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## Alternative Views of Perception and Action

### 1. *The Classical Sandwich*

A. A mainstream view of the mind has two main components. The first is a view of perception and action as separate from each other and as peripheral. The second is a view of thought or cognition as the central core of the mind, at least for creatures with cognitive abilities. Cognition is virtually central, even if the mere implementation of cognitive processes is distributed. The mind decomposes vertically into modules: cognition interfaces between perception and action. Perception and action are not just separate from each other, but also separate from the higher processes of cognition. The mind is a kind of sandwich, and cognition is the filling.

A fully orthodox view has one further feature. Not only is cognition central and distinct from peripheral sensorimotor processes, but the center is *classical* “at the right level of description.” A cluster of related properties of cognition—compositionality, systematicity, productivity, binding, and so on—are to be explained classically, in terms of processes involving symbols and recombinant syntactic structure. The subpersonal processes that explain the conceptual structure of thought mirror that structure syntactically. There

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is an isomorphism between contents and vehicles, or *causal systematicity* (see and cf. Davies 1991a; Fodor and Pylyshyn 1988, etc.). The mental sandwich has a classical filling.

On this orthodox view, nonclassical connectionist networks that lack context-free symbols and syntactic structure may be apt for modeling peripheral, sensorimotor functions. But they cannot explain the distinctive structural properties of thought "at the level of cognitive significance." They could at best model the brain's distributed implementation of classical cognitive processing.

B. There are several ways to resist the classical sandwich. First, we can ask: Is cognitive processing really classical? Second, we can ask: Is cognitive processing really central and distinct from sensorimotor processing? Third, we can ask: Are perception and action really peripheral and separate from each other? The third line is the one we pursue here. But the other two provide relevant context.

The first issue, about classicism, is the most familiar. Can connectionism account for the compositionality of thought without internal context-free symbols to combine and recombine within syntactic structures? If it can, is behaviorism implied? Is thought as we conceive it eliminated?<sup>1</sup>

The second issue, about centrality, is somewhat less familiar, but is getting increasing attention from philosophers and scientists. Cognition and sensorimotor control are traditionally studied separately from each other. Patricia Churchland urges that they should not be, and that to understand the emergence and dynamics of cognitive processes we may need to understand their origins in sensorimotor control processes.<sup>2</sup> Dynamic systems approaches to the mind aim to show how cognition emerges in development

<sup>1</sup> See and compare: Fodor and Pylyshyn 1988; Smolensky 1988; van Gelder 1990; Clark 1990a, 1991; Davies 1990, 1991a; Ramsey, Stich, and Garon 1990; Stich 1991; etc.

<sup>2</sup> "If we can see how the complexity in behavior that we call cognition evolved from solutions to basic problems in sensorimotor control, this can provide the framework for determining the nature and dynamics of cognition."

"There is an assumption, popular among philosophers, that the brain processes that make for cognition are one sort of thing and that the brain processes that contribute to motor control belong to an entirely different category. Accordingly, the assumption may be used to justify a disregard of research on motor control by those doing research on cognition. But if we look at matters from an evolutionary and neurobiological point of view, the assumption is not only naive, it in fact trammels the theoretical imagination. . . . [I]f we want to understand the fundamental principles of cognition, we may need to understand the emergence in evolution of those paradigmatically cognitive processes, and hence we may need to understand their origins in sensorimotor control. . . . [A] principled disregard of sensorimotor control by philosophers may deprive them of just the perspective needed to understand the fundamental principles underlying intelligent behavior" (Churchland 1986, p. 451).

See also Jackendoff 1987, pp. 271–72; Hutchins 1995, pp. 292, 316, 364–66, etc.

from cycles of perception, action, perception.<sup>3</sup> Neuropsychologists such as Edoardo Bisiach observe the way cognitive processes can be entrapped by sensorimotor disorders. This is important if normal function can be revealed by dysfunction. For example, a left-neglect patient (see essay 9) claimed of her left hand that it did not belong to her, though she readily admitted that her left shoulder was part of her body. What about the bits in between hand and shoulder? She *inferred* that her left arm and elbow were part of her body, given, as she said, the evident continuity of these members with her shoulder. But she was elusive about the forearm, and persisted in denying ownership of the left hand. In another case of cognitive entrapment, a left-neglect patient's left hand was held up by the examiner between the examiner's own two hands, in the patient's right visual field. The patient was asked whose hands they were.

PATIENT: Your hands.

EXAMINER: How many of them?

PATIENT: Three.

EXAMINER: Ever seen a man with *three* hands?

PATIENT: A hand is the extremity of an arm. Since you have three arms it follows that you must have three hands.

(See Bisiach and Geminiani 1991, pp. 30–36 and *passim*; Bisiach 1988b, p. 469.) Bisiach also emphasizes the often overlooked sensorimotor character of participation in natural language (Bisiach and Berti 1989, p. 152; Bisiach 1988b, p. 489; see also Thelen and Smith 1994, pp. 329–31).

Two theoretical points are important in addressing the relations between sensorimotor and cognitive processes. One concerns emergence and the other the role of the environment.

First, the emergent global properties of dynamic systems, especially non-linear systems, are often striking and surprising. However, there is nothing mysterious or spooky about them. Dynamic systems demystify emergence. A self-organizing dynamic system may be fully deterministic, even though its emergent properties cannot be predicted other than by letting it run and seeing what it does. Emergent properties are a function of the mathematical specification of the system, but may not be a transparent, or even a translucent, function. Dependence of a system's behavior on initial conditions may be so sensitive that accurate measurement of those conditions disturbs them significantly. And emergent structure may vary discontinuously with continuous

<sup>3</sup> See for example Thelen and Smith 1994, pp. 129; Thelen, "Time-Scale Dynamics and the Development of an Embodied Cognition," in Port and van Gelder 1995, p. 96; Port and van Gelder 1995, p. 150.

changes in system parameters. Structure at the emergent level may not be explicable in terms of any independently identifiable isomorphic structure at the emerged-from level. So discontinuities can emerge from seamless processes. These points about emergence are emphasized by neural network theory and dynamic systems/chaos theory, which are closely related. Dynamic systems theory provides a general framework for understanding the behavior of neural nets, which can include chaotic behavior.<sup>4</sup> Familiarity with the unpredictable emergent properties of dynamic systems should make us wary of claims that cognitive properties or conceptual structure simply could not arise except in ways that depend on isomorphic underlying properties or structure. It should also make us wary of projections of properties or structure from the personal to the subpersonal level.

Second, the environment is part of the relevant dynamic system for many purposes. As Varela writes: "If one says that there is a machine *M* in which there is a feedback loop through the environment, so that the effects of its output affect its input, one is in fact talking about a larger machine *M'* which includes the environment and the feedback loop in its defining organization" (1979, p. 12). Significant structure may be distributed not just within internal states but also across internal and external states. Emphasis on the role of information present in the environment creates an affinity between neural network and ecological approaches (see section 3 below; Elman et al. 1996, p. 158; Turvey 1990; Allport 1980; Kelso, Del Colle, and Schoner 1990, p. 140ff., 166ff.; Smolensky 1988, p. 16; Churchland, Ramachandran, and Sejnowski 1994, pp. 36–37).

For purposes of understanding cognition, the relevant system may include the social and linguistic environment as well as the natural. Consider a connectionist network trained and tuned in part by systematic sensory-motor interactions with a richly structured linguistic environment, as feedback loops pass through this environment picking up information. Functions from the network's linguistic output back to linguistic input reflect linguistic structure in the environment and constrain the network's organization. Organization in the network could be induced in part by the way self-produced words result in other-produced words. Such organization might permit new combinations of words, answers to new questions: networks can generalize beyond the cases they are trained on (see and cf. Elman et al. 1996, ch. 2, etc.; Rosenfield 1989, p. 148ff.). Behavior does causal work in such a system; it's not merely evidence of something else that's doing the work.

<sup>4</sup> See and compare: Elman et al. 1996, esp. ch. 4; Pollock, "The Induction of Dynamical Recognizers," in Port and van Gelder 1995, p. 286; Clark 1990a, sec. 3; Turvey 1990; Kugler et al., 1989–90; Edelman 1987, p. 142; Morton 1988; Freeman 1991; Skarda and Freeman 1987; Schoner and Kelso 1988; Basar 1990; etc.

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The structural properties of cognition may emerge as a network with the right architecture is trained up in this way by dynamic sensorimotor interactions with the perceivable products of linguistic actions, namely, the words and sentences of natural language out there in the environment, as opposed to internal symbols (see and compare Hutchins 1995, esp. chs. 7, 9; Dennett 1991c; Smolensky 1988; Clark 1990a on rogue competence; Barwise 1987). The whole dynamic system would include both network and linguistically structured environment through which feedback loops pass. If the classical structure of an internal "language of thought" could explain the properties of cognition, why in principle couldn't the classical structure of natural language do so without the extra inward step?

The point about partially unloading structure onto the environment can be made in terms of the distinction between the level of implementation and the level of cognitive significance. As noted, it is sometimes claimed that non-classical approaches can at best model the implementation of cognition, but not the level of cognitive significance. At some level of description, it is claimed, classical structure must account for the properties of cognition, however that structure is implemented (see various works by Fodor; Fodor and Pylyshyn 1988; cf. Smolensky 1988; van Gelder 1990). But, even if this is granted for the sake of argument, it does not follow that the level of description where classical structure is found must describe internal states only. It could instead describe a system of relations that cuts across internal/external boundaries and includes natural language. When we describe the process of linguistic output bouncing off the sociolinguistic environment (other linguists) and producing linguistic feedback, we describe natural language. If sensorimotor interactions with natural language can induce some nonclassical networks to implement the properties of cognition, why suppose *internal* classical structure is also needed? Explanatory classical structure at a level of cognitive significance would already be present, in natural language itself.<sup>5</sup>

Notice that there is no opposition between the point about unpredictable emergent properties and the point about environment-inclusive systems (cf. Clark 1990a). Indeed, in some contexts they may support or depend on one another. It is a further question why there is natural language in the environment at all; the full story would have to explain the evolution of language, or the coevolution of language and the human brain. Of course, not just any old internal architecture makes natural language possible. But it is an empirical question whether whatever explains the existence of natural language involves internal syntactic structure.

<sup>5</sup> For discussion of further issues implicit here, see the Hurley 1998, especially the discussion of whether causal systematicity applies internally or externally and to type-explanatory processes or to token-explanatory processes.

The third way of challenging the classical sandwich view of the mind does not focus on cognition, and its purported classical or central character. Rather, it works from the outside in. It focuses on the supposed periphery, and criticizes the traditional conception of perception and action (see essays 8, 9). This will be our main approach in the remaining sections of this essay.

C. These different lines of resistance to the classical sandwich start out looking distinct, but end up converging and interacting. Traditional presuppositions about the separateness of perception and action may hold in place the assumption that the mind decomposes vertically so that cognitive processes are central and distinct, as well as an assumed dichotomy between internal classical structure and behaviorism. A better conception of perception and action may help to understand how cognition might emerge from dynamic sensorimotor systems and the role of environmental structure in such systems.

For example, instead of seeing the mind as vertically divided into internal modules, with cognition interfacing between perception and action, we can see it as horizontally modular or layered, where each layer is content-specific and loops dynamically through internal sensory and motor processes well as through the environment. This change will of course affect our view of cognition. But a horizontally modular view can fruitfully address issues about how evolution and culture add each layer, how they twist the layers or strands together into cognitive abilities, and how the strands can untwist or dissociate (see figure 10.1; see also essay 5, sec. 4.D, on the contrasting metaphors of the interface and the twisted rope).

The functional distinction between vertical modularity and horizontal modularity, and its relationship to properties of cognition and to rationality, are worth a small digression.

In traditional cognitive science, the mind is seen as dependent on underlying processes the overall structure of which is *vertically modular*.<sup>6</sup> Each ver-

<sup>6</sup> The vertical/horizontal contrast drawn in this section should not be confused with the vertical/horizontal contrast drawn by Fodor (1983, pt. 1). It is closer to but not identical with the vertical/horizontal contrast drawn by Clark (1997, pp. 12–14 and elsewhere) and to that implied by Goodale and Milner (1992) when they suggest that functional modularity extends from input right through to output (this would count as horizontal modularity, in present terms). It is closer still to some of the contrasts developed by Brooks (1991) between the horizontal domain-specific layering of his subsumption architectures and the traditional Artificial Intelligence approach. See also essay 5 above and Hurley 1989, pp. 317ff.

