indicates cognitive penetration of VP and conceivably of EV. Additional work is required to test this possibility.

NOTES

1. For instance, small, low luminance contrast features are important diagnostic signs in mammograms, a fact which expert radiologists have learned. Our data reveals that their sensitivity to such features is superior to novices', and that the process of learning to detect these features is not simply one of learning where, and to what to attend, but reflects changes within early vision.

2. In addition to the psychophysical data supporting EVL to which certain alternative interpretations have been proposed (e.g., Mollon & Danilova 1996) there is also good physiological evidence for change in early visual processing areas (e.g., Frégnac et al. 1988; Gilbert & Wiesel 1992).

Attentive selection penetrates (almost) the entire visual system

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Abstract: Pylyshyn claims that if a system is cognitively penetrable, its function depends in a semantically coherent way to the organism's goals and beliefs. He rejects evidence of attentional modulation observed in neurons within the visual system, claiming that any modulation seen is not logically related to goals and behavior. I present some of this evidence and claim that it is connected in exactly the way Pylyshyn requires and thus it refutes his main thesis.

I will focus on Pylyshyn's main definition of cognitive penetrability: if a system is cognitively penetrable, then the function it computes is sensitive in a semantically coherent way to the organism's goals and beliefs. He adds

> Note that changes produced by shaping basic sensors, say by attenuating or enhancing the output of certain feature detectors (perhaps through focal attention) do not count as cognitive penetration because they do not alter the contents of perceptions in a way that is logically connected to the contents of beliefs, expectations, values, and so on, regardless of how the latter are arrived at (sect. 1.1, para. 1).

This is a convenient assumption because it dismisses the evidence that makes his thesis impossible.

Pylyshyn cites Moran and Desimone (1985) who trained monkeys to attend to one location or another within a single receptive field depending on task instructions. They write:

> The task used to focus the animal's attention on a particular location was a modified version of a 'match-to-sample' task. While the monkey held a bar and gazed at the fixation spot, a sample stimulus appeared briefly at one location followed about 500 msec later by a brief test stimulus at the same location. When the test stimulus was identical to the preceding sample, the animal was rewarded with a drop of water if it released the bar immediately, whereas when the test stimulus differed from the sample the animal was rewarded only if it delayed release for 700 msec (p. 783).

The monkey behavior and the cell responses led Moran and Desimone to conclude that when there were two stimuli within the receptive field, the response of the cell was determined by the properties of the attended stimulus; the attended stimulus is determined by the goals presented to the monkey. This basic result has now been extended to many other visual areas including V1, V2, V4, MT, MST, IT (Desimone & Duncan 1995; Treue & Maunsell 1996). Pylyshyn insists that the modulation must be logically connected with the organism's goals. If the above does not describe goal-specific responses, then Pylyshyn should elaborate on what he means.

Even more telling is the conclusion reached by Chelazzi et al. (1993) regarding the time course of attentive modulation. They recorded from IT neurons during a visual search task where the monkey is required to make an eye movement to foveate the target; correct foveation led to a juice reward. About 90–120 msec before the onset of eye movements, neural responses to nontargets are suppressed. This is clearly not a pre-perceptual effect; or is it post-perceptual, because the monkey has not yet acted on the percept. It is clearly an attentive effect that occurs during perception. This result goes against Pylyshyn's view of attentive selection.

Pylyshyn goes on to say there is no evidence that cells can be modulated by nonvisual information; the experiments of Haenny et al. (1988) do exactly this. A monkey is given the preferred orientation of visual stimuli using tactile stimulus; a disk with inscribed orientated gratings is placed under a table and away from view. Their conclusion was that such extra-retinal signals represent a prominent contributor to the activity of V4 cells in the behaving monkey. It seems abundantly clear that Pylyshyn cannot with a simple assumption eliminate the major source of trouble for his key claim.

One could attempt to use the "wiring diagram" of the visual system (Felleman & Van Essen 1991) to help Pylyshyn's cause. If there are portions of the visual system that are impenetrable, then it might also be the case that some internal layers of the system are unreachable from higher layers. The highest level visual areas in the hierarchy are areas 46, TH, and TF; area 46 is connected to no area earlier than MT and V4, TF is connected to no area earlier than V3 and VP, and area TH is connected to no area earlier than V4.

Area IT, the complex of visual areas just below these 3 areas in the hierarchy, has no direct connections to areas earlier than V4. Thus, it does seem that the higher level areas have no direct access to the earliest layers. However, the wiring diagram of Felleman and Van Essen is now dated and is no doubt incomplete. Whether or not these observations can actually lead to cognitive impenetrability of some sort is very unclear. If we simply acknowledge that connection lengths of arbitrary length are not optimal in the system, and allow one visual area as a transit station (V4), then all of the higher order areas have access to the entire set of visual areas. The hierarchy of visual areas spans 10 layers and area V4 is connected to at least one area in each layer. Thus, there is no issue regarding impenetrability since the higher order layers can affect processing in any earlier layer indirectly. In my model of visual attention (Tsotsos et al. 1995), attentional influences are transmitted layer to layer and do not depend on direct connections precisely because of the connection length constraint (Tsotsos 1990). The model is at least an existence proof that the strategy of attention penetrating all of the layers except for the retinal layers is realizable and does exhibit many of the characteristics of human attentive behavior.

Can we answer the unanswerable?

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Abstract: Pylyshyn circumvents an even more fundamental question: Are the mechanisms of visual perception accessible to the theoretician? Neurophysiology, computer modeling, and psychophysics, as well as his definitions of visual phenomena suggest that he has asked an unanswerable question.

In raising the question of the penetrability or impenetrability of visual perception by cognitive factors, Pylyshyn ignores one of the most fundamental questions in psychological science. He argues that it is possible by means of converging psychophysical, neurophysiological, and computational evidence to validate the impenetrability hypothesis he puts forward. Several of us have argued