claim that perception, or specifically, early vision, is unlike cognition and cannot use higher order processes such as inference. Complex perceptual processes are not inferential, they are merely compiled, built-in procedures. Not only is vision not cognition, it is not even like it. Cognition is the sole site of reasoning and rational problem solving.

This is serious cognocentrism. Pylyshyn confuses what people know with what cognition knows and what perception really ought to know. This does not demonstrate that perception and cognition use different procedures. If I make a decision despite something only you know, you do not call me irrational, you call me ignorant. And the same holds for perception. It is not irrational, it is just ignorant of the knowledge available to cognition.

You could analyze a picture cognitively, say, deciding whether a dark patch was a shadow, a dark object, or a marking on a lighter object by checking whether there were any possible objects in the scene for which this could be a shadow, whether the region was uniformly darker than its surround all along its border, whether there was a light source consistent with the shadow, or alternatively, whether the dark area itself could be recognized as a known object. If this were done on a numerical representation of the image, to disable any help from the visual system, we would note that this is a possible task for cognition but that it would be extremely slow. The visual system performs the very same, highly sophisticated and complex steps at great speed, interrogating knowledge bases, verifying image support, and selecting the eventual interpretation of the image from among several alternatives. Two things distinguish this process from cognition. It is extremely fast, whereas cognition is slow and its knowledge base is independent of the knowledge base used for cognition.

Clearly, perception and cognition have access to different knowledge bases – things known and reportable consciously have only indirect influence on perceptual outcomes. The details of the knowledge that drives perception cannot be reported verbally. However, this separation of knowledge bases is not limited to cognition and perception; it is often found within cognition itself. As only one example: religious beliefs are, almost by definition, held independently of rational analysis of the physical world – they are cognitively impenetrable. By choice.

Let us look at what Pylyshyn means when he says cognition. Cognition, he says, is present when a system's output "can be altered in a way that bears some logical relation to what the person knows." So if a person "knows" that the two lines of the Müller-Lyer illusion are the same length and yet persists in seeing them as different lengths, that percept is cognitively impenetrable. But who is the "person" who "knows" this fact about the two lines? The "person" cannot include a visual system because the visual system believes the lines are different and reports this as the percept. In truth, it can only be the verbally responsive, conscious part of the person that "knows" the lines are equal. Pylyshyn has linked cognition and cognitive-style processes solely to consciousness, to reportable knowing. [See also Puccetti: "The Case for Mental Duality" *BBS* 4(1) 1981.]

Not that cognition is restricted to conscious events. Clearly, much of the flow of cognition consists of inaccessible, unreportable gaps, memory retrievals, intuitions, rapid routines which return conscious results but whose details cannot be inspected. But the path of cognition is marked by a sequence of conscious states, like Hansel's trail of bread crumbs through the forest. Unless Pylyshyn defines it differently; what he claims we know appears to be only what we can tell another person.

In this case, Pylyshyn has not shown that vision is cognitively impenetrable, bereft of cognitive-style processes like inference and rationality. He has shown only that vision is impenetrable to consciousness. This fact alone does not constrain the nature of the processes used by vision. It does not rule out inference unless we accept that inference is solely a property of consciousness, but there would be no grounds for that rather strange assertion.

There are undoubtedly profound differences between vision and cognition but Pylyshyn has not identified differences in process, only differences in access to knowledge. What is needed is a description of the specific procedures which are unavailable to unconscious vision. If none can be named, no differences should be assumed.

## Even feature integration is cognitively impenetrable

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**Abstract:** Pylyshyn is willing to assume that attention can influence feature integration. We argue that he concedes too much. Feature integration occurs preattentively, except in the case of certain "perverse" displays, such as those used in feature-conjunction searches.

Attention plays a central role in Pylyshyn's approach to the relation between cognition and perception. He claims that many of the effects generally attributed to the influence of cognition on early vision are actually due to the influence of attention on perception. We agree, but we think he has not gone far enough. He believes that attention is routinely called upon to perform the task of encoding combinations of features – the "attention as glue" hypothesis of Treisman (e.g., Treisman 1988) and others (sect. 6.4). Thus Pylyshyn believes that through attention, cognition can influence the perceptually essential task of feature integration.