Note that in present terms, Fodor's view counts as vertically modular: he functionally distinguishes transducers, input systems, central processors, motor systems, and supposes the flow of information becomes available to these systems in about that order; input systems mediate between transducer output and central cognition by producing mental representations on which central cognition then operates; input systems are "informationally encapsulated," while the central system is not (1983, pp. 41–42). However, in present terms, horizontal modules are domain-specific. We do not give up domain-specificity by moving from vertical to horizontal

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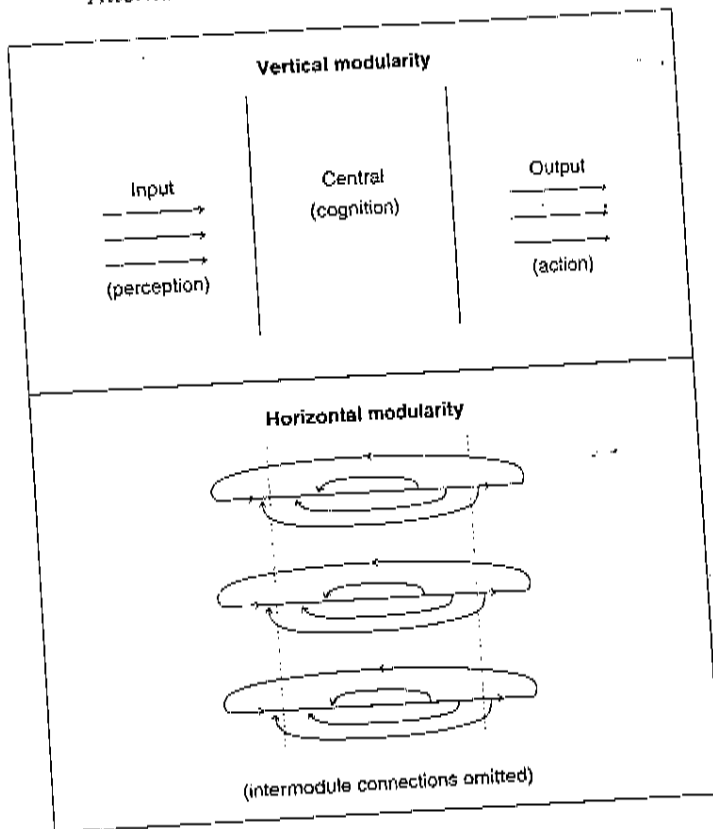


FIGURE 10.1. Vertical versus horizontal modularity

tical module performs a broad function, then passes the resulting representations on to the next. Within the perceptual module, information about location, color, motion, and so on, is extracted from inputs by various parallel streams of domain-specific perceptual processing. The representations produced by the various streams of input processing converge and are combined by perception. The unified result is sent on to cognition, the central module that interfaces between perception and action. This is where the processes occur on which rational thought and deliberation depend. Rationality is conceived as depending on internal procedures involving the manipulation of internal representations, including those passed on by perception. Based on current and stored input and cognitive processing, a motor plan is

modularity. See and compare Jackendoff 1987, p. 267; Thelen and Smith 1994, pp. 174, 220; Elman et al. 1996, pp. 37, 40–41, 100, 108, 158, etc.

formulated, and it is passed on to motor-programming processes for execution. There is a linear sequence of separate processing stages, from perception to cognition to action. There may be parallel processing within each stage, for example, before information about color and about motion are combined within perception. Nevertheless, the overall functional structure is vertically modular.

We should not confuse talk about the mental states of a person with talk about the underlying subpersonal processes on which those personal-level mental states causally depend. The vertical modularity view is a view about the functional structure of subpersonal causal processes. But we can understand why the vertically modular view has seemed natural. At the personal level, we distinguish between a person's perceptions, her reasoning, her intentions. Vertical modularity finds similar distinctions at the level of subpersonal functions and causal processes. It may be natural to assume such an isomorphism between one level of description and another, as in the Input-Output Picture (discussed in other essays, especially essay 9).

Nevertheless, this vertically modular conception of subpersonal causal processes is coming under pressure in recent cognitive science and philosophy of mind, from neural network and dynamic systems approaches (Thelen and Smith 1994, pp. 174, 220, etc.; Port and van Gelder 1995; Brooks 1991; Elman et al. 1996; Kelso 1995; Clark 1997, pp. 13ff., 58; Hutchins 1995, pp. 292, 316, 364ff., etc.; see also Jackendoff 1987, p. 267; Milner and Goodale 1995, pp. 10–13, 26, 41–46, 65, 163, 170, 179, 200). These suggest a contrasting conception of the mind as depending on distributed subpersonal processes that are *horizontally modular* in functional structure. One way of thinking of these is in terms of layer upon layer of content-specific networks. Each layer is dynamic: it extends from input through output and back to input in various feedback loops. And layers are dedicated to particular tasks. For example, one network may govern spatial perception and the orientation of action (the so-called “where” system), another may govern food recognition and acquisition-type behavior (part of the so-called “what” system), another may govern predator recognition and fleeing-type behavior (another part of the “what” system), another may govern imitative responses to the observed behavior of others, so on. We can think of evolution and/or development as selecting for each layer. Since each subpersonal layer is a complete input-output-input loop, essentially continuous and dynamic, involving external as well as internal feedback, not only are sensory and motor processes coupled, but the neural network is coupled to the creature's environment. Horizontal modules are essentially “situated.” Each dynamic layer is a system that is distributed across a perceiving and acting organism and relevant parts of its environment (perhaps including other organisms: see Hutchins 1995 on socially distributed natural cognition). However, just as a



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given environmental object or feature can be presented in personal-level content in different ways, it can also feature in more than one subpersonal horizontal layer or module or system of relations.

On a horizontally modular view, what happens to vertical boundaries? Vertical boundaries, such as those around sensory or motor processes, or around central cognitive processes, or indeed around the organism as a whole, are relatively transparent and permeable. The mind is "leaky," as Andy Clark puts it (1997). (Of course, it does not follow that vertical boundaries must disappear entirely.)

Can a horizontally modular view accommodate cognition and rationality? If our minds are really dependent on horizontal layers dedicated to particular tasks, is our rationality really an illusion? Considerable recent work has been devoted to arguing in effect that properties of cognition and rationality can emerge from horizontally modular systems. But these properties need to be rethought, in a way that does not depend on a linear sequence of separate stages or on procedures strictly internal to a central interface between input and output. Rationality might instead emerge from a complex system of decentralized, higher-order relations of inhibition, facilitation, and coordination among different horizontal layers, each of which is dynamic and environmentally situated (cf. Milner and Goodale 1995, p. 202). Just as evolution, development, and culture can select a network at each layer that can do the job needed, they might also operate on such relations between the layers to favor rationally flexible responses to problems the environment sets the organism.

D. It may be helpful to consider a more specific illustration of how horizontal modularity might seem to threaten rationality, and how the threat might be diffused. Take as an example of a functional horizontal layer the imitation system.<sup>7</sup> First, some facts.

Newborn infants imitate gestures made to them: for example, they will stick out their tongues reliably when they see someone sticking out his or her tongue. Various empirical reasons have been given for regarding this as intentional behavior, not as merely reflexive (Meltzoff 1995; Meltzoff and Moore, 1977, 1983a, 1983b, 1985, 1995).

Patients with certain kinds of frontal brain damage can be affected by an imitation behavior syndrome, in which they persistently imitate gestures the experimenter makes, even when these are socially unacceptable. When asked why they imitate, since they had not been asked to imitate, patients display a degree of cognitive entrapment: they say they feel they have to, that it is their

<sup>7</sup> I am grateful to Joelle Proust for bringing some of this work on imitation to my attention.

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duty, that the gestures they see somehow include an order to imitate them, that their response is a natural reaction. They do not disown their behavior and may attempt to justify it. Though their behavior reflects some loss of autonomy and rationality, it has been viewed as voluntary and not reflexive. For example, a patient with the frontal imitation syndrome might refuse to imitate hair combing because he wore a wig that would come off: so his imitative behavior is not simply reflexive, and is subject to some voluntary control. But there is still some loss of rationality: in this example, there was no reason to imitate to begin with, so no need to have a reason for refusing. (By contrast, echo-reaction apraxia patients, with a different kind of brain damage, have immediate, automatic, reflexive imitative reactions, which the patient himself may criticize but cannot control.) It has been suggested that these frontal patients have damage to an area that normally functions to inhibit the activity of a system that makes particular connections between perceptions and actions. On this view, damage to the inhibitory area can release underlying imitative patterns of behavior, among others (Lhermitte, Pillon, and Serdaru 1986; Lhermitte 1986; Stengel, Vienna, and Edin 1947).

But the tendency to imitate is not confined to the young and the brain-damaged. Normal experimental subjects instructed to point to their noses when they hear "nose" or to a lamp when they hear "lamp" perform perfectly while watching the experimenter perform correctly. But they are unable to avoid mistakes when they observe the experimenter doing the wrong thing: they tend to imitate what they see rather than follow the instruction heard, even though they have been clearly instructed to follow the verbal command (Eidelberg 1929; Prinz 1990). The underlying tendency to imitate is inhibited in normal adults under many conditions, but it is still there, and its influence can be revealed experimentally. It may operate under a range of natural conditions as well; dysfunction may reveal aspects of normal function.

A tendency to imitate involves a certain threat to rationality. Imitation need not be merely reflexive, but can entrap cognitive processes. This is typical of a horizontal module, considered in isolation from others. The connections it makes between perception and action are too rigid, may not be rationally mediated by someone's desires or intentions (as in the imitation syndrome patients). Imitation is often counterproductive or an irrelevant distraction from the task at hand. More generally, the tight mapping between external stimulus and response involved in imitation seems to threaten the holism of the mental: the way action depends on the rational interaction of belief and desire. A closely related point is often made in criticizing behaviorism (see section 3 below). No given perception by itself can determine what someone should do, because different purposes will rationally lead to different intentional actions, and purposes are not fixed by perception. Yet despite these points, a tendency to imitation may have important and

beneficial functions. Why might evolution favor neural or subpersonal structures with imitative tendencies? This is not hard to see. Variations in the inherited behavioral traits of adults may slightly favor some members of a given generation over others, so some reproduce and others do not. Offspring may benefit if they can acquire the behavioral traits of their successful parents through imitation as well as through inheritance. A young creature that has an innate tendency to act the way it observes others act will, through observing its parents, tend to pick up the behavior of creatures that have survived long enough to reproduce.<sup>8</sup> A tendency to imitate would permit adaptation within as well as between lifetimes. In the human case, in particular, imitation may play an important role in the acquisition of language.<sup>9</sup>

We must consider the way minds are made up as well as how we make up our minds. The tendency to imitate may be among the developmental means by which sensorimotor systems are calibrated and by which people acquire a basic vocabulary of intentional actions, both nonlinguistic and linguistic, so to become the kinds of mature agents to whom the principles of rationality and autonomy generally apply. But if so, the lingering influence of this underlying tendency may rarely be altogether absent, even in adults. There may not be a total discontinuity between the tendency to imitate in development and in maturity. These are evidently important issues for many social and political purposes, as well as scientific and philosophical.

How can we have it both ways? How can the beneficial functions of imitation be secured without creating a general threat to rationality? Imitation needs to be inhibited and facilitated appropriately in relation to other systems, if the subject/agent is to achieve rationality, at least under a range of normal conditions. There could be motivational or other mechanisms to override or inhibit the imitative tendency, while releasing it in certain circumstances or developmental periods. In addition to a variety of dedicated horizontal layers, we need higher-order structures that connect these layers, facilitating or inhibiting their functions when they are related to one another in certain ways, or under various environmental conditions.

Now the higher-order structures that connect the horizontal imitation system with other horizontal layers can also have beneficial functions, and so

<sup>8</sup> Development and evolution may work together. A weak innate imitative tendency might be strengthened as a result of imitative experience, if connections between sensory and motor neurons that fire together are strengthened. As a result, neural connections would be calibrated on meaningful and functional gestures and behaviors, which would facilitate the emergence of more complex intentions and compound behaviors.

<sup>9</sup> It is interesting to note that the area of the monkey brain in which mirror neurons have been found corresponds to Broca's area in the human brain, one of the areas thought to be responsible for linguistic abilities (di Pellegrino et al. 1992). Mirror neurons have matching sensory and motor fields. See section 2 below.

can also be the objects of evolutionary search. Evolution can search the space of higher-order structural possibilities for sets of relationships between horizontal modules that inhibit and facilitate their operation in appropriate environmental contexts and at appropriate developmental stages, in ways that increase overall fitness. One (oversimple) supposition might be that the beneficial functions of imitation are concentrated in early development. Thereafter, the imitative tendency may be inhibited and overlaid in a wide range of normal circumstances (though not necessarily all). Even so, its underlying influence could still be revealed under nonnormal conditions and by brain damage. Another hypothesis is that it may be evolutionarily advantageous to mimic certain behaviors in certain circumstances in order to obtain the benefits of cooperation without incurring its costs. Cheating via mimicry is one way in which the imitation system might be brought under cognitive control. For example, the imitation system might be switched on to mimic the behavioral appearances or signals used by cooperators to identify one another, in order to receive cooperation, and then switched off by the cheater just before it comes to the point of reciprocation (on "greenbeard" genes and their vulnerability to cheater mutants, see, e.g., Dawkins 1982, pp. 144-45).

