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Attention is a sterile concept; iterative reentry is a fertile substitute

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ABSTRACT

Attention has been defined as a filter, a limited resource, a spotlight, a zoom lens, and even as a glue that binds disconnected visual features into a coherent object. Here, I claim that all of these metaphor-based explanations are circular. As such, they fail to provide adequate accounts of the phenomena they are purported to explain. In contrast, those very phenomena can be explained on the idea that perceptions emerge from iterative exchanges between cortical regions linked by two-way pathways. Processing can occur in one of two modes: *feed-forward* and *reentrant*. In feed-forward mode, the system is configured optimally for the expected input, and perception occurs on the feed-forward sweep. This form of processing corresponds to what is commonly referred to as “preattentive”. If the system cannot be configured appropriately, perceptions emerge from iterative reentrant processing, which is slower, and corresponds to what is commonly referred to as “attentive”.

1. Introduction

Bruce Bridgeman was a good friend and an inspiring colleague; he was also a polymath. From his many contributions, I have selected two – dating back to the 1980s – that are ostensibly unrelated to one another but, when considered together, lead to a novel formulation of the concept of *attention*. First, [Bridgeman \(1986\)](#) believed that selective attention is subserved by a neural network centered in the frontal eye fields (Brodmann’s Area 8). Indeed, he suggested that a better name for that region might be “frontal attention fields”. Second, [Bridgeman \(1980\)](#) was amongst the first to question the then prevalent feed-forward ideas fostered by the discovery of receptive field properties of cortical visual neurons aptly characterized as simple, complex, and hypercomplex ([Hubel & Wiesel, 1977](#)). Instead, he proposed and documented the idea that visual perceptions emerge from iterative exchanges between cortical regions linked by two-way pathways. To see how such reentrant processing can be related to attention, we need to take a look at the literature.

2. What is “attention”?

In a passage that has become hackneyed through use, William James had this to say:

Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thoughts.... It implies withdrawal from some things in order to deal effectively with others. (1890/1950, Chapter XI).

In William James’s definition, attention is regarded as a *process* as distinct from a *thing*. In contrast, later theories have reified the concept, turning it into a thing that can be deployed and captured. In various incarnations, attention has been defined as a filter

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(Broadbent, 1958), a limited resource (Lavie & Tsal, 1994), a spotlight (Posner, Snyder, & Davidson, 1980), a zoom-lens (Eriksen & St. James, 1986), and even a glue that binds disconnected visual features into a coherent object (Treisman & Gelade, 1980). In all these metaphors, attention is regarded as a causal agent that can enhance performance. On the other hand, there are valid reasons why at least some aspects of attention should be regarded as an effect rather than a cause (e.g., Krauzlis, Bollimunta, Arcizet, & Wang, 2014; Krauzlis, Lovejoy, & Zénon, 2013; Zénon & Krauzlis, 2012).

Defining attention by means of a metaphor may enhance an intuitive grasp of the concept but can be an impediment to scientific understanding. A major drawback of these metaphors is that they do not specify what underlying mechanisms mediate the purported function. For example, as pointedly noted by Tsal (1989), Treisman and Gelade's Feature Integration Theory does not specify the processes by which the attentional glue binds features into objects. The same can be said for the other metaphors. As Amos Tversky pointedly noted, "Metaphors replace genuine uncertainty about the world with semantic ambiguity. A metaphor is a cover-up" (quoted in Harari, 2016).

Any one of these metaphor-based definitions can be shown to be circular. Consider, for example, the finding that a stimulus flashed just ahead of an object in motion is perceived more readily and more accurately (e.g. Spalek, 2007). The enhanced performance has been attributed to the deployment of attention to the region of space just ahead of a moving object. To illustrate the circularity of this claim, I paraphrase an imaginary dialogue between Galileo and his side-kick, Simplicio:

SIMPLICIO: a stimulus flashed at a location just ahead of a moving object is perceived more promptly and more accurately.

GALILEO: why is that?

S: because the attentional spotlight is deployed to that location, and stimuli presented at an attended location are processed more promptly and more accurately.

G: and how do we know that attention has been deployed to that location?

S: we know it because stimuli presented at that location are perceived more promptly and more accurately.

Simplicio's account is flawed because it is circular. *Mutatis mutandis*, the same can be said of the other metaphors.

Besides giving rise to circular accounts, the term "attention" is remarkably lacking in specificity. In the metaphors listed above, that term refers to a range of phenomena that differ markedly from one another. This can generate a good deal of confusion. Referring to two separate phenomena with a single term can have untoward consequences. To say it with Coltheart (1980, p. 207), if we have a visual process X and another visual process Y, then we can call process X "attention" and process Y something else, or call process Y "attention" and process X something else. What we cannot do without creating the utmost chaos is to use the term "attention" to refer both to X and to Y if it is indeed the case that X and Y are different things.

The upshot of all this is that the term "attention" has become of dubious usefulness. It usually stands for some unspecified causal agent, and acts merely as a place holder for something else. As Anderson (2011, page 4) pointedly notes,

The fact that many uses of the term are vacuous can be demonstrated by simply deleting the term and seeing whether the explanatory content is significantly reduced. For example, when Treisman (1985) writes: "Some discriminations appear to be made automatically, ~~without attention~~ and spatially in parallel across the visual field. Other visual operations ~~require focused attention and~~ can be performed only serially." the references to attention can be struck out without losing any understanding of the empirical results, and their inclusion doesn't deepen our theoretical understanding.

But circularity and lack of specificity do not impugn the large body of empirical findings that have been motivated by the concept of "attention". How those findings are explained, however, is still a problem. The findings are obviously still true, but the important point is that attempts to explain them in terms of "attention" are beset by circularity and lack of specificity. So, those findings are still in need of explanation. I propose that a more fitting account of the empirical evidence can be given in terms of iterative reentrant processing, a concept pioneered by Bridgeman (1980) in the context of metacontrast masking.

3. Iterative reentrant processing

Bridgeman (1980) recorded single-unit activity in primary visual cortex of awake monkeys following the presentation of brief visual stimuli. Bucking the feed-forward views of information processing prevalent at the time, the experimental evidence led Bridgeman to conclude that:

... visual information enters the primary cortex in an early burst of activity, then is carried by corticocortical connections to other areas, perhaps outside the striate cortex, where it is convolved with other types of (endogenous) information, and is then returned to the same striate cortex cells for further processing (page 361).

Reentrant conceptions such as this, permit those metaphors to be replaced by more informative accounts. To illustrate, let us revisit the finding that a stimulus displayed just ahead of a moving object is perceived more promptly and more accurately. An account of that finding might be offered by postulating an attentional spotlight that is deployed just ahead of a moving object (e.g., *attentional momentum*; Pratt, Spalek, & Bradshaw, 1999). But, as we have seen, that account is flawed because it is circular. What is needed is an account that avoids circularity.

The wherewithal for such an account has been provided by Sillito, Jones, Gerstein, and West (1994). A drifting sinewave grating was displayed to an anaesthetized cat while concurrent single-unit activity was recorded from directional motion sensors in primary visual cortex (Brodmann's Area 17) and from corresponding neurons in dorsolateral geniculate nucleus (dLGN). The important finding was that corticofugal signals lowered the firing threshold of the dLGN neuron located next (i.e., just ahead) in the path of

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