We believe that feature integration *never* requires attention and that the evidence regarding the role of attention in feature integration stems from an overgeneralized interpretation of data obtained in visual search experiments. Consider a typical visual search of this type. Denote the target, say a black square, by $T_{bs}$, and two distractors, a black circle and a red square, by $D_{bc}$ and $D_{rs}$. When observers are asked to search for a single $T_{bs}$ target among $N$ tokens of the $D_{bc}$ distractor – called a single-feature search – the magnitude of $N$ has only small, if any, effect on the time it takes them to find $T_{bs}$. If, however, observers are asked to search for the $T_{bs}$ target among $N_{bc}$ tokens of $D_{bc}$ and $N_{rs}$ tokens of $D_{rs}$ (a conjunction search), the magnitude of $N_{bc} + N_{rs}$ has a large effect on the time it takes them to find $T_{bs}$.

The common explanation of such findings runs as follows: different features, such as color and form, are independently processed in different modules. The feature that differentiates the distractor from the target (in our example, form) activates a single module; the other module is assumed to be silent because the stimulus does not vary with respect to the dimension to which it is sensitive. Because finding the target in this display does not require feature integration, the output of one module can guide the observer directly to the target. Hence, in single-feature search, targets can be located with only a small influence of $N$. According to feature integration theory, even though the observer may be guided directly to the target, recognition of the target requires focal attention, for a reason that will presently become apparent. In the conjunctive search, neither module alone can locate the target. Therefore finding the target requires observers to combine the output of the modules, which they can do only by applying focal attention to each item serially. Hence in conjunctive-feature search, targets are located with a large influence of $N_{bc} + N_{rs}$.

The data do not force these conclusions. The design of the visual search display forces the observer to perform a serial search but not for the reasons usually given. It is reasonable to believe that a central function of early vision is to define the spatial boundaries of objects, and that the multiple retinotopic maps found in the cortex are modules that specialize in finding spatial boundaries within a certain dimension. As we will show later, (1) these modules do not work independently, and (2) features are routinely integrated preattentively.

Specifically, feature boundaries around objects are generally coincident; for example, color and texture both change abruptly at the edge of an object. The stimuli used in conjunction searches are "perverse" in the sense that the output of the preattentive integration that is the centerpiece of our theory would be two objects coexisting in the same region of space, a paradox. Returning to the example we gave earlier, if in the display used for conjunctive search you drew a boundary between the black blobs and the red blobs and another between the square shapes and the round shapes, the boundaries would not coincide. Under these circumstances, and only under these circumstances, we believe that the visual system recruits attention to salvage a preattentively uninterpretable input. It does not follow however that attention is required for all feature integration. Thus in our view focal attention is not required to integrate features. Rather, attention – rather like the cavalry called in to save the threatened settlers – is called in only when normal preattentive processing is in trouble.

In a series of seven experiments studying preattentive vision we (Cohen 1997; Kubovy et al., in press) have collected considerable evidence in favor of our theory. In these studies we have shown that (1) when different feature dimensions form coincident boundaries, these boundaries are detected better than would be expected if the modules were independent; (2) when different feature dimensions form inconsistent boundaries, these boundaries are detected more poorly than would be expected if the modules were independent. These data show that the modules are not preattentively independent, and that they interact intelligently. When appropriate, the outputs of the two modules are synergistic; under other circumstances they are antagonistic. We have surmised that the mutual antagonism that we observed may be the signal that brings attention to bear on solving the perceptual puzzle posed by inconsistent boundaries.

In summary, we have erected an additional barrier between cognition and visual perception, we note that it is not unreasonable to think of a function as important as feature integration as being done preattentively and impenetrably by default.