Rationality can be conceived as an emergent property of such a complex system, distributed across organisms and their structured environments. Despite the potential conflicts between imitation and rationality, rationality may build on and develop out of the imitative tendency, among others. Rationality may emerge from complex relationships between horizontally modular subpersonal systems which, considered in isolation, generate behavior that is less than rational.<sup>10</sup>

The moral of our consideration of imitation is, we can rethink rationality in horizontally modular terms. More generally, alternative views of perception and action can contribute to our understanding of cognition. This may provide some context and motivation for considering these alternatives. But our main purpose here is not to spell out this contribution. A better sense of our options about perception and action is needed first.

<sup>10</sup> As Hutchins (1995, ch. 5) has emphasized in his work on network simulations of socially distributed cognition, the rationality of the whole cognitive system does not require the rationality of the components of the system. Overall rationality may be an emergent property of the whole system. For example, confirmation bias is a propensity for a cognitive system to affirm prior views and to discount, ignore, or reinterpret evidence that runs counter to an already formed view. But given confirmation bias in individuals, certain structural conditions on communication within the group may enhance the cognitive performance of the overall system so that it does not display confirmation bias as a whole. Confirmation bias in individuals with different starting points and limited intercommunication produces a diversity of views. The trick then is to find a way of airing these diverse views in a way that facilitates finding and settling on the correct resolution.

## 2. Background

A. In later sections we will focus on four "alternative" approaches to perception and action: behaviorist views, ecological views, motor theories of perception, and control systems theory. But before doing so, it will be useful to review some background.

How should the traditional view of perception and action be characterized? Here are some descriptions given by opponents from various "alternative" camps in the course of criticizing it. The mind passively receives sensory input from its environment, structures that input in cognition, and then marshals the products of cognition to action in a peculiar sort of shotgun wedding. Action is a by-product of genuinely mental activity. The motor cortex is the keyboard upon which the sensory mind plays to produce behavior (Weimer 1977). The motor system is the obedient and uninteresting chattel of the sensory system and its clever offshoots in higher mental processes (Turvey 1977). The perceptual system registers and constructs meaning for sensory events, while the action system formulates and executes motor commands. The two systems are not in essential contact with one another, and they provide separate research areas. Indeed, perceptual experiments are often designed to exclude the supposedly distracting and distorting influence of action, which is a subordinate function (MacKay 1987). The task of "passive" or "pure" vision is to construct a detailed representation of the world, and this task is prior to and independent of other tasks such as cognitive and motor processing (Ballard 1991; Churchland, Ramachandran, and Sejnowski 1994).<sup>11</sup>

This tradition has an old-fashioned, sexist view of the marriage of perception and action: they are *separate but unequal* (MacKay 1987). Perception is the primary and dominant function, action is subordinate and derivative. Not surprisingly, given such an orientation, perception has been the focus of study, and action has been relatively neglected (MacKay 1987, ch. 1; Gallistel 1980, p. 360). Theories of perception are rarely constructed with reference to action, and theories of action are scarce on the ground. "Curiously, the few action-based accounts of perception and of mind in general have been advanced on a nonexistent theory of action" (Turvey 1977, pp. 211-12, 259).

It has *almost* become fashionable to reject the tradition of treating perception and action separately. It is not hard to find expressions of the views that: perception and action are interdependent and inseparable (MacKay

<sup>11</sup> Ballard (1990, 1991) contrasts the "passive vision" paradigm with his favored "animate vision" paradigm. This regards perception and action as interdependent in several senses, and employs points familiar from both ecological and motor theories of perception. Ballard stresses the qualitative differences between animate and passive vision, and the computational advantages of the former.

1987; Trevarthen 1978, pp. 108, 115), that movement is part of the perceptual process (Jeannerod 1979, p. 71), that the preparation to respond is the perception (Sperry 1952, p. 301), that awareness is structured by action (Allport 1987), that perception depends upon and leads to action, and that the motor behavior of an exploring animal is essential to perception (Edelman 1989, p. 54; Edelman 1987, pp. 8, 142, 238; Llinas 1987, p. 352). Such views are gaining ground with recent developments in artificial life and dynamic systems approaches to the mind (e.g., Varela 1979; Langton 1995; Thelen and Smith 1994). But they still count as challenges to the mainstream approach.

B. Opposition to the received view has a variety of sources and motivations. One is neurophysiological. The view is increasingly taken that the distinction between sensory and motor neurons is arbitrary, or at least not sharp: "[T]here is nothing intrinsically motor about the motor cortex, or sensory about the sensory cortex" (Edelman and Mountcastle 1978, p. 9). Perception and action share processing units, and supposedly motor components may perform perceptual functions (Turvey 1977; Henn 1979, pp. 70; MacKay 1987, p. 4; Weimer 1977; Mace 1977, p. 61). Perceptual categorization may depend on the linking of sensory and motor maps into a global map (Edelman 1987, 1989). There are various dissociable strands of sensorimotor processing, such as "what" and "where" strands. But within a strand there can be tight and highly specific links between perception and action, whether at the level of single neurons or of cell populations (Allport 1987, p. 412, etc.; Milner and Goodale 1995, pp. 44–46, 58).<sup>12</sup>

The firing of individual neurons may correlate not just with specific types of sensory stimulation, or just with specific types of movement, but rather with the conjunction or the disjunction of these. "Coarse coding" can bridge the sensory-motor or input-output distinction. In some brain areas, cells with sensorimotor fields are much more common than cells with just sensory or just motor fields. Other cells fire in correlation with combinations of specific types of sensory stimulation and of motivational state or readiness to respond in a certain way, though with neither separately (see Requin 1985, pp. 149–50; Requin, Rihle, and Seal 1988, pp. 194–96; Rolls and Williams 1987, p. 41; Allport 1987, 1993).<sup>13</sup> Some cells with sensorimotor fields code for the

<sup>12</sup> The specificity of efference-afference feedback loops in perceptual processing is emphasized by Singer, Wallace, and Collins 1979, p. 80. See also essay 5, sec. 4.B, C, on the unwinding of "what" strands from "where" strands, and the comparison of the interface and the twisted rope metaphors.

<sup>13</sup> Related points are made in work on the basal ganglia and Parkinson's disease. It is possible that deficits in the ability to move voluntarily are due to deficits in sensory control. Since there are no sensory-motor boundaries in the brain, responses to sensory signals may depend on motor context and vice versa. The capacities for cognition and movement may be intertwined and share a neural substrate (Schneider 1987; Lidsky 1987).

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distal goals of action rather than proximal events. For example, use of the same muscles for a different purpose would not correlate with activation of such goal-related sensorimotor neurons (Rizzolati et al. 1988, pp. 501, 503, 506, etc.).

A particularly interesting type of sensorimotor neuron, which may be relevant to the explanation of imitation, has been discovered in monkeys (di Pellegrino et al. 1992; Jeannerod 1997). Mirror neurons have matching perceptual and motor fields: they fire when the agent perceives someone acting in a certain way or when she does the same thing herself (or both). For example, certain cells fire when the monkey sees the experimenter bring food to the mouth with his hand or when the monkey does just the same (but *not* when either one transports food to the mouth by fork, or something else to the mouth by hand).

Blending of sensory and motor features is also found at the level of neuron populations. In the olfactory bulb, patterns of EEG wave amplitudes across cell populations form maps, resembling contour diagrams of mountains and valleys. These maps correlate not simply with which odor is presented, but also with reinforcement context. "As long as we do not alter the animals' training, the same map emerges every time an animal sniffs a particular odorant," such as sawdust. But the "amplitude map representing a given odorant changes strikingly when we alter the reinforcement associated with that scent." Amplitude maps seem not to register what is perceived separately from its motivational significance. These global patterns of neural activity "are at all times locked into both sensory and motor patterns of input and output." These findings are interpreted to cut against computational accounts of olfaction as requiring decompositional structure and context-independent symbols (Skarda and Freeman 1987, pp. 172-73, 184, etc.; Freeman 1991, pp. 36-37, 41, etc.).

In sum, neurophysiological evidence at both the single-cell and cell population levels suggest shared coding for perception and action: that the contents of both perceptions and intentions can depend on neural processes that blend sensory and motor features.

C. Another, related source of resistance to the received view is the increasing importance attributed to various dynamic feedback processes. Feedback for present purposes is not to be narrowly understood in terms of simple negative feedback control circuits, but rather more broadly, in terms of circular causal flow that includes flow from outputs back to inputs, even when these backflows are multidimensional and unsynchronized, as in complex self-organizing systems (see section 6 below, and especially note 35). The presence of multiple levels of neural transformation between input and output "with feedback pathways at all levels" contributes to the difficulty of segregating

sensory and motor roles. Categorization is seen to arise from the "reentrant" mapping of motor activity along with sensory information from many modalities; motor and sensory signals may be completely coupled and may act together to form the global maps that are the basis of development (Thelen and Smith 1994, pp. 160, 247; Jackendoff 1987, pp. 110, 263; see also and cf. Henn 1979, p. 70; Allport 1993; Edelman on "reentry" 1987, 1989; Gray 1995; Jeannerod 1979, p. 71; Sperry 1952, p. 301). "[S]chemes in which sensory input is routed through a central network into motor responses" are seen as failures in part because "modulating the optic array through movement and modulating movement through changes in the optic array go hand in hand; thus the cybernetical loop of afference, efference, reafference is virtually continuous" (Turvey 1977, p. 248; see also Allport 1980, pp. 26, 33, 39, 53, etc.).

Feedback loops may be internal, such as copies of efferent signals, or may be external, such as patterns of afference that are a function of movement through the environment. Ecological theories of perception emphasize the latter, while motor theories of perception and control theories of action appeal to both. When we look at these views in more detail below, we'll see that the relationships between feedback loops with different orbits are an important source of information about the environment and the self.

D. The idea that coding for perception and for action may share processing units is, as we've seen, one source of resistance to the received view. There is some evidence that such shared coding might involve dynamic relations between afferent and efferent signals within large populations of neurons, as well as individual neurons with sensorimotor fields. But in addition to neurophysiological evidence for shared coding, there are arguments of a theoretical, functional and/or behavioral character for shared coding from horizontally modular phenomena.

Consider again the tendency to imitate. We have seen above that normal subjects tend to copy what they see done rather than to follow verbal commands inconsistent with the perceived example, even when they are trying to obey the commands rather than to copy the example. And it is arguable that a general tendency to imitate would convey evolutionary advantages. What kind of processing would facilitate imitation?

A related question is, What kind of processing would explain the advantage in reaction times of matching tasks over mapping tasks? In general, tasks that require the matching of behavioral response to perceptual cue have a significant reaction time advantage over tasks that require an arbitrary mapping from cue to response. For example, in what is known as the Simon effect, reaction times are shorter when there is correspondence between the left-right position of the stimulus and of the response than when there is not. This



remains true when the hands are crossed, which differentiates between central and distal accounts of the correspondence effect in favor of a distal account. Moreover, when the location of the required response is separated from location of the intended effect of responding (for example, push a right-side lever in order to get a left-side light to come on), it is the intended effect's location, not the action's location, that corresponds with the stimulus. Reaction times are shorter when the perceived stimulus and the intended effect share the same side, even if the subject must act on other side in order to achieve the intended effect.

Prinz (1990, 1992) appeals to the tendency to imitate and to the reaction time advantage of matching over mapping tasks to argue for the common spatial coding of perception and action.<sup>14</sup> On the face of it, imitation involves an immensely complex mapping. On the received view of perception and action as separate, translation would be needed between unrelated afferent and efferent codes. By contrast, if perception and action share neural codes, the contents of certain experiences and certain intentions could be inherently related. The problem of translation would be reduced or eliminated. Since the relations between neural signals that reflect sensory and motor events at the bodily periphery are arbitrary, we should expect common coding for perception and action to be distal rather than proximal. That is, we should expect common codes for perception and action to code for distal events in the space where action and perception meet, such as events of hands grasping objects, rather than for proximal events, such as patterns of activation of sensory receptors or of muscle neurons.

Such imitation and matching phenomena are suggestive of shared coding. But alone they do not demonstrate it, since the greater neural efficiency shown in imitation and matching tasks might have a different neurophysiological explanation. But when these arguments are combined with neurophysiological evidence for shared coding, such as the discovery of mirror neurons, the case begins to build.

