The Relation Between Perception and Action: What Should Neuroscience Learn From Psychology?

Patrick R. Green

Department of Applied Psychology
Heriot-Watt University
Edinburgh, Scotland

Research in neuroscience is making progress toward understanding the “dorsal” mechanisms responsible for the fast modulation by optical information of actions such as reaching and grasping. The function of “ventral” visual pathways is not to support perception, as distinct from action. Instead, it is to control extended actions that unfold over longer time scales and draw on optical information over larger spatial scales, than simple, fast limb movements. Perception and sensation should be regarded as particular forms of extended communicative actions and not as alternative end points for the use of environmental information. The neural mechanisms involved in controlling extended actions are not yet understood, and psychological theory has a role to play in framing their investigation by neuroscience.

Milner and Goodale’s (1995) theory is an important achievement. It begins with a core set of observations that brain lesions can produce strong and surprising dissociations between different ways of using vision. It then goes on to draw together converging evidence from single-cell physiology and psychophysics into a coherent whole that represents real progress toward understanding the biological systems that link optical stimulation and action. In neuroscience, the theory is usually seen as part of a common coding approach, which rejects the traditional distinction between sensory and motor areas of cerebral cortex (e.g., Gallese & Goldman, 1998; Goodale, 1998; Prinz, 1997). In contrast, ecological (and perhaps also cognitive) theorists are more struck by the wedge that it seems to drive between perception

Requests for reprints should be sent to Patrick R. Green, Department of Applied Psychology, Heriot-Watt University, Edinburgh EH14 4AS, Scotland. E-mail: p.r.green@hw.ac.uk
and action. This is because, for neuroscience, much of the excitement surrounding the theory attaches to the dorsal pathway and its close links to premotor areas. These suggest that a fairly small number of fast neural operations between the primary visual and premotor cortex allows actions such as reaching, grasping, or stepping to be modulated by optical information. In contrast, the functions that Milner and Goodale assign to the ventral pathway represent a familiar way of thinking about visual perception in neuroscience. It is easy for such a view to slide into an assumption that the link between perception and action can be fenced off safely above the lateral sulcus, leaving the temporal lobe safe for cognitive mediation. I agree entirely with Michaels’s (2000) aim of resisting this way of thinking, but I want to outline a somewhat different way of doing so, one that I argue asserts the place of psychology relative to neuroscience more strongly.

Is there actually evidence for a single visual pathway outside the dorsal one, with clearly defined functions? Conscious awareness of the surroundings is claimed as an important function of the ventral pathway. However, one should be cautious of ascribing awareness to any single cortical area and remember that a wide variety of brain lesions can produce dissociations between awareness and performance. Sometimes these can be adequately explained as the loss of a ventral pathway required for conscious awareness, as in blindsight (Weiskrantz, 1986) or in visual form agnosia (Goodale, Milner, Jakobson, & Carey, 1991), when visually guided actions are aimed or scaled accurately without awareness of a target object. In other cases, dissociations can be more subtle. In both prosopagnosia (e.g., DeHaan, Young, & Newcombe, 1987) and neglect (e.g., Marshall & Halligan, 1988) there have been demonstrations of patients being unable to report the identity of faces or drawings when asked explicitly but who show “covert” recognition in implicit tasks, such as associative priming. Results of this kind indicate that in some circumstances recognition can be dissociated from awareness and therefore that both cannot arise from the operation of a single ventral system. A safer conclusion from existing evidence is simply that the dorsal pathway can operate effectively without giving rise to awareness.

Another set of functions claimed for the ventral pathway is to form and use representations of objects and events. If one accepts Michaels’s (2000) critique of this argument, a more neutral claim could be made that effects of experience and learning on perception occur in the ventral but not the dorsal pathway. However, it is difficult to maintain this as a distinct function unique to ventral areas. If the dorsal pathway is responsible for scaling limb movements in relation to the surrounding environment, it must in some way embody information about the dimensions and dynamic properties of the body. Furthermore, this must be capable of modification through learning so that visuomotor calibration is maintained as the body grows or becomes impaired. It also seems that the dorsal pathway must be involved where the mode of control of fast limb movements changes through learning; Michaels’s discussion of learning to use inherently ambiguous optical variables to control the timing of ball punching (Michaels, Zeinstra, & Oudejans, 2001) provides an ex-
ample. As matters stand, there are no grounds to ascribe learning effects to a ven-
tral system, or systems, alone.

If current evidence supports a distinct dorsal pathway, but leaves the number
and functions of more ventral pathways an open question, how should psychologi-
cal theories of visual perception respond? I suggest by assuming that all operations
carried out in the brain on optical information are concerned with action. One
should not look for separate systems for controlling action on the one hand and for
awareness, representation, or learning on the other hand. Rather, the problem is to
understand how neural systems are organized to control actions taking place over
different temporal and spatial scales. To clarify, consider the following series of
things that one might see a person do:

1. Reach toward a door handle and grasp it.
2. Walk toward a door and open it.
3. Get up from a chair and go into another room.
4. Stop reading a book and go to the kitchen to get a snack.