## What is the point of attempting to make a case for cognitive impenetrability of visual perception?

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**Abstract:** We question the usefulness of Pylyshyn's dichotomy between cognitively penetrable and cognitively impenetrable mechanisms as the basis for his distinction between cognition and early vision. This dichotomy is comparable to others that have been proposed in psychology prompting disputes that by their very nature could not be resolved. This fate is inevitable for Pylyshyn's thesis because of its reliance on internal representations and their interpretation. What is more fruitful in relation to this issue is not a difficult dichotomy, but a different look at perception such as proposed by Gibson (1979).

When one begins with the assumption that the function of vision (early or otherwise) is to provide the perceiver with a "structured representation of the 3-D surfaces of objects sufficient to serve as an index into memory," a fundamental problem arises. The assumption of early vision as a representation-producing process involves the further assumption of a representation-interpreting process. As we know, however, this admits the further and thornier problems of infinite regress and solipsism (see Katz 1983). Pylyshyn seems to allow as much in his discussion of what he calls "Bruner's influential theory": If "poor folk" actually see (not metaphorically "see") a coin as larger than the same coin seen by "rich folk" then the misperceptions and consequent maladaptive behaviours that may occur in folk who are in various other deprived states do not bear contemplation. Given this unsatisfactory state of affairs it is appealing to be told that in the visual brain there are mechanisms that eliminate the more fanciful or even dangerous interpretations of representations "provided" by early vision. Even more appealing is the guarantee that these "smart" mechanisms are unable to be influenced by the perceiver's motivations, beliefs, and knowledge; that is, the mechanisms are cognitively impenetrable. However, it is our view that the solution to the problems inherent in theories of perception based on the generation and interpretation of representations provided by Pylyshyn's notion of cognitive impenetrability is problematic on several grounds which we explore in this commentary. We conclude that a better solution to the problem is provided by Gibson's approach to perception.

The origins of Pylyshyn's current version of cognitive impenetrability can be seen in his 1973 publication "What the mind's eye tells the mind's brain: A critique of mental imagery." In this he argued that "the picture metaphor underlying recent theoretical discussions of . . . [the relationship between perception and imagery] . . . is seriously misleading – especially as it suggests that the image is an entity to be perceived" (1973, p. 1). As an alternative Pylyshyn (1973) proposed that mental representations of the world were abstract rather than picture-like, and involved, for example, propositions in the form of pre-compiled subroutines, or rules, which *were* the interpretation. Part of Pylyshyn's argument rested on the claim that there was no necessary connection between a person's introspections and the nature of mental representations. An extension of this disconnection between conscious awareness and mental representation is at the heart of the earlier (Pylyshyn 1980; 1981) and present versions of cognitive impenetrability; that is, not only are mental representations opaque to inspection by the mind's eye, they are immune from influence by the mind.

Pylyshyn's choice of mental imagery as the vehicle to present his notion was not surprising given that imagination can properly be regarded as a quintessentially cognitive activity. More surprising, however, is the conspicuous absence of consideration of imagery in the present elaboration of cognitive impenetrability. This omission cannot be explained on the grounds that the problems at the heart of the imagery debate have been solved (see Tye 1991). In the 1980s psychophysical data initially interpreted as revealing functional equivalence between imagery and perception were "explained away" in terms of, for example, tacit knowledge (Pylyshyn 1980; Richman et al. 1979), or on methodological grounds (Broerse & Crassini 1981; 1984). More recently, claims of functional equivalence have been made based not only on psychophysical data, but also on brain-imaging data (e.g., Kosslyn et al. 1995). The problems, discussed over many years, inherent in interpreting psychophysical data taken to demonstrate equivalence between imagery and perception still remain. Furthermore, as Sarter et al. (1996) point out, interpretations of brain-imaging data are also problematic: although these data are typically taken to reveal something about the role of neural activity in "causing" mental states, Sarter et al. (1996) argue persuasively that such conclusions cannot be drawn, given the nature of brain-imaging data.

It may be that Pylyshyn's failure to engage in further discussion of the relationship between imagery and perception reflects an appreciation of the fact that the current imagery debate, like the debate about imageless thought at the start of this century (see Boring 1950), and the debate about the role of representations in perception, is more about faith than about fact. That is, given their