Shared coding for the contents of perceptions and actions could take stronger or weaker forms. A strong claim of shared coding would be that certain corresponding contents of perceptions and of intentions are the same, or virtually the same, function of the same subpersonal processes. A weaker claim would be that they are both functions, if different functions, of the same subpersonal system of sensory-motor, or input-output, relations. This weaker claim would make for context-dependence that cuts across the distinction

<sup>14</sup> See also Brewer 1993. The motor theory of speech perception provides an example of a common coding view. According to this view, speech perception is mediated by motor codes that are involved in speech production. See Allport 1984 for a review of the evidence. Consider also the role of imitation in language acquisition.

between sensory and motor events. That is, the contribution of sensory events to perceptual content could depend noninstrumentally on motor context, and the contribution of motor events to the contents of basic intentions could depend noninstrumentally on sensory context. For example, perceptual content might vary with motor factors, even when sensory input is unchanged, because perceptual content is determined by the *relations* between sensory and motor, or afferent and efferent, events.<sup>15</sup> Distributed coding for perception and for action might be superposed on the same population of neurons in ways that facilitate imitation and matching but under normal conditions do not significantly constrain or interfere with one another. However, non-normal conditions (such as the wearing of left-right-reversing or other distorting goggles) may reveal the extent to which the spatial contents of perceptions and actions are invisibly interdependent in normal conditions (see essay 9).

Does the neurophysiological and behavioral evidence support a strong claim of shared coding, or could it be accommodated by a weaker claim? Mirror neurons might underwrite a strong form of shared coding, but we can also envisage how weaker forms might work and give rise to phenomena such as imitation. Superpositional context-dependent coding in neural networks can give risk to "cross talk" or interference between the codes composed on the same network (Clark 1990b, pp. 100, 113, 122, etc.; see also essay 1, sec. 5.D, above). Cross talk is usually discussed in the context of a network performing various pattern completion tasks, but the generic logic of the idea can be generalized to relations between the contents of perception and of action. Moreover, while cross talk may account for certain familiar errors, it could also have benefits. Might imitation be a perception-action cross talk phenomenon with an evolutionary function? If so, we might be able to account for the tendency to imitate without going all the way to strong shared coding. Both strong and weak forms of shared coding may have a role to play.

<sup>15</sup> Cf. MacKay 1987. MacKay opposes the assumption of separate coding for perception and action. But he puts motor or efference copy theories of perception, as well as control systems theories of action, into the separate coding category. He sees these theories as postulating separate coding components that are brought into relation with one another, as perceptual mechanisms come to the aid of action mechanisms and vice versa, rather than shared or common coding mechanisms. See p. 167. By contrast, these theories and the complex dynamic feedback systems they involve are here used to illustrate a way of departing from the separate coding assumption.

Why this disagreement? MacKay has not registered the distinction between instrumental and noninstrumental dependence that has been belabored in earlier essays in this book (especially essay 9). If you conceive of the relations in question as necessarily instrumental, then MacKay's view may be correct. But such a conception does not account for cases such as those discussed in essay 9. The contents of perceptions and of actions can depend noninstrumentally on complex dynamic feedback systems.

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Would shared coding for perception and action threaten the widely accepted principle of the holism of the mental? This says that action is made sense of holistically at the personal level, as the rationalized product of combinations of beliefs and desires, or perceptions and motivations. What action a given perception leads to depends on motivations, which are optional. By itself, the perception does not lead to any particular action, while in combination with different motivations, it could lead to many different actions. But the contents of the perceptions and intentions that share coding will be very closely related. This is why the tendency to imitate could be a symptom of shared coding. However, the threat of shared coding to holism does not materialize when we recall the points made earlier about how a horizontally modular view can accommodate rationality (section 1.C, D). Shared coding within each horizontal module must be seen in the context of higher-order relations between modules.

E. We've seen that perception and action are traditionally viewed as separate phenomena. And we've considered various neurophysiological and behavioral grounds for resisting the assumption that perception and action are separately coded. But let's now probe a bit deeper into the presuppositions of the traditional view and how these structure the alternatives.

There are two presuppositions that make the traditional view natural. The first is that the relevant causal flows are primarily one-way or *linear*: in from the world through sensory systems to perception to cognition to motor systems to action and finally out to the world again. The second is that the relations between perception and action can be adequately understood as *instrumental*: perception is a means to action and action is a means to perception; they are merely mutually expedient. Either or both of these presuppositions can be rejected.

For example, behaviorism rejects the instrumental view, but not the linear view. It sees action as constitutively rather than merely instrumentally related to perception. But it casts action as output, and gives no essential role to feedback or to the dynamically circular structure of causal flows. This combination leaves behaviorism open to the objection that it is verificationist: that it collapses the distinction between perceptual experience and its effects in action. These effects may be evidence for experience but do not constitute it. On the other hand, ecological or Gibsonian theories of perception reject the linear view, but not the instrumental view. Gibson saw perception in dynamic terms and emphasized the importance of sensory feedback from movement. Action is just as much a cause as an effect of normal perception; the circle of causes and effects is continuous. But nevertheless Gibson saw feedback as instrumental, since he insisted that passive movement would do as well as active in providing a means to higher-order patterns of input.

	LINEARITY	DYNAMIC LOOPINESS
Relations between perception and action:		
MERELY INSTRUMENTAL	"Separate-but-unequal" tradition	Ecological views
ALSO CONSTITUTIVE	Behaviorism	Motor theories, control systems theories, dynamic systems approach, Two-Level Interdependence View

FIGURE 10.2. Relations between perception and action: linear/loopy versus instrumental/constitutive

Perception and action are interdependent, on his view, but only instrumentally interdependent, in the sense used here (see figure 10.2).

In the following sections we'll consider behaviorist and ecological alternatives in more detail. It turns out to be unsatisfactory to reject one but not the other of these presuppositions. We'll then consider the advantages of rejecting both presuppositions: of giving dynamic feedback an essential role while allowing that perception and action can be constitutively as well as instrumentally interdependent.

### 3. Behaviorism

A. Behaviorism and related views take as their point of departure a framework in which action is seen as an effect of perception. Feedback from output to input is ignored or considered to be a mere complication, not of the essence (see Nelson 1969, p. 446). There are primitive stimulus-response versions of this framework. There are also more sophisticated versions, such as versions of functionalism, which interpose cognition between stimulus and response and recognize the holistic character of patterns that obtain among stimuli, various combinations of propositional attitudes, and responses. But the primitive and more sophisticated versions of the framework have in common a linear or one-way view of the primary causal flows. The patterns and causal roles that functionalism standardly recognizes are not essentially dynamic.<sup>16</sup>

<sup>16</sup> Although the Ramsey-sentence technique used by functionalism *could* be explicitly applied to dynamic patterns. Such "dynamic functionalism" would not share the linearity of behaviorism, but it would admit of variable realization. For one way of distinguishing classical

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From a point of departure with this linear and one-way character, behaviorist views make a constitutivizing move. They move from seeing perceptions and actions as separate, causally and instrumentally related events, to seeing action as constitutive of perception. Given the point of departure, this move seems to collapse perceptual experience into its effects, to reduce perceptual experience to what is merely the evidence for it in behavior. So the objection arises that behaviorism is a form of verificationism.

But the charge of verificationism here presupposes the prior one-way framework, the point of departure that sees actions as effects, output. To test that claim, compare a constitutivizing move made within a different framework. Suppose our point of departure sees the causal flows as essentially circular, regards actions to be as much causes as effects of perceptions, and sees both as emerging from a complex dynamic feedback system. Suppose we now consider the possibility that perceptions and actions are not necessarily separate, causally related events, but that action can be constitutively related to perception.

For example, in a Two-Level Interdependence View, perception and action can be seen as constitutively interdependent or co-constituted because both depend noninstrumentally on relations between input and output within a complex dynamic feedback system (see various other essays, especially essay 9). "Complex" feedback is not restricted to the external and instrumental role it plays in Gibson's view (1986). Internal and external feedback loops play complementary and interactive roles; comparisons between them carry information about self and world. Action is not merely a means to patterns of input, on which perceptual content depends. Rather, perceptual content may in general depend noninstrumentally on dynamic relations between input and output. If similar claims hold for the contents of basic intentions, then the personal-level contents of both perceptions and basic intentions are noninstrumental functions, even if different functions, of the relations between subpersonal-level input and output. This is a weak form of shared coding.

As a result, it is possible for changes in the relationship between input and output to make for changes in both perceptual and intentional content, in a kind of dual bootstrapping. A change in the content of basic intentions may be a function of a change in the relations between input and output that constitutively—not merely instrumentally—also makes for a change in the content of perceptions. In this sense the contents of perceptions and of intentions may be noninstrumentally or constitutively interdependent. Constitutive interdependence in this sense needs to be distinguished from the constitutive role in perception that behaviorism gives action, as well as from

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the merely instrumental interdependence of perception and action recognized by Gibson.<sup>17</sup>

In this context, the constitutivizing move no longer has a verificationist character. It is not the constitutivizing move in itself that leaves behaviorism open to the charge of verificationism. It is rather making this move against the background of the linear, one-way framework. If we fail to recognize that behaviorism is not the only way to give action a constitutive relationship to perception, our sense of the range of philosophical options will be distorted.

B. Another common objection to behaviorism is that it cannot accommodate the holism of the mental. To understand how this objection arises we can again consider behaviorism's point of departure.

The traditional view of perception and action is often expressed in terms of the Input-Output Picture (which discussed in various other essays, especially essay 9, and is intimately related to vertical modularity; see section 1 above). Perception is seen as input from world to mind and action as output from mind to world. Given the two presuppositions we have identified, of a linear, one-way causal structure and of merely instrumental relations between perception and action, this projection of the input-output distinction and the perception-action distinction onto one another seems inevitable.

Against this background, various views are taken about exactly what relationship holds between causes and perceptions and between actions and effects, respectively. Issues about internal/external boundaries arise. Where do we cut the chain of causes leading to perceptual experience to find what determines their contents? Where do we cut the chain of effects leading from tryings to find what determines their contents? In the head or in the environment (see essay 7)? What is perceived directly and what merely inferred? What is done directly and what merely done by doing something else?

These debates about internal/external boundaries put at issue materialist descendants of a Cartesian mind/world cut.<sup>18</sup> But they often leave unchallenged the descendants of a Humean cut, between input-side and output-side contents. On such views, the contents of perceptions and beliefs are independent of the contents of desires and intentions. The former are responsible

<sup>17</sup> It may not always be obvious whether a theory should count as behaviorist or as a motor theory. James Taylor's view is a case in point. He has been interpreted as proposing that "the conscious experience of visual perception is nothing more or less than . . . learned [motor] responses" (Festinger et al. 1967, p. 6). But the implications of his theory, as applied, for example, to motor-dependent perceptual adaptation, go well beyond behaviorism in the direction of a motor theory, even if he does not make this as explicit as some other theorists do. See Taylor 1962, chs. 8 and 9, *passim*, and also pp. 42, 130–31, 247, 347.

<sup>18</sup> Precedent for using the term "Cartesian" to describe materialist views is found in Dennett 1991a.

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to causes, the latter to effects. They aspire to different directions of fit with the world. Perception and belief do not by themselves constrain desires or action. In principle, I might prefer the destruction of the world to the scratching of my little finger.

The Humean cut straightforwardly accommodates the holism of the mental. If perceptions and intentions, beliefs and desires, are independent, then given perceptions or beliefs do not by themselves lead to or explain any particular behavioral effects. They do so only in rational or rationalizing conjunction with certain desires or intentions.

We can see this background as a point of departure for behaviorism and related views. These dare to realign perceptual experience with effects instead of causes. This flies in the face of the Humean cut. In doing so it appears to undermine the holism of the mental. That is, behaviorism tries to take a short cut through the rational interaction of perception and intention, belief and desire. But this attempt fails to respect a rational agent's degrees of freedom. The "wrong" purpose can always interpose itself between given perceptions and behavior, creating an obstacle to any smooth behaviorist transition from content of perception to type of behavior.<sup>19</sup>

So it is natural to react against the behaviorist threat to the holism principle by reaffirming the Humean cut and something like the Input-Output Picture. But this is another place where our sense of the philosophical options needs expanding. Behaviorism is not the only alternative to the traditional view of perception and action. Even if the Humean cut provides one way of underwriting holism, respect for holism does not require it.

To see this, consider again a Two-Level Interdependence View of perception and action. This is broadly compatible with holism. The constitutive interdependence of perception and action, on this view, reflects their superposition: their codependence on the same complex systems of input-output relations and feedback. This does not entail that certain perceptual experiences necessitate certain intentions. The contents of perceptions and of intentions may be different functions of a given system of subpersonal relations within a horizontal layer, and in any case may reflect the higher-order relations between different horizontal layers. Holism can be respected in general even if there is cross talk between the contents of perceptions and intentions, for example in the "where" or spatial system, or in the tendency to imitate.

<sup>19</sup> Here is one expression of the familiar objection that behaviorism fails to respect the holism of the mental: "It is a behaviourist myth long exploded that, for normal adult humans, distinctive types of resultant behaviour are associated with particular perceptual inputs *tout court*. . . . [P]urposes are optional, and I cannot see that there are any types of behaviour which are apt in any given environment without relativity to a purpose" (Fricker 1991). The objection is made to McGinn's endorsement of the realignment of perceptual contents with effects (1989, pp. 65-66, etc.).



