling ball was shown to depend on an optical variable of expansion (looming). It is that variable that in-

fluences the participants' elbow flexion. Some aspect of that variable, perhaps its small value, led to the conclusion that for the punching task the optical variable "was information for action rather than information for perception" (p. 248). To my mind this makes no sense: There cannot be action without perception (except for actions that are carried out on the basis of memory alone). It sounds almost as if the participants in the experiment were capable of punching the ball with their eyes closed, that is, without seeing it! In a similar manner Michaels wrote that patient DF, who lacks a ventral system, "can post a letter *without seeing* [italics added] the orientation of the mail slot" (p. 251). Patient DF can certainly see/perceive the orientation of the mail slot or obstacles in her path. She does this with the aid of her dorsal system. She has no conscious awareness of the slot or the obstacles and thus cannot report on them, but she can see them.

Michaels (2000) continued this line of thought and developed a model that she suggested will replace the Gibsonian model of the relations among stimulation, sensations, perception, and action. In the Gibsonian model she presented, stimulation can lead to either sensations or to perception, and perception to action.<sup>1</sup> In her revision of the Gibsonian model, she broke the Gibsonian stimulation→perception@action chain and suggested that stimulation can lead directly to action. She wrote of her model:

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. (p. 251)

As before, I find this break between perception and action unwarranted. I see no logic for such a break, and I find it hard to fathom its origins other than a misconstrued definition of *perception*. If perception is only a conscious process, as posited by the constructivists—and clearly many actions can occur without the intervention of consciousness—then it might be said that actions occur without perception. However, as Gibson (1979/1986), and Michaels herself, noted, perception need not, or does not, always entail consciousness. Michaels quoted a "working definition of action" by the Vrije Universiteit group (p. 251). Part of that definition included a lawful relation between information and movement. However, that is exactly the essence of dorsal perception. In a word, if one accepts the ecological definition of perception (that I claim is carried out by the dorsal system), then perception is what comes between information (*stimulation*, in Michaels's model) and action, and there is no reason to sever the perception–action link.

Michaels (2000) also dealt with the purpose of the ventral system, mislabeling it "vision for perception" (p. 254). She was unhappy with the interpretations sug-

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<sup>1</sup>In *The Ecological Approach to Visual Perception* Gibson (1979/1986) tended to reject the concept of "sensations"; see the Subject Index: "Sensations—insufficiency of the concept." "Information→perception→action" without "sensations" would better represent his later stand.

gested by Milner and Goodale (1995) and wrote that “they all ring hollow from an ecological perspective.” Her main problem is with the concept of representations:

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. (p. 254)

She is, of course, not alone in her uneasiness with the concept of representation, and many psychologists not of the ecological bent also have troubles with it. However, any attempt to deal with the processes of recognition and identification cannot evade the issue. When one recognizes one’s grandmother as one walks into the room, that recognition must of necessity be based on some sort of internal representation. Gibson was influenced by his behaviorist educational background and eschewed “mentalistic” concepts, but I would suggest that today we have to face up to the existence of something akin to “representation” to explain what I have labeled the *ventral* type of perception. A plethora of experimental studies are seeking the anatomical locations and physiological mechanisms underlying memory in its various forms, and I hope some of these will appease the qualms of some concerning representation. Hatfield (1990) made the case for Gibsonians accepting a connectionist model of representation as compatible with their edicts. Whether the physiological findings or the connectionist models will be a panacea for those troubled by the concept of representation is not clear. However, at this stage of our knowledge (or lack of such) I would suggest that we accept the idea of a second perceptual system, the ventral system, that uses some sort of stored knowledge to enable recognition and identification. I find Michaels’s suggestion that the ventral system is a system for “telling” hard to accept. The ventral system is a perceptual system, and although it supplies visual information that can be stored and later told, it can only be seen as the first (perceptual) link in the chain of other processes that must transpire before telling.

Finally, I make a very brief digression on the question raised by Michaels (2000) of “whether affordances should be viewed as a ventral-stream or dorsal-stream activity” (p. 253). Although she noted that her analysis does not provide an unequivocal answer to that question, I would suggest that the two-visual-system analysis does suggest a clear answer to this question: Affordances are picked up by the dorsal system. In fact, the pickup of affordances can be seen as the prime activity of the dorsal system. The validity of this statement is contingent on a clear specification of what exactly is meant by “affordances.” First, it should be noted that affordances can be picked up without concomitant action, such as when the affordance of the graspableness of an object is perceived as being too big, and no action is taken. More important, I feel that the concept of affordances must be limited only to instances in which the possibility of an action vis-à-vis some object, surface, or event in one’s environment is involved. Thus, Michaels’s facetious example of academia affording career building is clearly not an example of an affordance. What is more,

some of Gibson's (1979/1986) statements on affordances are troublesome for the view I espouse. His assigning "meaning" to affordances is problematic, especially if he is referring to semantic meaning. In my view, Gibson's suggestion that mailboxes afford letter mailing is similarly problematic. It would be better to say that the slot in the mailbox affords insertion of an object of appropriate size and shape (see Norman, in press).

A very different interpretation of the implications of the two visual systems to perceptual theory than that of Milner and Goodale (1995) has been proposed. It suggests that the ventral visual system parallels a constructivist approach to perception and the dorsal visual system parallels the ecological approach. In this interpretation the ecological/dorsal system is not simply "an action system" but the perceptual system that allows organisms to negotiate their environment. The concerns voiced in Michaels's (2000) commentary stemmed from her adoption of Milner and Goodale's view that the dorsal system is not a perceptual system. There is no need for concern!

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