At each step, one sees an action that extends over a longer period of time and
subsumes the action at the previous step. At the same time, one also sees that the
temporal and spatial extent of the environmental information used to control the
action becomes wider. At Step 1 it includes the position and dimensions of the
door handle. At Step 2 it includes the layout of furniture, walls and door, and the
dynamic properties of door handles and doors (both in general and in this specific
case). At Step 3 the layout of the rooms of the house becomes involved, and at Step
4 such things as the narrative structure of the book and the contents of the refrig-
erator become involved. Ecological and cognitive theory obviously give very differ-
ent accounts of the transitions between these examples, but for these purposes they
are meant only to illustrate a crucial property of human action: that its control
must involve systems working concurrently at a range of temporal and spatial
scales.

In these terms, the dorsal pathway can be seen as a distinct system controlling
action at the smallest scales. The evidence indicates that it modulates limb move-
ments quickly and that it has narrow temporal (Goodale, Jakobson, & Keillor,
1994; Westwood, Chapman, & Roy, 2000) and spatial (Murphy, Carey, &
Goodale, 1998) windows on the environment. Other systems must come into play
to control actions unfolding over longer periods than a second or so. Michaels
(2000) suggested that this may be the function of a single ventral pathway, but it is
just as likely to involve many cortical areas, among them the ventral areas identi-
fied by Milner and Goodale (1995). One can picture patterns of neural activity in
cortical areas evolving and then disappearing over many different temporal and
spatial scales, ranging from hundreds of milliseconds in local dorsal areas to longer
time periods across many areas extending into the ventral region. The result is a dy-
namic hierarchy of control systems established in the cortex that allow for the se-
rial ordering of actions over different scales simultaneously. Such a model would lead one to expect multiple systems beyond the dorsal pathway and to expect reciprocal interactions between all pathways to achieve synchrony between control systems established over different scales. Working toward an understanding of the control of action at larger scales will, I predict, lead to a fractionation of the supposed “ventral pathway” into a much more complex model. It is here that psychological theory should look for its role in framing the wider problems for neuroscience to address.

If there are no good grounds for assigning perception and action to different brain systems, are there any for treating them separately at a psychological level? Michaels (2000) suggested that sensation, perception, and action can be treated as three different results of stimulation, but I would like to offer an alternative suggestion: that perception and sensation are both forms of action. In particular, they are embedded in more extended communicative actions, or “telling” actions, to use Michaels’s term. This is a particular class of actions that involve communicating something about the world to another person. Such an action must always be a relatively extended one, as its control must draw on information about the person or people making up the audience (or potential audience) as well as other aspects of the surroundings. Communicative actions will engage a hierarchy of smaller units of action, including not only speech or writing but also nonverbal gestures. A particular limb movement, such as shaping the hand to grasp an object, can form part of a number of different communicative actions. To take an everyday example, this movement might be a component of a more extended action to withhold information from another person that the actor is opening a door, by opening the door slowly and therefore quietly. In the more contrived circumstances of an experiment the same movement might be part of an extended action that communicates the size of an object to another person through a “pantomime.” The same fast, local action can therefore be recruited into many different extended actions, including a variety of communicative ones. As I argued earlier (Green, 1995), the dissociations shown by patients such as DF (Goodale et al., 1991) can be understood as an inability to recruit actions such as hand shaping in this way.

To return to the nature of perception and sensation, I suggest that each of these terms covers a variety of actions in which a person prepares to communicate information about some state of affairs in the world to another person. Often, the action is not completed, and the result is a private experience. If it continues into a more extended act, some exchange between people develops, whether a natural everyday one or a more constrained one between experimenter and participant. In an act of perceiving, a person prepares to communicate some property of an object or event that is marked out as important by some physical or social context. This might be a person’s age, the speed of a car, or the color of a piece of clothing. Or it might be a property marked out by an experimenter’s instructions, such as the attractiveness of a face or the direction of motion of a grating. Depending on the interests of the experimenter, these two sets of properties may of course overlap. An
act of sensation is similar but involves properties of an object or event defined in a way more closely related to physical parameters. In this view, perception and sensation are not precisely defined or clearly separated but instead are broad and overlapping sets of phenomena. Both always involve some act of selecting properties of the world as part of a developing communicative action that may or may not go to completion with a verbal exchange.

Treating sensation and perception in this way does not undermine the use of psychophysical methods to study how people use stimulation provided by the environment. These methods work by establishing a defined and controlled communicative action and investigating how it changes as properties of stimulation are varied. These relations then provide one with knowledge about constraints on the use of environmental stimulation or allow one to deduce the properties of particular neural operations on that stimulation. Psychophysical methods cannot step inside the system that links stimulation to action or give one direct access to components of that system. In particular, perception and sensation are not components but are particular modes of operation of the whole system.

I strongly agree with Michaels’s (2000) argument that ecological psychology must assert its place in framing the problems that neuroscience should address. However, I believe that the best way to achieve that aim is to maintain the fundamental importance of the link between stimulation and action and to place questions about the organization of action at the center of those problems. How is action controlled at many different temporal and spatial scales simultaneously, and how is the information provided by the environment used to achieve that end?

REFERENCES