The spatial interdependence of perception and action is revealed, for example, in the long-term effects of left-right-reversing goggles (essay 9). This kind of interdependence casts light on what enables a creature to have a perspective. But it is no threat to holism or to a rational agent's degrees of freedom.

Behaviorism retains the one-sidedness of the traditional view of perception, but shifts from one side to the other: from input to output. Both views assume that perception should be conceived in a one-sided way, rather than as depending on relations between input and output. This assumption is rejected by a Two-Level Interdependence View.

C. So far the rejection of the one-sidedness assumption has been illustrated by reference to a Two-Level Interdependence View. But it can also be illustrated by reference to familiar ideas about teleology.

Appeals to teleological and evolutionary considerations are made, whether explicitly or tacitly, by a variety of views about mental contents. Some of these views endorse a one-sided account of how perceptual content is determined. For example, Dretske (1981) conceives his account as an input-side view, while McGinn (1989) endorses output-side views.

But there is a problem with combining either kind of one-sidedness with appeals to teleological considerations in accounts of how perceptual content is determined. Evolutionary teleology inherently involves relations between input from environment to organism and output from organism to environment, a dynamic system of causes and effects. This is either explicitly or tacitly recognized by other views that appeal to teleology or adaptation in accounts of content (Millikan 1984; Burge 1986a). We should be wary of misinterpreting such views as one-sided (see essay 7, sec. 6).

Moreover, an explicit endorsement of one-sidedness may be at odds with the teleological elements of an account of content. The point can be illustrated both for supposedly input-side accounts and for supposedly output-side accounts.

For example, Dretske contrasts his account of content in terms of causes and informational origin with output-oriented or consequentialist accounts:

Internal states derive their content (in the first instance, at least) from their informational origin, not from their effects, although (from an evolutionary standpoint) it is hard to see why or how structures of this kind could develop unless they had some beneficial (and therefore appropriate) effect on behavior. (1981, p. 209)<sup>20</sup>

<sup>20</sup> Dretske's input-side account of content is in terms of the higher-order intentionality of the outermost informational shell, that unique piece of information carried by a structure in digital or conceptual as opposed to analog or sensory form. For example, if the most specific infor-

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*That a system believes something depends, partially, on the effects (on system output) of these internal states, since to qualify for cognitive content an internal structure must have executive responsibilities. But the content is determined solely by the structure's origin. (1981, pp. 201-2)*

He supposes that over a period a certain type of internal state evolves, in response to the array of information-bearing signals, which is selectively sensitive to certain information. This type of structure acquires its content from the sort of information that leads to its development. But once developed, it acquires a life of its own. The type can confer its content on subsequent tokens of the type, even if particular tokens do not have this informational origin: "The meaning of a structure derives from the information origins of that structure, but a structure type can have its origins in information . . . without *every* (indeed, without any) subsequent tokens of that type having this information as its origin" (p. 193). So there can be a mismatch between content and informational origin for token states or structures. But the informational origin of a type of structure still fixes its content. And the information origin of a type of structure is determined through evolution and hence by the effects of that structure. The appeal to evolutionary teleology essentially involves effects as much as causes.

According to the output-side views Dretske opposes, internal states derive what meaning they have from their effects on behavior: "[R]oughly speaking, if the dog eats it, he must *think* it is food" (1981, p. 203). Dretske offers a counterexample. Salamanders whose right and left forelimbs are surgically interchanged, so that each limb faces backwards, will as a result execute forelimb movements that push the animal away from food and toward noxious stimuli. Such behavior tells us nothing about the creature's beliefs, because their content is a function not of the appropriateness of the behavior they give rise to but the kind of incoming information to which they are sensitive (1981, pp. 207-8).<sup>21</sup>

mation a signal carries is that *t* is a square, then it carries that information in digital form, but it also carries the less specific information that *t* is a rectangle, a parallelogram, a quadrilateral in analog form. Only the former information, the most specific or outermost informational shell, has, in virtue of its digital or conceptual character, the properties of higher-order intentionality, or opacity in intentional contexts. Dretske uses this idea to respond to the objection that the notion of information doesn't cut down the number of stopping places on the way "in" sufficiently to determine content (1981, ch. 7, esp. pp. 177-78).

<sup>21</sup> He also objects to output-side views that "until the internal states that produce that behavior already have a meaning *independent* of the behavior they produce, the behavior can be deemed neither appropriate nor inappropriate" (1981, p. 205). Beliefs only make particular behavior appropriate in conjunction with other mental states. Some beliefs do indeed suggest how the believer will behave, by reference to assumptions about normal needs and purposes, but these suggestions are defeasible (1981, p. 206). This is essentially the holism objection to behaviorism, discussed in the previous section.

But this conclusion is overdrawn. Just as there can be mismatches between informational origin and content in particular cases, there can be mismatches between behavioral effects and content in particular cases. We can draw a general distinction between *type-explanatory* processes, which explain why a type of thing exists at all, and *token-explanatory* processes, which explain a particular occurrence of that type (see also essay 8, sec. 9; Hurley 1998). Dretske fails to give the output-side view the benefit of this distinction, even though he in effect allows it to his own input-side view. The supposedly rival view about content can similarly appeal to the effects of structures of a certain type that explain its presence, rather than to the effects of tokens of that type in particular cases (compare the parasitism strategy, discussed in essay 7).

The distinction between type-explanatory and token-explanatory processes undercuts the contrast between supposedly rival accounts of perceptual content as input-side or output-side. On each side we find tacit appeal to the opposition's resources. If both appeal to evolutionary teleology, then both should allow that the causes<sup>22</sup> and the effects of a type of structure contribute to determining its content. And both should allow that there can be mismatches between the content and either the causes or the effects of token structures.

McGinn (1989) also sets up a supposed rivalry between input-side and output-side accounts of content. Do environmental causes individuate content, or do behavioral effects? Unlike Dretske, he favors the latter view: "[W]hen it comes to a competition between action and environment, in the fixation of perceptual content, action wins" (1989, pp. 65–66).<sup>23</sup> He understands "externalist" views such as Burge's as input-side views, and teleological views as output-side views.

But again this contrast is suspect. Burge's account of content in terms of normal causes tacitly makes content depend on output as well as input, since

<sup>22</sup> Or informational origin. Dretske allows for an understanding of causal relations broad enough to include informational relations, in 1981, ch. 1.

<sup>23</sup> He describes a Twin Earth case in which round things produce squarish proximal input: "In making experience necessarily fit the world, while allowing behaviour to be environmentally inappropriate, strong externalism introduces a fracture at the joint between experience and behaviour. It becomes quite incomprehensible why a perceiving agent should ever function in the way suggested—moving squarewise when it seems to him that there is a round thing there. . . . A quick way to appreciate the bizarreness of what the strong externalist is claiming is to consider Percy's [McGinn's Twin Earthling] action-directed propositional attitudes—his intentions and tryings. These too will be said to have their content fixed by the actual environment, so the strong externalist has Percy intending to negotiate a round object and trying to move in a suitably curvilinear path; these volitional attitudes have *round* as part of their content. But Percy puts these into effect by moving squarewise! . . . Surely it is far more plausible to suppose that he acts as his experience indicates, thus aligning perceptual content with his behaviour, not his environment" (McGinn 1989, pp. 65–66).

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normality involves adaptation resulting from natural selection operating on the ways in which creatures interact with their environment (Burge 1986a, p. 131; and see essay 7). Conversely, teleological accounts that invoke evolutionary adaptation make content depend on causes as well as effects. Phenotypes are identified not merely as any old effects, but as those effects that in turn have differential effects on their genotypic causes. What a genotype is for is something that is determined by a dynamic, circular process. Though tokens of genotypes and phenotypes interact causally, genotype and phenotype are constitutively interdependent (see and cf. Millikan 1984, pp. 90-91, 94, 111, 139, 335).

Of course there are different ways of appealing to teleology in accounts of content. The point is not that all differences are dissolved. It is simply that we should be wary of classifying accounts of content that appeal to teleology, whether explicitly or implicitly, in one-sided terms. It is misleading to see rivalries between such accounts in terms of input versus output. Evolutionary teleology involves dynamic feedback processes and hence relations between input and output.

D. Talk of interdependence is one point of contact between modern philosophy and some of Hegel's views, for example, on the interdependence of subject and object. This may endow such talk with a whiff of mysticism. But a nonnegligible amount of contemporary philosophy seems to consist of the rediscovery of broadly Hegelian positions, even if they are not recognized as such. This is not sheer reinvention of the wheel. We can demystify by providing some of the missing arguments, and examples.

A digression to elaborate on the relations between genotype and phenotype may help to demystify talk of constitutive interdependence. It may also help to understand how in general relations of constitutive interdependence can emerge from a causal structure that is essentially circular and dynamic, rather than linear and one-way. The point is to illustrate constitutive interdependence, not to endorse a particular account of genotype and phenotype.

Genotype and phenotype are interdependently individuated. This genotype would not be the genotype it is, nor would that phenotype be the phenotype it is, unless this were the genotype for that phenotype. Nevertheless, tokens of genotype and phenotype stand in causal relations to one another, and their interdependent identities reflect this.

The effects of tokens of a given genotype vary with its context, including other genes as well as the rest of its natural environment. But even holding context constant, tokens of a given genotype have various effects. Some are proximal effects on the physiology or behavior of the carrying animals. Some are distal effects on the behavior of other animals, on artifacts (such as beaver dams), and even on the natural environment (such as resulting lakes).

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Which type of effect is identified as the phenotype corresponding to a given genotype, the phenotype that the genotype is *for*? Genes are favored relative to their alleles by some of their effects and not others. Incidental effects don't alter the gene's survival chances. The phenotypic effects are those that have in turn differential beneficial or harmful effects on the survival of the genotype whose instances caused them, relative to the competitive alleles of that genotype. (The preceding follows Dawkins 1982.)

According to Dawkins, it is not essential for phenotypic effects to be wrapped up in discrete organisms (1982, p. 115).<sup>24</sup> The extended phenotype can be manipulated, not necessarily cooperatively, by genes in unrelated individuals, acting at a distance. The beaver dam might reflect the interaction of the dam-building genes of the various beavers working on it. And one animal's genes can be "for" the behavior of another, manipulated animal. They can fake another animal's hormones, or control its growth. The influences of genes in different bodies can conflict or cooperate. Environmental and behavioral effects can be tugged in different directions by the various genes whose survival they differentially effect. The phenotype is a point of convergence between many different genetic influences.

But now turn the question around and consider the way genotypes are in turn individuated by reference to phenotypes. Genes are fragments of genetic information that serve as units of selection. But they don't necessarily have rigid boundaries. Many genes fall between sequences of nucleotides that operate as genetic punctuation marks. But not all. Some genes overlap, or contain other genes: the reading frames of these different genes are simply shifted relative to one another along the same stretch of DNA (Dawkins 1982, p. 86; Hofstadter 1985, pp. 524-25). The fact that such overlap of genetic information is the exception rather than the rule does not undermine the point that genotypes are identified by reference to phenotypes. The point applies to the identification of punctuation marks as such.

Which stretches of DNA, how long or short, should be counted as tokens of one genotype? If we choose too short a portion, a single nucleotide, then it cannot "be said to have a phenotypic effect except in the context of the other nucleotides that surround it." Though changes at the level of a single nucleotide can be responsible for evolutionarily significant changes in phenotype, the unvarying remainder of the genome is necessary to produce a phenotype at all. "While it is undoubtedly meaningful to speak of a single nucleotide as

<sup>24</sup> Indeed, that genes are organized into discrete organisms at all is something that needs explaining in terms of genetic selection. Dawkins explains the organism as a unit initiated by a new act of reproduction via a single-celled developmental bottleneck, which permits a return to the drawing board every generation (1982, ch. 4). "Replicators that gang up in multicellular organisms achieve a regularly recycling life history, and complex adaptations to aid their preservation, as they progress through evolutionary time" (p. 259).

exerting power in this sense, it is much more useful, since the nucleotide only exerts a given type of power when embedded in a larger unit, to treat the larger unit as exerting power and hence altering the frequency of its copies" (Dawkins 1982, pp. 90–91).

On the other hand, if we choose too long a stretch, its existence is threatened by crossing over in each generation. It is unlikely to survive. We must choose a portion of a length such that its effects have in turn significant differential effects on its own survival relative to that of its alleles, its competitors to occupy the same stretch. A gene is a stretch of genetic material that, via its phenotypic effects, differentially benefits its own survival relative to that of its competitors (Dawkins 1982, ch. 5).

