is the existence of two anatomically distinct (sustained and transient) visual channels.

To reiterate, these examples, as well as many others, represent instances of explanations of perceptual phenomena that are pitched at the level of neurons. If such explanations are permissible – which they certainly appear to be – then perception surely cannot be direct, because neurons must intervene between the environment and the percept.

2.2 Perception and cognitive psychology. Over the past two decades, the field of cognitive psychology has come into its own as a bona fide, well-recognized area within psychology. As we see it, research in cognitive psychology seeks to study the flow of information through the nervous system and subsumes the areas of attention, perception, memory, and mental representation. Any one of these research topics – perception is the case at hand – is rarely studied in isolation. Rather, within the framework of cognitive psychology, perception is viewed as one aspect of a larger cognitive system. Of interest are relations between the various components of the system. One major research endeavor concerns the interface between perception and memory, which in turn places heavy emphasis on an account of the mechanisms by which perception of one stimulus is affected by the perception of other stimuli presented nearby in space or time. The point we wish to stress is that an interest in these issues in and of itself precludes the notion that perception can be direct – that is, the question of how perception of stimulus A is affected by the prior perception of stimulus B presupposes that perception of stimulus A is not completely determined by the information in stimulus A. We will illustrate by considering once again the topic of visual masking, and in addition we will make some remarks about the highly related topic of subliminal perception.

Suppose a target stimulus such as the letter "G" is briefly presented to an observer. Under ordinary circumstances, this stimulus will be "perceived," in the sense that the observer will be able to report that the target occurred. But perception can be prevented (that is, the observer's ability to report the target can be driven to chance) by presenting a visual mask following the presentation of the target. Furthermore, it can be shown that different kinds of masks can halt the flow of information corresponding to the target at different points prior to where conscious perception (defined as the ability to report the letter) occurs. When, for instance, a random-noise mask (random dots overlapping the target in space) or a homogeneous light flash is used, the information corresponding to the target appears to be obliterated early, probably at a retinal level (cf. Turvey 1973). In a metacontrast situation, on the other hand, the contours of the mask do not have any spatial overlap with the contours of the target. Here, the information corresponding to the target appears to be barred from consciousness at a much later level in the system, as indicated by the fact that the target can be "unmasked" by a second mask that masks the first (Dember & Purcell 1967); the target, unperceived though it is, can still initiate a reaction-time response (Fehrer & Raab 1962); and evoked potentials corresponding to the target are undeterred by the mask (Schiller & Chorover 1966). We emphasize that perception of the original target can hardly be direct if (a) it can be masked by a temporally nonoverlapping stimulus to begin with and (b) different types of masks can preclude perception of the target at different places in the nervous system.

The old issue of subliminal perception has recently received renewed attention, much of it deriving from the work of Marcel (in press). The main thrust of Marcel's research has been to show that a stimulus masked from consciousness (whose presence is reportable only at a chance level) can nontheless exert considerable influence over other stimuli presented close in time. Perhaps the most dramatic of Marcel's results involves a lexical decision paradigm. In a lexical decision paradigm (see, for example, Meyer & Schvaneveldt 1971) reaction time to decide whether a letter string (for example, DOCTOR) is a word is reduced if the word is preceded by an associated word (NURSE) relative to when it is preceded by an unrelated word (FROG) or by no word at all. Marcel's contribution was to show that this result follows *even when the preceding word has been masked out of* been perceived in the sense that it exerts many of the standard effects within the cognitive system that are exhibited by normally (consciously) perceived stimuli. This result is of interest from the present perspective for two reasons. First, like the masking example described above, Marcel's results demonstrate perceptual phenomena that can be explained only via recourse to a multistage processing system, thereby weighing against the notion of direct perception. Second, as alluded to by Ullman, a convincing demonstration of subliminal perception removes the percept itself from the realm of conscious experience, which is rather at odds with Gibson's (for example, 1972, p. 215) assertion that perception implies (presumably conscious) experience, and his dismissal of the computer metaphor (p. 217) on the grounds that a computer cannot have the experience of being "here."

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Perceptual activity and direct perception

Ullman's version of direct perception is not Gibson's. Indeed, Gibson would have disputed the view Ullman calls direct perception at least as vigorously as Ullman does. Gibson did not believe that perception was a matter of pairing stimuli with percepts, and he did not believe that there is no meaningful decomposition of the registration process. But understanding what Gibson was getting at requires a broader review of his system. The differences between Ullman and Gibson are far greater than Ullman seems to appreciate. These should be clarified.

