fact that I can react to the stimulus in certain ways, just as an obviously unconscious motion detector can be properly said to be sensitive to movement without this sensitivity implying awareness in any form. Conscious sensitivity, however, crucially involves phenomenal content. It is this specific difference between sensitivity and awareness that one should be focused on.

Both the GWT and the recurrent processing hypothesis (RPH) defend the idea that recurrent processing is essential for conscious experience. However, only GWT assumes that parieto-frontal activity is necessary to amplify initial posterior activity, causing "ignition." In contrast, the RPH proposes that recurrent processing in visual regions is sufficient for conscious perception.

It strikes us, however, that there is a crucial difference in the characteristics of the stimuli used to support either GWT or RPH. Indeed, studies reporting anterior correlates of consciousness generally use complex stimuli (e.g., Del Cul, Baillet, & Dehaene, 2007), whereas studies reporting posterior correlates of consciousness mostly use very low-level stimuli (e.g., Fahrenfort, Scholte, & Lamme, 2008). Whether or not one is a aware of a given stimulus could thus depend on the region that is involved in processing it, so integrating GWT and RPH by letting the emergence of consciousness in Lamme's Stage 3 or Stage 4 depend on the complexity of the stimulus.

In this respect, recent evidence (Sandberg, Timmermans, Overgaard, & Cleeremans, 2010) suggests that for simple stimuli, introspection is in fact rich, graded, and fairly accurate when properly probed by qualitative graded scales referring to the stimulus (from "No experience" to "A clear experience") rather than through dichotomous (yes/no) reports. Strikingly, Overgaard, Fehl, Mouridsen, Bergholt, and Cleeremans (2008) found that, using this method, blindsight patients reveal (severely degraded) awareness of stimuli presented in their blind field. Thus, such graded reports correlate better with behavior and indicate that above-chance identification is always associated with some awareness, at least for simple stimuli.

Whether a subjective report is exhaustive could thus depend on the extent to which feature integration is necessary to respond appropriately to a stimulus (Timmermans, Sandberg, Cleeremans, & Overgaard, 2010). Conversely, stimulus complexity could lie at the heart of the impression of unreportable phenomenal overflow. Kouider, de Gardelle, Sackur, and Dupoux (2010) recently proposed the partial awareness hypothesis, which holds that rich phenomenality is a "perceptual illusion" brought about by partial bottom-up information that is accessed at *some* but not *all* representational levels, in combination with prior top-down information at the accessed level. Thus, phenomenal awareness never overflows access in this framework. In this sense, becoming aware of a stimulus does not merely involve filtering and selective amplification of a (overflowing) phenomenal field through attention, but rather the active construction of content based on fragmentary input of complex material, biased by priors.

Our own perspective on these issues begins with the notion that the brain *learns to be conscious* by continuously and unconsciously redescribing its own activity to itself (see Cleeremans, 2008). For such redescriptions to be possible at all, the target first-order representations need to be strong, stable, and distinctive—a condition that is itself only possible through recurrent processing. On this view, thus, phenomenal experience depends on the interaction between sufficiently strong first-order representations and the existence of learned redescriptions (metarepresentations) that reflect the manner in which the target first-order representations are known at some level (i.e., their meaning). There may be many levels of such metarepresentations in the brain. Which end up being active during some information-processing episode will depend on both stimulus complexity and task instructions.

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Is recurrent processing necessary and/or sufficient for consciousness?

Naotsugu Tsuchiya[1] and Jeroen J. A. van Boxtel[2]

[1]Division of Humanities and Social Sciences, California Institute of Technology, Pasadena, CA, USA; and Tamagawa University, Tamagawa, Japan
[2]Division of Biology, California Institute of Technology, Pasadena, CA, USA
E-mail: naotsu@klab.caltech.edu

DOI: 10.1080/17588928.2010.497582

Abstract: While we agree with Lamme's general framework, we are not so convinced by his mapping between psychological concepts with their underlying neuronal mechanisms. Specifically, we doubt if recurrent processing is either necessary or sufficient for consciousness. A gist of a scene may be consciously perceived by purely

feedforward, without recurrent, processing.

Neurophysiological studies of perceptual suppression show recurrent processing in visual cortex for consciously invisible objects. While the neuronal correlates of attention and consciousness remain to be clarified, we agree with Lamme that these two processes are independent, evinced by our recent demonstration of opposing effects of attention and consciousness.

Lamme's hypothesis powerfully explains several phenomena such as masking and iconic memory. However, other lines of research suggest that recurrent processing (RP) is neither necessary nor sufficient for conscious perception.

First, RP seems unnecessary for conscious gist perception of visual scenes. A gist of an unfamiliar and unexpected natural scene can be extracted with a very brief exposure and rapidly reported (Kirchner & Thorpe, 2006). Even when the iconic trace is masked (and presumably RP is terminated), it can be consciously perceived in the near absence of attention (Li, VanRullen, Koch, & Perona, 2002). This happens before the details of the scene become available. These properties of gist perception suggest that its computation can be performed in a purely feedforward manner.

Second, RP seems insufficient for conscious perception. For example, in perceptual suppression phenomena (Leopold & Logothetis, 1996; Maier et al., 2008), objects evoke the same sustained neuronal firing regardless of their conscious visibility. Assuming that sustained firing is a reflection of RP, as Lamme does in other papers, these findings suggest an insufficiency of RP for conscious visibility.

Perhaps, varying amounts of RP are correlated with different kinds of qualia (e.g., no RP for a gist); feedforward activation in an area that has widespread connectivity with the rest of the brain may be sufficient to produce consciousness because it has a higher possibility to produce larger phi. On the other hand, RP in an area that is not connected with frontal areas, like V1, may not give rise to consciousness.

While consciousness may not be tightly correlated with RP, some forms of attention are, and they promote long-distance coherent activity (Womelsdorf & Fries, 2007). In the cases of sustained invisibility mentioned above, some visual aftereffects are enhanced by attention (Kanai, Tsuchiya, & Verstraten, 2006). It would be interesting to study whether attention enhances processing of objects with sustained invisibility via enhanced RP and/or widespread activation.

Although RP and depth of widespread activation may not map onto consciousness and attention, respectively, we do believe that consciousness and attention are supported by distinctive neuronal mechanisms (Tsuchiya & Koch, 2008) based on two lines of evidence: (1) By classifying percepts based on their relation with attention and consciousness, we find examples of attention without consciousness and consciousness without attention, the latter including gist perception and iconic memory. (2) By independently manipulating attention and consciousness, one can demonstrate the opposite effects of attention and consciousness.

As to the second point, the perception of afterimages is modulated in opposite ways by attention and consciousness. By manipulating the visibility (a proxy for the content of consciousness) of an afterimage inducer, *perceptual invisibility* of afterimage inducers is shown to *reduce* afterimage duration. On the other hand, *attending* to afterimage inducers *reduces* afterimage duration. Recently, we directly demonstrated the opposite effects with a 2×2 factorial design, removing any stimulus or task confound (van Boxtel, Tsuchiya, & Koch, 2010). We explain the opposite effects by assuming that attention and consciousness enhance luminance and contrast adaptation to different degrees (Brascamp, van Boxtel, Knapen, & Blake, 2010). It would be difficult to explain the opposite effects of attention and consciousness using the line of reasoning based on RP and extent of activation.

While we agree with Lamme's point that neuroscience should go beyond introspection and that attention and consciousness are independent, evidence from gist perception, perceptual suppression, and afterimages suggests that local RP may not explain consciousness.

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