So, on this account, a genotype survives because of its phenotypic effects, and its phenotypic effects are present because they help the genotype for them to survive. This is the familiar adaptive feedback cycle of effects in turn having effects on the survival of their causes. Though a gene's effects depend on, among other things, its intrinsic properties, such as the order of nucleotides, the latter do not identify it as the genotype *for* a particular phenotypic expression. What a gene is for is determined by its relations rather than intrinsically, and by type-explanatory processes rather than merely token-explanatory processes. Both the gene's phenotypic effects and the feedback effects of the phenotype on the survival of the genotype are context-dependent. The phenotype a given genotype is *for* are those of the genotype's effects that differentially benefit their genotypic causes, in a given context. The genotype *for* a given phenotype includes those of its genetic causes whose differentially beneficial phenotypic effects are targeted effectively back on themselves. Of course, maladaptation is still possible.

What can we learn about content from this account of the relation of "forness" between genotype and phenotype? If we are attracted to theories of content that appeal to teleology, the points made apply directly. Input-output dichotomies applied to such theories are spurious. We should look neither to causes nor effects separately. Teleological systems are systems of dynamic relations between causes and effects, including feedback.

But even apart from teleological accounts of content, some general lessons hold. The constitutive interdependence of genotype and phenotype is not merely compatible with but emerges from a dynamic feedback system of natural causal relations among environments, organisms, and genetic material. So in principle there need be nothing mystical about constitutive interdependence. It may hold between perception and action because the contents of perceptions and of intentions depend on relations between input and output within a complex dynamic feedback system, whether or not a specifically teleological system. We should be wary of input-output dichotomies applied to theories of content in general.

#### 4. *Ecological Theories of Perception and Action*

A. Recall the two presuppositions of the traditional view. Relations between perception and action are linear or one-way, and are instrumental. We have considered how behaviorism rejects the instrumental view, but not the linear view. Let's now consider ecological theories, which reject the linear view but not the instrumental view.

The locus classicus of the ecological theory is Gibson's 1986 book, *The Ecological Approach to Visual Perception*. We'll review some salient features and criticisms of the ecological view, focusing on the role it gives to action.

Gibson rejects a stimulus-response view of the relationships between perception and action. In his view, the whole moving body is the complete natural visual system; ambulatory vision is the norm. A frozen field of view provides only impoverished information, and normal vision is not compounded of snapshot-like units but is essentially dynamic. Perception is not the stimulation of receptors or the processing of sensory inputs by the mind. Rather, it is the act of information pickup, the extracting of invariants from the flowing array of ambient light via movement.

Gibson is hostile to information-processing approaches to visual perception in general and in particular to the idea that coded signals are transmitted along the optic nerve in the activity of perception. He regards this idea as unnecessary and as carrying the homuncular implication that signals need to be decoded and interpreted for the mind to receive them. "The information for perception is not transmitted, does not consist of signals, and does not entail a sender and receiver" (Gibson 1986, pp. 61, 63). The brain is a part of the visual perception system, along with the eye and its movements and the moving body. The whole moving system *directly* registers or picks up or "resonates to" invariants in the structure of ambient light, and the process is circular, not one-way.

Among other things, the system picks up higher-order invariants that specify opportunities that the environment affords for action. Reality understood in ecological terms, as opposed to physical terms, is made up of meaningful things. In perceiving our environment and its affordances for action, we discover meanings rather than impose them. The subjective-objective duality is blurred in several ways. The boundary between animal and environment is not fixed, but can be extended, by attaching something to the body. And paths of locomotion are possible moving points of observation, which can be occupied by different animals in the same environment. So movement knits animals together into a shared world.

Action is critical in Gibson's view of perception because it makes it possible to pick up higher-order invariants from the flow of the optic array. Movement extracts information from ambient light, while the flow of

ambient light also provides information about movement. The pick-up of information about the self and about the environment go hand in hand. While invariants picked up through movement specify unchanging features of the world, variant information specifies the self or change in the world.

Some commentators have expressed the role of action in Gibson's theory in very strong terms. For example, Neisser writes that "the distinction between perception and action can be made only at the level of theoretical analysis; in ordinary behaviour they are inseparably fused. Except in special cases, we do not first perceive and only then proceed to move. We perceive *as* we act and *that* we act; often our own actions constitute the very characteristics of the ecological self that we are simultaneously perceiving" (1988, p. 40).<sup>25</sup> Ecological theorists of action emphasize the interdependence of invariants in perception and in action. Action enables the pick-up of invariant information in varied circumstances, yielding perceptual constancy, while perception guides an invariant intention through varied circumstances, yielding action constancy. The whole loop through action, perception, action and resulting perception is critical for both perception and action. Action is as much cause as effect, as much exploration and discovery as response (see Turvey 1977; Mace 1977, p. 49; Turvey, Carello, and Kim 1990).

But for all the emphasis given to the interdependence of perception and action by the ecological view, their interdependence is seen as instrumental in the sense used here (see essay 9 on instrumental dependence). Gibson emphasized that the role of movement in ecological theories could be performed as well by passive as by active movement. Movement is merely a means for gaining access to higher-order invariants present in afferent stimulation. While patterns of input depend instrumentally on movement, perception depends noninstrumentally on patterns of input rather than on relations between input and output.<sup>26</sup> Gibson added dynamic sophistication to the instrumen-

<sup>25</sup> See also Scheerer (1984), who thinks Gibson's view about the dependence of perception of higher-order invariants on movement can be seen as a radical motor theory of perception. But this overlooks the contrasts drawn here between ecological and motor theories on whether feedback is internal or external, instrumental or noninstrumental. By contrast, Welch (1979) does in effect recognize the relevance of the instrumental/noninstrumental distinction to Gibson's account: "[I]t is important to distinguish between motor activity as a necessary *pre-condition* for subsequent visual change and motor activity as a necessary concomitant of a unique visual experience. Presumably only the latter . . . would represent a blow to Gibson's theory" (p. 85). Welch also points out that not just efference copy but also proprioceptive, vestibular, or other nonvisual inputs serving to maintain visual stability during bodily movement would represent negative evidence for some of Gibson's claims.

<sup>26</sup> For a good summary of aspects of what is here called "instrumental" interdependence, see Turvey, Carello, and Kim 1990. An essentially instrumental role is suggested for movement by Engel, König, and Singer 1991: the coherent movement of certain stimuli, which may be produced by subject movement as well as by object movement, may contribute to a solution to the binding problem and hence to object perception. The latter is of course not an ecological theory.



tal view of action in perception, but nevertheless he resisted a view of its role as more than instrumental.

B. The ecological research program has yielded notable and widely acknowledged successes (Lee and Young 1986; Turvey, Yosef, and Burton 1989, etc.). Even opponents of the ecological approach often admit its strong points as a kind of metatheory, in drawing attention to the richness and specificity of the information that movement makes available. But the "directness" claimed for perception by the ecological approach has generated considerable opposition (e.g., Ullman 1980).

Part of the difficulty lies in unclarity about the criterion of directness for these purposes. What is it about the idea that the brain processes information that is supposed to make for indirectness? How does the issue about directness relate to issues about classical decompositional processing? Is the idea of registering higher-order information directly opposed to the idea that sensory signals are internally decomposed and recomposed and manipulated syntactically (see Skarda and Freeman 1987; Freeman 1991)? If nonclassical neural networks enable perception, does that also count as indirect perception?

On one possible interpretation, there is an affinity between the ecological view and nonclassical, connectionist, and dynamic systems approaches, which also emphasize access to information in the environment. On this (charitable) interpretation, Gibson's hostility to information processing is best seen as hostility to the assumption that information processing must be understood in terms of decompositional structure. But these are empirical issues. We shouldn't attempt to decide them on general principles or a priori argument.

At any rate, it is worth separating the valid and important insights of the ecological approach from some of Gibson's overreactions, in particular against the idea of information processing. Perhaps the received tradition has focused too much on the internal aspects of perception and ignored the external aspects. But we can correct this bias and take on board the dynamic role of movement in making available information in the environment, without going to the opposite extreme of denying that the brain processes information at all. The point Gibson rightly insists on is the role of movement in making higher-order information available. But this point holds whether the brain registers information component-wise and then computes higher-order relationships, or instead "picks up" higher-order information whole. Unless we were moving through the world, certain information would not be available for either component-wise or all-of-a-piece registration. Both movement through real environments by whole organisms and brain activity play essential roles in extracting information from the environment and enabling a creature to have a perceptual perspective.

C. The view that perception is the given, is input passively received by the mind from the environment, is often rejected (for discussion see essays 2, 6). But we should distinguish different reasons for rejecting the "myth of the given." Claims that activity has an essential role in perception can appeal to various senses of "activity," at both the personal and subpersonal levels. At the personal level, intentional conceptualizing and classifying activity can be distinguished from intentional motor activity. At the subpersonal level, internal information processing in general can be distinguished from efferent or motor processes in particular (even if the afferent/efferent distinction is not sharp). And passive external movement can be distinguished from active or intentional movement.

On the one hand, it can be tempting to see what is wrong with the myth of the given purely in terms of the role of internal activity. When philosophers reject a passive conception of perception, they often have in mind either conceptual/classifying activity or internal information processing, as opposed to motor activity through space. Often the personal/subpersonal distinction is not clearly registered (but see Kitcher 1990; and see essay 2, secs. 8, 9).

On the other hand, Gibson's insights about the importance of external and instrumental feedback in perception correct an emphasis on the role of internal activity in perception to the exclusion of external movement. He shows how the capacity for movement through an environment contributes to the perspectival structure of perception. It is right to insist on the importance of motor activity. But it is wrong to set up a rivalry between movement through the external environment and internal activity. This is the effect of insisting that passive movement through the environment would serve perception as well as active, self-controlled movement and of rejecting the role of efferent signals in perception. If we allow the importance of movement but deny the importance of active movement we are left with a dynamic version of the myth of the given.

We should avoid both extremes. The activity that makes the myth of the given mythical is not merely internal or computational or conceptualizing activity, but includes external motor activity. But this motor aspect is not captured merely by passive movement. Active, self-controlled external movement enabled by causal continuity with internal activity is the essential complement of perception.

D. One manifestation of Gibson's hostility to the idea of internal information processing is his opposition to motor theories of perception. Both views reject a linear or one-way view of the relations between perception and action. Both emphasize the importance of feedback from action and the dynamic loopiness of the perceptual process. But the contrast between them can be drawn in terms of the two distinctions we have already used to characterize Gibson's

account. First, feedback can be external or internal. Second, its role can be instrumental or noninstrumental. In Gibson's theory, feedback is external and instrumental, since it is in principle produced just as well by passive as by active movement.

The ecological approach describes the role of external feedback loops, such as the effects of movement through an environment on the flow of the visual array, while motor theories describe the role of internal feedback loops, such as the dependence of perceptual processing on copies of efferent signals or motor commands. Motor theories appeal to the relations of afference to copies of efferent signals in order to distinguish self movement from environmental movement. (Many of the examples discussed in essay 9 are home territory for motor theories; see Bach-y-Rita 1984, p. 156; Trevarthen 1984, pp. 332–33). Gibson sees this as an "information processing" rival to his own account of the role of feedback, which is redundant once the virtues of his ecological view are appreciated. On the ecological view, direct sensitivity to natural regularities or stimulation invariants under the displacement of receptors lets the subject dispense with motor signal feedback. There is sufficient information in stimulus transformations as the animal moves to distinguish self movement from environmental movement without appeal to efference copy. Motor theories are criticized by ecologists for assuming that afference may by itself lack structure or be ambiguous as between self-movement and environmental movement, so that the appeal to efference is needed to resolve the equivocality. For example: "But efference, it can be argued, is itself equivocal; in the case of walking forward . . . on a treadmill, the efference is the same whether or not one is displacing as a whole relative to the surroundings. Presumably, then, advocates of efference-mediated visual perception should propose an additional mechanism, one that appeals to afference . . . to resolve the *efferent* equivocality . . . !" (Turvey 1979, p. 82).

Now this *tu quoque* is hardly a *reductio ad absurdum*. Efference can indeed be ambiguous, as Grossberg and Kuperstein emphasize in their work on sensorimotor calibration and control: the brain may not know a priori what the relationship is between output signals and muscle plant reactions (Grossberg and Kuperstein 1989, p. 15, etc.). Both the disambiguation of afference by efference and the disambiguation of efference by afference may be part of a complex, dynamically loopy perception and action system, featuring both external and internal feedback loops.<sup>27</sup> Motor theories can also claim the interdependence of perception and action. The circle of disam-

<sup>27</sup> Compare Dretske's view of efference copy effects as the monitoring by efference of an afference monitor, in 1981, pp. 119–23. This view appears not to allow for the simultaneous calibration of efference by afference; but see the remarks bottom of p. 122, which might be developed along these lines.

bifurcation is a virtuous one, and there is no need for an additional separate mechanism.