Comparing representative cases. In comprehending and comparing scientific theories it is useful to notice what concrete cases lie at their core. One can ask what a thoroughly representative instance looks like. For Ullman a paradigmatic instance of perceiving would be a case of object or event identification in which one imagines some unknown presented to a perceiving system and the job of the perceiving system is to say what the unknown is or what some if its properties are. Perceiving is a kind of question-answering system. Thus Ullman identifies a class of problems as problems of the *recovery* of structure. For recovering structure from motion the problem is to show how a system might draw explicit conclusions about 3D arrangement when access to the real 3D arrangement can only be had through a changing 2D array. Where accomplished, one can say that the 3D structure was *recovered* from the sequence of 2D changes. Ullman understands the problem of perceptual theory to be that of designing systems which can bridge the "gap between the physical stimulus and the perception of objects." For vision, light distribution at the receptors is input, percepts are output. Perception is kept distinct from action. I hope this is a fair rendering of his position. I take it to be roughly the view shared by nearly everyone who works on perception except Gibson.

Gibson's paradigmatic case of perceiving is perceptually guided locomotion. Animal movement must be regulated with reference to the environment (Bernstein 1967; Turvey, Shaw & Mace 1978). Even in the limiting case of upright standing, an animal is oriented to the surface of support as the object of its activity. To think about perceiving in Gibson's way, one must think of specific animals and specific activities, then inquire as to what environmental support is required to perform those activities, and what perceptual information and abilities must be present for the adequate regulation of those activities. Over the years, Gibson became increasingly impressed with the tight link between perceiving and acting. As he developed his position that the changing optic array was far more informative about the environment than a nonchanging array (Gibson, Olum & Rosenblatt 1955; Gibson 1958; Gibson, Kaplan, Reynolds & Wheeler 1969), he saw that it was advantageous, if not absolutely necessary, for an animal to move about in order to satisfy conditions for adequate perceiving. "So we must perceive in order to move, but we must also move in order to perceive" (Gibson 1979, p. 223). Exploratory locomotion is an example of perceptual activity for Gibson (1966). An exploring animal locomotes and adjusts the postures of its body and its members (including the head, eyes, and lens in the case of vision) partly according to the requirements of continued unobstructed activity and partly according to the requirements of acquiring more information. Much information is *obtained* by the organism rather than imposed on it. Information is used to guide the acquisition of more information. When Gibson spoke of registering or extracting information he meant to include all of the coordinated bodily movement as well as whatever neural events might be involved in the regulation. To properly compare his approach to Gibson's, Ullman might wish to explain the role of his computed percepts in ongoing activity.

Direct perception. Like Ullman, Gibson believed that one could establish a continuum from clear cases of direct perception to clear cases of indirect, mediated perception. To establish the dimension he explained, "Direct perception is what one gets from seeing Niagara Falls, say, as distinguished from seeing a picture of it. The latter kind of perception is *mediated.* So when I assert that perception of the environment is direct, I mean that it is not mediated by *retinal* pictures, *neural* pictures, or *mental* pictures" (1979, p. 147).

Between the cases like Niagara Falls and the picture of Niagara Falls lie cases in which instruments such as telescopes may be used to enhance information (1979, p. 259). Farther out than pictures on the extreme of indirectness he placed knowledge acquired by description; that is, explicit knowledge (1979, p. 260).[1] This is clearly not the same as Ullman's continuum. It is seemingly more concerned with what Ullman calls direct realism whereas Ullman claims to be interested in the *processes* of direct perception. But for Gibson, perceptual processes include coordinated activity. Continuing the paragraph I cited above, he said, "*Direct perception* is the activity of getting information from the ambient array of light. I call this a process of *information pickup* that involves the exploratory activity of looking around, getting around, and looking at things" (1979, p. 147). The crucial point for Gibson is that the possibilities of exploring the real Niagara Falls are very different from the possibilities of exploring the picture. There is information to specify these differences, and the information obtained from exploring these two different situations will also be different.

