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Stage 3 and what we see

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Abstract

In his article, Lamme provides a neurotheoretical argument that recurrent processing (RP) produces the phenomenological sensations that form the contents of our conscious experiences. Importantly, he argues that this processing includes local intra-areal (i.e., horizontal connections) as well as local inter-areal feedback (i.e., from higher level sensory areas to lower level ones) interactions that occur within the sensory cortices. This has direct implications for what the contents of these experiences may be and the role that neuroscience can play in identifying them.

Lamme argues that we subjectively experience Stage 3 processing that includes local intra-areal (i.e., horizontal connections) as well as local inter-areal feedback (i.e., from higher level sensory areas to lower level ones) interactions that occur within the sensory cortices. Having attributed phenomenology to stage 3, a question remains of how much information it can represent, and how much it thereby contributes to our phenomenological experiences.

Referencing the large capacity representation revealed through studies of iconic memory, Lamme suggests that Stage 3 processing represents a virtual copy of the physical world, and concludes that when examining his Figure 1, one in fact experienced all of the objects in the circular array. This implies Stage 3 processing and that our phenomenological experiences have an unlimited capacity to represent the world around us. However, the capacity of Stage 3 processing (in fact all processing of visual information) is limited by the optics of the eye, the receptive field properties of individual neurons, and their impacts on the dynamics of the circuits to which they belong. Starting at the earliest stages of processing, these physiological limitations lead to numerous ambiguities (e.g., the aperture problem: Adelson & Movshon, 1982) such that an infinite number of physical stimuli can produce the same neuronal activity. It could be argued that a fundamental goal of visual processing in general is to resolve such ambiguities.

As demonstrated by visual illusions and the principles of perceptual grouping, it is clear that we do not experience a direct representation of the physical world, but rather a limited “best guess” of what it might be (Wertheimer, 1924/1950). Certain aspects of how this best guess is constructed, such as the local interactions that support perceptual grouping (i.e., colinear facilitation: Polat & Sagi, 1993), texture segmentation (De Weerd, Sprague, Vandenbussche, & Orban, 1994), as well as competitive interactions that can weaken the representations of co-occurring stimuli (Beck & Kastner, 2009; Desimone & Duncan, 1995), are likely embodied at least partially if not entirely in Stage 3 processing. As such, Stage 3 processing does not allow us to experience a virtual copy of the physical world nor even a direct representation of the retinal image. You likely did not, as Lamme suggests, really see all the

objects in his Figure 1, but instead saw the limited information about those objects (as well as the entire visual field) that the visual system was capable of representing.

This leads to an intriguing argument that the contents of our phenomenological experiences should not be considered in terms of the physical stimulus alone, but rather in terms of how information is represented in visual cortex, which, depending on the circumstance, may only loosely correspond to the stimulus itself or even the stimulus-driven inputs. This view provides a direct link between the neuroscience of consciousness and the systems neuroscience of vision. Namely, if we can understand the nature of the information being represented in the visual system, we may begin to understand the contents of our conscious experiences.

Finally, the various parallel pathways (both spatially specific and feature-specific) of visual cortex represent a dynamic system in which activity (both feedforward and recurrent) is ongoing, ever-changing, and dependent not only on its own internal dynamics (e.g., adaptation) but also on numerous inputs that are both stimulus and nonstimulus driven. As such, our phenomenological experiences (and their underlying neural mechanisms) are likely not isolated constructs that appear when a stimulus is present and then disappear when it is removed (as tacitly implied by Lamme's four-stage model), but rather are ever-present and simply change in response to changes that occur within the underlying neural mechanisms. When a stimulus is taken away, there is not a *loss* of consciousness, but a *change* in consciousness. Such changes need not be stimulus driven *per se*, but could arise, for example, from strictly top-down influences of spatial attention (Kastner, Pinsk, De Weerd, Desimone, & Ungerleider, 1999), prior experience (e.g., Bar, 2009), or as a result of internal dynamics as is the case in phenomena such as Troxler filling-in (De Weerd, Gattass, Desimone, & Ungerleider, 1995; Troxler, 1804).

We suggest that in order to understand the contents of our visual experiences, the focus may be better placed on the neural circuits that underlie them (e.g., those that support RP throughout the visual system) and frame questions in terms of how perturbations in the ongoing activity of these circuits arise. Thus, the question is reframed from "How is the conscious experience of a visual stimulus *created*?" to "How is the ongoing stream of conscious experience (and the underlying neural activity) *changed* and what has it *changed to*?" This viewpoint naturally allows the past states of the underlying network to be taken into account when considering how specific inputs will influence the information that will be currently represented. Furthermore, it naturally dissociates the phenomenological experience of a given stimulus from the stimulus itself.

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