So the opposition on this point is unnecessary. The validity of Gibson's insights about the important role of external feedback in perception is not compromised by the role of internal feedback. The external ecological feedback loop and the internal efference copy feedback loop can both have an essential role. They may play complementary and interacting roles within an overall theory. This ecumenical approach has been pursued, for example, by Shebilske's "ecological efference mediation theory of natural event perception" (Shebilske 1987; see also Mace 1977, p. 61; and sections 5 and 6 below).<sup>28</sup>

We can also be ecumenical about instrumental and noninstrumental feedback. In the remaining sections we shall consider how motor theories and control system theories can recognize the *complexity* of the subpersonal feedback systems that enable perception and action. Complex dynamic feedback can be both external and internal, both instrumental and noninstrumental.<sup>29</sup>

### *5. Motor Theories of Perception and Complex Dynamic Feedback Systems*

A. Ecological views reject a linear or one-way view of the causal relations between perception and action in favor of a dynamic, circular view. But they restrict action to an external and instrumental role in perception. Behaviorist views give action a constitutive role in perception, but fail to recognize the essential role of dynamic feedback from action. As a result, they substitute one kind of one-sidedness for another.

Motor theories in principle have it both ways.<sup>30</sup> They are conceptually more liberal than ecological or behaviorist views. They can recognize that perceptual content depends neither on input nor on output alone, but on dynamic feedback relations between input and output. The role of feedback is in principle complex. Higher-order relations between external and internal

<sup>28</sup> Trevarthen (1984) notes that even Gibson eventually recognized that the subject's motor purposes were needed to explain fully the relation between environmental information and action.

<sup>29</sup> While Gibson sees feedback as external and instrumental, we should not assume that external feedback must be instrumental, or that internal feedback cannot be instrumental. Consider, respectively, the hypothetical acallosal subject discussed in essay 5, sec. 4, and the nonbasic case discussed in essay 9, secs. 3 and 8, and in sec. 6 below.

<sup>30</sup> The term "motor theory of perception" has at times been used very broadly, to cover almost any view that rejects the separate-but-unequal tradition and gives motor factors or their sensory consequences an important role in perception (Scheerer 1984). Both behaviorist and ecological theories have been regarded as motor theories in this broad sense. But this broad use blurs the distinctions we've been at pains to make between the different ways of departing from the traditional view.

feedback are an important source of information for perception. The contents of perceptions may depend constitutively on relations between input and output as well as depending instrumentally on output that is a means to patterns of input (see figure 10.2).

The emphasis here is on the advantages of this conceptual liberality rather than on whether motor theories are empirically correct in particular cases (see also essay 9, sec. 1). Conceptual liberality throws the various empirical possibilities into sharpest relief, even if the best empirical account of certain perceptual phenomena does not need all the conceptual resources liberality makes available.

B. Motor theories of perception distinguish *exafference*, *reafference*, and *efference copy* (Gallistel 1980, ch. 7; Festinger et al. 1967). "Exafference" is not feedback, but is input whose source is the external environment, such as the movement of external objects. Both reafference and efference copy are feedback. "Reafference" is input, or afference, that reflects an organism's own movement or other changes. It includes visual and proprioceptive inputs caused by limb movement. It also includes visual and other inputs from the environment insofar as they are affected by the organism's movements. For example, rapid movement in a straight line characteristically gives rise to a certain distinctive flow of the visual array and a certain distinctive patterning of sounds. Rotation within a stationary, vertically striped cylinder gives rise to another distinctive flow of the visual array. Exafference includes the kind of external and instrumental feedback emphasized by ecological theories. Finally, "efference copy" (or "corollary discharge") is feedback of output or efference internal to the central nervous system. Central efferent or motor output signals are projected to other processing areas of the brain, including to perceptual processing areas. Such processing areas may then receive both efference copy and reafference from the same movements. Efference copy has a smaller orbit or loop than does reafference. Together, efference copy and reafference make a record of movement available to the nervous system.

Over time, correlations are established between reafference and efference copy: normal relationships between input and output in certain environments. Information about self and world is carried by higher-order relationships between feedback loops with such different orbits. And perceptual contents can depend on input-output relationships as well as on relationships among inputs. Changes in either reafference or efference copy may change the relationship between them in a way that affects perceptual content. So perceptual content can change with efference even though afference does not change. Efference copy can play a noninstrumental role in perception.

Motor theories claim that efference as well as afference is needed to explain certain perceptual distinctions and constancies. Reafference, or affer-

ence whose source is self rather than world, is distinguished from exafference by its systematic relationships to efference. So the perceptual distinction between movement of the self and movement in or of the environment is a function of the normal relationships between afference and efference. If these are altered, for example, by the long-term use of left-right-reversing goggles, perceptual distortions may result (see essays 8, 9). Self-movement may give rise to illusions of the world moving. But over time perception tends to adapt to the new "normal" relationships between input and output.<sup>31</sup> Moreover, perceptual distinctions and constancies go hand in hand. For example, perception of position constancy is the complement of the perceptual distinction between self-movement and world-movement.<sup>32</sup>

C. Ecologists have claimed that invariants in stimulation made available by movement are normally sufficient to distinguish self-movement from world movement, and that efferent information is not needed. A global as opposed to local transformation of stimulation normally signifies self-movement. Earthquakes aside, whole environments don't normally jump in a particular direction (Turvey 1979, p. 82). But efferent signals may not be redundant in all circumstances (motor theories are invoked for many of the cases discussed in essay 9). Many aspects of ecological and motor theories can be combined. Again, conceptual liberality sharpens empirical issues. For example, Shebilske's "ecological efference mediation" theory respects the insight that significant complexity can be distributed across internal and external states, but also holds that efference and afference can interact to determine perceptual

<sup>31</sup> Motor theories offer explanations along these lines of some of the cases discussed in essay 9, such as the paralyzed eye and activity-dependent perceptual adaption. See Gallistel 1980; Festinger et al. 1967; Rock 1966, chs. 3, 7, 8; Taylor 1962, chs. 8, 9; Howard 1982, e.g., at pp. 310, 483, 512, and sec. 12.44; Held 1968. Compare also Poincaré, who held that voluntary movement provided the means of distinguishing changes in state from changes in position, since the latter can be corrected by a movement of the observer but the former cannot. For example, if an object simply changes position, a movement that restores the observer to her former position relative to the object will restore the former pattern of stimulation. But a change in color cannot in general be reversed by any movement she makes (Poincaré 1958, ch. 3; 1952, ch. 4).

<sup>32</sup> For applications of motor theories to position constancy, see Wolff 1984, p. 133; Rock 1966, chs. 3, 7, 8; Gallistel 1980, ch. 7; Taylor 1962, p. 131.

Rolls (1989, p. 148) discusses a network architecture that involves feedback from multimodal neural areas, which receive and combine different types of afference (such as signals carrying taste and visual information). Such a network can induce altered responses to input. For example, responses to distinct visual signals that are uniformly associated with the same taste signal by the multimodal backprojecting signal may be drawn together. Responses to very similar visual signals that are nevertheless associated with different taste signals by the multimodal backprojecting signal may be pulled apart.

Similar points could be made about feedback from areas where efference and afference converge. Could such a network model the role of efference copy in perceptual distinctions and invariants? In activity-dependent perceptual adaption? See the discussion in essay 9, and see Grossberg and Kuperstein 1989, especially ch. 3.

content. The contribution of each to perception may depend on its relation to the other. Shebilske makes a careful empirical case for his qualified combined view. Various suggestions have been made about the types of case for which ecological or motor accounts are especially successful.<sup>33</sup>

We can reject the assumption that perception must be a strictly input-side affair without going to the opposite extreme and denying that it can ever be. There is no reason to suppose that a motor account must apply to all types and aspects of perception. In certain cases, perceptual adaptation may be explained in terms of the relationships between different types of afference (such as visual and proprioceptive) rather than in terms of the relationships between efference and afference (Singer, Wallace, and Collins 1979, p. 81). Some kinds of perceptual adaptation seem to be activity-dependent, while others do not (see essay 9). There are many possible ways in which distinctions and invariants can be extracted from interactions between organism and environment. In this process, no neural boundary between input and output needs to be respected. Neural promiscuity is right and proper.

Mixed afferent-efferent relationships may seem a more natural basis for "where"-system than for "what"-system perceptions. The personal-level interdependence of spatial perception and action is part of what it is to have a perspective. This interdependence can be understood as emerging from a subpersonal system of mixed afferent-efferent relationships that carry spatial information. However, there is no ban in principle on mixed relationships outside the "where"-system emerging into perceptual consciousness. For example, color perceptions are not normally systematically related to actions. But under artificial conditions, even the perception of color constancy might adapt to become a function of afferent-efference relations (see the discussion of Kohler's blue-left yellow-right goggles in essays 8, 9).

#### *6. Action as the Control of Perception and Complex Dynamic Feedback Systems*

A. Control systems theories of action can also have it both ways in rejecting the traditional view. Feedback is of the essence; perception and action can be constitutively as well as instrumentally interdependent (see figure 10.2).

Control systems theories of action can be seen as complementary to motor theories of perception. Just as motor theorists resist a view of perception in terms of input, control systems theorists resist a view of action in terms

<sup>33</sup> See Mack 1979, p. 75, on observer-relative versus object-relative perceptions; Mikaelian 1979, p. 76, and Paap 1979, p. 77, on the relevance of the "what"/"where" distinction to the controversy about motor theories; Shebilske 1979, p. 80; 1984; 1987, p. 203; Wallach 1979, p. 85; Kugler et al. 1989-90, pp. 28-31.

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of output. Both theories appeal to a subpersonal system of complex dynamic feedback; both are conceptually liberal. They can be joined to obtain one possible specification of an overall framework for understanding the interdependence of perception and action and the way in which the contents of perception and of intentions may be superposed on a dynamic system of relations between inputs and outputs. This can be used to fill in the generic idea of a Two-Level Interdependence View (discussed in other essays).

The key idea of control systems theories of action is that action is the control of perception (Marken 1986; Powers 1980, 1973). It is neither purely stimulus-driven nor purely autonomous. The environment creates various disturbances after a system generates output. So the same output can have different effects, reflecting its interaction with different environmental disturbances. The same proximal output may be correlated with many different distal effects, and different proximal outputs may be correlated with the same distal effect (see essay 9, sec. 4). Outputs that produce a left turn on one occasion may produce a tail spin on the next. Centrally programmed output cannot generate consistent behavior given that unpredictable disturbances are generated after output. Yet organisms do just this. A negative feedback control system can accomplish this. It is able to produce consistent behavior by producing centrally selected inputs, not outputs. "The events recognized as behaviour are named for the uniform results produced by muscle actions, not for any particular pattern of the muscle actions themselves" (Marken 1986, p. 267). Muscle output must vary to produce the same result.

Intentional action, on this view, implies consistent results in face of disturbance, or control. A result is under control if it is protected against disturbance by action. Intended results are controlled results. The essential elements of a simple feedback control system are a sensor, a reference signal, a comparator, and an effector. Comparison of the sensory signal and the reference signal generates the error signal. The effector uses the error signal to produce output that counters disturbance, so as to keep the sensory and reference signals matching as closely as possible. The sensory signal reflects feedback from motor output as well as independent environmental influences.

A common misconception about feedback control systems is that operations around the feedback loop occur sequentially. If they did, Marken claims, the system would not control anything. Rather, all variables are changing continuously and simultaneously:

Many of the misconceptions about the operation of control systems result from the strong bias to view behaviour as 'output'. In fact, the behaviour of a control system is organized around the control of input; output is just an arbitrarily identified component in a causal loop, not the last step in a causal chain. The system does not really control the variables typically identified as out-



puts. . . . Reference signals originating outside the [control] system specify a particular value of input, not output. (Marken 1986, pp. 269, 274; see also p. 275 on deafferentation; Thelen and Smith 1994, p. 175; Port and van Gelder 1995, p. 23.)

The theory of action as the control of perception rejects the linear view, according to which stimuli affect sensory nerves, which send signals to higher centers, which relay and elaborate on them and eventually send out signals that excite the muscles, producing what we recognize as behavior. The apparent linearity is an illusion that feedback control theory can explain (see Powers 1980, pp. 226–30; Powers 1973).

B. What of the complexity of feedback? Control systems theory can appeal to internal as well as external feedback (Powers 1980). But can the role of feedback in control systems be understood in purely instrumental terms?

Just as Gibson gave us a more sophisticated understanding of the instrumental role of action in perception by appealing to dynamic feedback, so even simple control systems give us a more sophisticated understanding of the instrumental role of perception in action by appealing to dynamic feedback. An important step is made by admitting the importance of feedback at all, even in an instrumental role. However, control systems theory can also do more than this. Like motor theory, control systems theory can also show us how the role of dynamic feedback can be more than instrumental (cf. temporal atomism, essay 1).