Were Gibson to decompose the perceptual activity of a particular animal's exploring Niagara Falls, he would have talked about the overall posture and changes of posture of the body, the activities of the head on the body, the activities of the eyes within the head, and the activities of the pupil, lens, and retina (light and dark adaptation) in the eye. These adjustments do not occur sequentially or independently. They depend on one another. In short, they are coordinated. Now this coordination is a problem with complexity of truly heroic proportions but that still does not necessarily call for representations and computations (Turvey, Shaw & Mace, 1978).[2] The environment, on its side, may be decomposed as part of trying to understand its nested space-time structure. But in Gibson's framework the organism and the environment are the terms of the perceptual relation, and analysis of each does not destroy the terms or the directness of the relation (Shaw & Bransford 1977b).

Gibson's comprehensive system. Throughout his career Gibson was intent on developing a realist theory of perceiving, one that did justice, in principle, to the adequacy of perceiving for the purposes of everyday animal activity. Everywhere he looked he found barriers to realism in psychology (Shaw, Turvey & Mace in press). In order to build theories that even had a chance of doing justice to his realist commitment, he had to redesign the framework for *defining* problems in addition to offering theories that addressed problems. He listed five major novelties of his approach: (1) a new notion of what perception *is* (experience *of* things rather than merely experience); (2) new assumptions about what there is to be perceived (the topic of most of his 1979 book); (3) a new conception of the information for perception; (4) a new approach to perceptual systems (the topic of his 1966 book); (5) recognition that a system registers both persistence and change in the flow of structured stimulation (1979, p. 239). Contrary to what Ullman implies, Gibson knew that a consistent realism is a very difficult position to construct. He revised and refined his ideas constantly, as can be seen in comparing his earlier and later published works. All of the pieces have to fit – the theory of the environment, the theory of information, the theory of the animal, and the theory of how they are related.[3]

Conclusion. Gibson never did get to the kind of theory of perceptual process that Ullman wants. Indeed Gibson had no *role* for such processes. Ullman has not gotten to theories of processes that capture animals exploring environments. How shall the two be reconciled?

Notes

1. Gibson identified explicit knowledge with verbal knowledge, knowing by means of words or symbols. He distinguished this from direct perception of an environment. Thus, whatever else it may be, perceiving definitely is not a kind of explicit knowledge in Gibson's system. Compare this to Ullman: "The role of the processing is not to create information but to extract it, integrate it, make it *explicit* and usable" (my emphasis).

2. In fact the role of computation, which is sequential and discrete, in explaining coordinated control will be very unclear until integrated with dynamics in some fashion (Berstein 1967; Pattee 1971; 1974).

3. If I am right about realism being a *requirement* of Gibson's psychological theory, then of course Ullman is right in saying that Gibson's psychology could not offer inductive support for realism. But most philosophers only look to psychology for rhetorical support anyway. Philosophy is not science.

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Are mediating representations the ghosts in the machine?

The immediate paradox facing a student of perception lies in the apparent conflict between the many-to-one nature of the world-to-retina transformation and the undeniable feeling that there is only one world out there when we open our eyes. That feeling of certainty diminishes not a whit if we sit motionless, or close one eye, or look through a monochrome filter, or see a movie of the world. A student of computational vision can express the paradox in terms of constraints. Human visual perception appears to be a richly overconstrained process with unambiguous results. An analysis of the constraints implicit in image formation alone, however, leaves us well short of such a desirable state of affairs.

Gibson has always argued that this is a false problem. He first attacked it by proposing that the analysis of the image formation process was incomplete, suggesting, for example, texture gradient as a determiner of surface slope in perspective projection. He further argued that the perception of static scenes by a static observer was unnatural and overlooked the information provided by motion which supplies, through optical flow patterns, a large class of additional constraints. Most recently (Gibson 1979), he argued that the assumptions underlying the paradox are false – that is, the premise that perception is based on the interpretation of images is, in his view, incorrect. He replaced the image by the ambient optic array surrounding the observing organism. This array has both temporal and spatial structure. He, moreover, explicitly rejects many of his earlier views in the new formulation. In particular, instead of viewing perception as a two-stage process, he is insistent that *affordances* (environmental attributes relevant to the organism's purposes) are picked up *directly* from the optic array.

Since this approach and that underlying computational vision are also in apparent conflict, Ullman has taken on the task of examining some of the underlying assumptions of each and determining if they can or should be reconciled. The paper is an elegant and convincing attack on the premises of direct perception, although I must declare an interest as one schooled in the paradigm rejected root-and-branch by Gibson. Not much would be gained if I, as a commentator, simply nodded assent to Ullman's attack, so I will argue, not with his conclusions, but with the reasoning that led him to them.