Consider first *the nonbasic case*. Nonbasic intentions are intentions you act on by doing something else intentionally. More basic intentions are your means to acting on less basic intentions. Basic intentions are where the chain of what you intentionally do-by-doing-something-else begins. There may of course be further causes of what you intentionally do, but your act is not intentional described in terms of these further causes. For example, you do not normally intentionally fire a certain neuron. (See essay 9 on the basic/non-basic distinction.)

In the nonbasic case, it is tempting to assume some local mappings between the subpersonal, control system level of description and the personal level. At least, the nonbasic case does not provide pressure against this local mapping view in the way, as we shall see, the basic case does. On this view, the content of a nonbasic intention is carried locally by a reference signal, which functions as a target. A process of error minimization between the sensory and reference signals tends to bring the sensory signal as close as possible to the reference signal (see figure 10.3).

Sensory feedback here carries instrumental perceptual information about how the independently specified target can be met. Output signals carry the

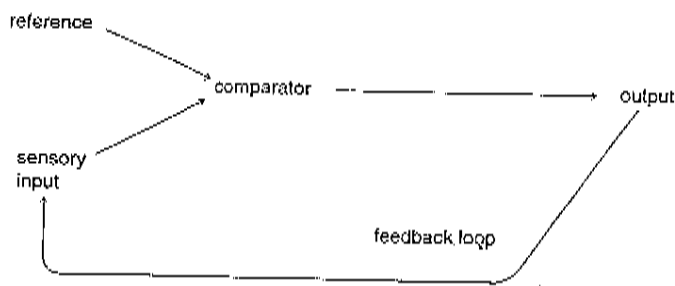


FIGURE 10.3. The nonbasic case

content of the basic intentions by means of which the nonbasic intention is effected.

We can refer to an example used earlier (essay 9) to illustrate the nonbasic case. Suppose you are a biofeedback subject trying to bring under intentional control the amount of alpha waves in your brain. Your governing nonbasic intention is to raise your alpha. Your brain is connected up to a monitor on which there is a line that ascends just when the amount of alpha increases and descends just when it decreases. So you also have another nonbasic intention, namely, to make the line on the monitor ascend. But you cannot act on these nonbasic intentions directly. You "try" various things. Suppose that as you move your eyes in various ways, the line on the monitor goes up and down. Eventually you realize that when you move your eyes in a certain way, the line on the monitor tends to ascend. The basic intention to move your eyes in that way was already available to you, but you can now act on your nonbasic intention to raise your alpha by moving your eyes in this way. By providing sensory feedback from intentional eye movement, the monitor gives you a new if nonbasic description under which you can act intentionally. You can now intend (to raise your alpha by making the line on the monitor ascend by moving your eyes). But no new basic intentions are acquired.

Suppose we apply the tempting local mapping to our example. On this supposition, the reference signal carries the content of the nonbasic intention to make the line ascend and motor output signals carry the content of the basic intention to move your eyes in a certain way. The sensory signal from the monitor carries perceptual information about how to make the effects of your basic intentions in eye movement match your nonbasic intention. When motor output fed back through the monitor reliably makes the reference and

sensory signals match, you have brought your alpha under intentional control.

These assumptions allow us to cast sensory feedback in an instrumental role. Sensory feedback reveals that something you could already do intentionally, such as moving your eyes, has a certain effect, which satisfies a nonbasic intention. It can be seen as simply providing a means of selecting, among independently determined basic intentions to make bodily movements, those that are the best means to effecting an independently determined nonbasic intention. On this view, your basic intentions depend only instrumentally on sensory feedback. But this instrumental role is essential, since there is no a priori connection between bodily movements and the effects specified by your nonbasic intention.

C. However, sensory feedback can also play a different, more fundamental role. Rather than mediating between basic and nonbasic intentions in the way that suggests such a local mapping, it can play a role in a system of relations on which the contents of basic intentions depend.

There is no a priori connection between efferent signals and bodily movements either (Grossberg and Kuperstein 1989, pp. 15ff.). But if intentions to move your body are basic, it would be wrong to retreat inwardly and treat the relationship between efference and bodily movement as equivalent to the relationship between bodily movement and the effects specified by a nonbasic intention. If we do, we may again be tempted to assume a local mapping and suppose that the content of independently available basic intentions is carried by efferent signals and that sensory feedback carries information about which already determinate basic intention is actually producing the desired bodily movements. This would be to treat bodily movements as something you do by doing something else. But then we lose our grip on the basicness of your intention to move your body. If your intention to move a limb in a certain way is basic, then you do not act on it by intentionally *doing anything* else, such as producing a motor signal in the brain, even if your intention depends on such signals. You just do it. The local mapping is not appropriate to the basic case.

These remarks presuppose that intentions to move the body are basic. But this assumption is not essential, and no foundationalism is implied. The things you can just do, like the things you can just see, are not fixed once and for all. Perceptual experience and basic agency have a degree of plasticity and adaptability (as various cases discussed in essay 9 illustrate). But wherever we locate basic intentions in a given case, parallel points can be made. Instrumental relations do not hold between basic intentions, whatever they are, and something even "further back" along the causal chain. If we insist on casting feedback in an instrumental role, we create an inward regress of basic intentions.

But there is another possibility. Input following primitive motor reactions to stimuli can serve subpersonally to calibrate and recalibrate the relationships between output and input signals within a neural network that implements adaptive sensory-motor control (Grossberg and Kuperstein 1989). The content of basic intentions may be a function of such a distributed subpersonal process or system of relationships. It may be that basic intentions emerge only when such a system is in place. They may need a kind of natural biofeedback to get started (cf. Schwartz 1980, p. ix). If so, then the content of basic intentions can be carried by subpersonal relations between input and output. The contribution of sensory feedback to determining the content of basic intentions within such a system of relations would not be instrumental. This would be the counterpart of the way, according to motor theories, the content of perceptions can also depend noninstrumentally on subpersonal relations between input and output. In both cases the distributed processes on which content depends dynamically relate inputs to outputs.

We can use control systems terms to conceptualize the contrast between the instrumental role of sensory feedback in the nonbasic case and its noninstrumental role in the *basic case*. In the basic case there is no reference signal determined exogenously to the system of relations but instead internal feedback of output signals, or efference copy.<sup>34</sup> As before, an external or reafferent feedback loop includes sensory input. The system keeps running track of relationships between reafferent and efference copy feedback loops (see figure 10.4).

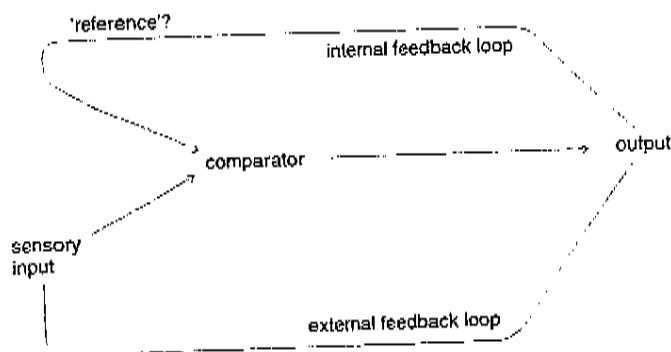


FIGURE 10.4. The basic case

Here, the local mapping between the control system level and the personal level that was tempting in the nonbasic case should be resisted. The depen-

<sup>34</sup> Powers's account of control systems emphasizes that feedback loops can be internal as well as external to the organism.

dence of basic content on subpersonal structures is nonlocal, distributed across the whole system. A new basic intention emerges through a kind of bootstrapping process. In place of a predetermined reference signal is internal feedback of motor output. Motor output is subpersonally calibrated against input from sensory feedback on the reafferent loop. The relationship between reafferent sensory feedback and efference copy does not fit the instrumental, local mapping model. Sensory feedback does not merely guide output signals to produce an independent target value, as we assumed in the nonbasic case. Rather, the contribution of output signals to the content of basic intentions depends on their context within the complex subpersonal system of dynamic feedback that calibrates them against sensory input. So the content of basic intentions depends noninstrumentally on these relationships between input and output.<sup>35</sup>

Return to our example. Suppose now that there is no correlation between your alpha waves and any basic intention previously available to you, such as moving your eyes. So no previously available basic intention can be a means to the end of raising your alpha. Yet somehow, after practice with the monitor, you are able to bring your alpha under intentional control. Feedback has enabled a new basic intention to emerge, the intention to raise your alpha. Sensory feedback is not here playing the instrumental role of allowing you to

<sup>35</sup> See Grossberg and Kuperstein 1989 on the role of efference copy or corollary discharge. See also Kuperstein 1988a, 1988b. Compare the distinction between the nonbasic and basic cases with Lacroix's distinction between two different views of biofeedback: compare figures 10.3 and 10.4 herein with the upper and lower portions of figure 3 in Lacroix 1986, p. 154.

The modest contrast drawn here between the basic and nonbasic cases can be compared to the stronger contrast Kelso draws between simple feedback control systems and more complex self-organizing dynamic systems. Even in systems with larger numbers of interdependent elements, multiple channels of unsynchronized "feedback," and no preset reference signals which contain the design for the final form, stable structures may emerge from the tangle (1995, p. 9; see also Clark 1997, p. 106; Elman et al. 1996, pp. 85, 110). Kelso finds the idea of feedback being compared with reference signals inadequate for understanding such complex self-organizing systems. In such systems, questions about who sets the reference value do not even arise. Kelso explains how complex self-organizing systems avoid regresses and homunculi by demystifying the emergence of steady states from nonlinear multidimensional interactions.

However, the modest contrast drawn here is the thin end of Kelso's wedge. To draw it we use the concept of feedback in a more generic sense than Kelso does: as implicated by recurrent or reentrant or circular causal flow that includes flow from outputs back to inputs, even though this may not take the form of a simple control system with preset reference signals. In complex feedback systems, feedback may be multidimensional and unsynchronized; "targets" and "comparisons" and indeed control might be distributed and/or emergent. Given the difference in terminology, there is no conflict between the present view and Kelso's comments about feedback. Whether self-organization counts as a kind of control is a further issue that need not be resolved here. The point here is that the way basic intentions emerge from complex dynamic feedback systems cannot be understood in terms of local mappings and exogenous reference signals. We do not need to disown the generic concept of feedback in order to see what is wrong with an exclusively instrumental view of it.

select an independently available basic intention as the best means to your end. Rather, the content of a new basic intention depends nonlocally on the relations between input and output within a dynamic system.

On this view there is no regress of basic intentions, no inward retreat of a hidden agent. Basic intentions emerge from distributed dynamic complexity, leaving their agents embodied and embedded in the world, right where they seem to be.

### *7. Putting It All Together: Two-Level Interdependence*

Motor theory accounts for perception in motor as well as sensory terms. Control systems theory accounts for action in sensory as well as motor terms. Neither is one-sided. Both can appeal to complex dynamic feedback systems at the subpersonal level. We can combine them to get one way of filling in a Two-Level Interdependence View.

To summarize: On such a view, perception and action can be constitutively as well as instrumentally interdependent, because the contents of both perceptual experiences and intentions can be functions of relations within a complex dynamic system. While we cannot simply read off relations among contents from relations among subpersonal vehicles, different contents superposed on the same system or network of relations may be interdependent, or display "cross talk" (Clark 1990b, pp. 120ff.; van Gelder 1991, p. 47). Some of the content relations that emerge from cross talk count as errors, but other may have higher-order functions or be positively selected for. For example, distinctions and invariants in the contents of both spatial perceptions and spatial intentions could codepend on the relations between input and output signals within a network. Cross talk in such a network may help to explain aspects of what it is to have a perspective, such as the way perceptual distinctions and invariants complement and constrain intentional distinctions and invariants, and vice versa (see essay 9; cf. Fetz 1984, pp. 467–70; note 23 above). It may also help to explain the tendency to imitate and the advantages of matching over mapping tasks. But these possibilities involve no verificationism. And they are compatible with the holism of the mental.

This alternative to the received view can be characterized negatively in some ways that are already familiar. It departs from both assumptions of the traditional view: linearity and instrumental relations between perception and action (see figure 10.2). It does not respect the isomorphism assumed by the Input-Output Picture: the mapping of perception and input onto one another, and the mapping of action and output onto one another. But it does have something to say about relations between the way content is carried and the way content is determined.

More positively, we can characterize this kind of view as an expression

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of three general ideas. The first is the idea of context-dependence. Content can be a function of distributed processes, of a network of relations, rather than of the intrinsic properties of discrete, local vehicles. Content can be both carried relationally and determined relationally. The second is that there is no neural boundary that might prevent the first point from applying to relations between input and output. The third is that superposition of contents can make for interdependence. Networks of relations can carry various codependent or superposed contents in such a way that such contents are interdependently determined.

Finally, because a Two-Level Interdependence View sees perception and action as mutually and symmetrically interdependent, it frees us of the myth the giving as well as the myth of the given.<sup>36</sup> It is not just expedient that perceivers are agents. But it is not just expedient that agents are perceivers, either.

<sup>36</sup> See essays 2, 6.