

The functional utility of consciousness depends on content as well as state.
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ABSTRACT:

This commentary considers Merker's mesodiencephalic proposal in relation to quantitative measures of neural dynamics suggested to be relevant to consciousness. I suggest that even if critical neural mechanisms turn out to be subcortical, the functional utility of consciousness will depend on the rich conscious contents generated by continuous interaction of such mechanisms with a thalamocortical envelope.

MAIN TEXT:

Merker's target article provides a lucid and compelling alternative to currently dominant (thalamo-)cortico-centric proposals regarding the loci of neural mechanisms underlying consciousness. Taking a quantitative perspective, this commentary challenges Merker's claim that the functional utility of consciousness is independent of the level of sophistication at which conscious contents are integrated. I also comment on the proposed function of consciousness in the coordination of motivation, action, and target selection, and finally, I suggest some implications for non-human consciousness.

An important step in the evolution of scientific theory is the development of useful quantitative measures that connect different levels of description. The scientific study of consciousness requires such measures in order to generate explanatory links between features of neural activity and features of phenomenal experience. Several recent studies have discussed various measures of the 'dynamical complexity' of neural activity, including 'neural complexity' (Edelman & Tononi, 2000; Tononi & Edelman, 1998), 'information integration' (Tononi, 2004), and 'causal density' (Seth, 2005; Seth, Izhikevich, Reeke, & Edelman, 2006). These measures share the idea that the dynamical complexity of a neural system reflects the extent to which the activity of its components is both *differentiated* (i.e., small subsets of a system are relatively independent of each other) and at the same time *integrated* (i.e., large subsets tend to behave coherently).

Critically for theories of consciousness, the balance between differentiation and integration is also a fundamental aspect of phenomenal experience: Each conscious scene is one among a vast repertoire of possible conscious scenes (differentiation) and yet is experienced as a unified whole (integration) (Tononi & Edelman, 1998). Thus, a well specified measure of dynamical complexity can provide an explanatory link between neural activity and phenomenal experience. Importantly, cortical networks appear

particularly well suited to generating neural dynamics of high complexity (Sporns, Tononi, & Edelman, 2000).

The detailed description of mesodiencephalic mechanisms provided by Merker raises the interesting possibility that mesodiencephalic and corticocentric models could be compared on their propensity to generate complex neural dynamics. Although such modeling work remains to be done, it seems plausible that a model mesodiencephalon by itself would *not* support neural activity of high dynamical complexity, at least when compared to a model thalamocortical system. Why? Previous computational models of closely associated mechanisms which are also involved in sensorimotor selection, such as the basal ganglia and the medial reticular formation, reveal dynamical properties appropriate for segregation of multiple competing sensorimotor streams (Humphries et al., (in press); Prescott, Redgrave, & Gurney, 1999). Such dynamical segregation seems inconsistent with the integration required for high values of complexity. Moreover, the small size of mesodiencephalic systems as compared to thalamocortical systems, in terms of numbers of neuronal elements, suggests that the latter should support dynamics with greater differentiation.

Having dynamics of high complexity is important not only in accounting for fundamental aspects of phenomenology, but also for supplying functional utility. According to the 'dynamic core hypothesis' of Edelman and Tononi (2000) and its recent extensions (Edelman, 2003; Seth et al., 2006), the functional utility of a complex neural/phenomenal state is that it provides a highly informative *discrimination*: By being differentiated, any given conscious state is distinct from an enormous repertoire of other states, each reflecting different combinations of internal and external signals. By being integrated, each conscious state can appear as distinct *to the system itself*, and is therefore useful *for* the system in guiding action.

The above position differs from Merker's claim that the functional utility of consciousness "will turn out to be independent of the level of sophistication at which the contents it integrates are defined" (p.3). From the point of view of discrimination, functional utility will correlate closely with the sophistication of conscious contents. A richly elaborated conscious scene will provide a more informative and hence a more useful discrimination than a comparatively impoverished scene. In other words, the functional utility of consciousness should not be construed only in terms of conscious 'state' (i.e., a position on a continuum ranging from coma to normal alert wakefulness), independent of the degree of elaboration of conscious 'content' (i.e., the richly differentiated components of each conscious experience). As Merker makes clear, subcortical mechanisms are proposed as a locus for the generation of conscious state, whereas conscious contents remain dependent on cortex. Thus, even if critical neural substrates turn out to be subcortical, the functional utility of consciousness will depend on cortical systems as well.

Merker himself argues that consciousness is useful for integrating target selection, motivational modulation, and action selection. This proposal marks a valuable departure from many previous studies which, possibly for reasons of practical necessity and

misplaced conceptual hygiene, treated these overlapping and interdependent processes as in principle separable and independent [see (Seth, in press) for further discussion of this issue]. Merker's proposal can also be viewed in terms of discrimination because each integration can be thought of as an informative discrimination among a repertoire of motivationally-modulated sensorimotor mappings. Moreover, that such integrations are suggested by Merker to take place in a conscious 'analog reality space' parallels the dynamic core hypothesis in proposing that conscious qualia *are* high-order discriminations in a multidimensional signal space (Edelman, 2003).

Finally, it is worth considering the important question of non-human consciousness. A strong case can be made that the ability of organisms to verbally report conscious contents should *not* be taken as a necessary criterion for consciousness (Seth, Baars, & Edelman, 2005). Rather, using humans as a benchmark, a number of interlocking criteria can be identified, at both behavioral and neurophysiological levels of description. These criteria include 'informativeness' as measured by dynamical complexity. Whereas in humans and other mammals the relevant dynamical complexity may depend on the interaction of a mesodiencephalic system with a thalamocortical system, in non-mammals it may depend on different anatomies, for example, a differentiated telencephalon in birds, and the optic, and vertical and superior lobes in cephalopods (Edelman, Baars, & Seth, 2005). In any case, by shifting the theoretical spotlight away from cortex and towards architectonic features that are conserved among a wider range of species, Merker's article lies squarely in the productive tradition of challenging human and mammalian privilege.

REFERENCES:

- Edelman, D. B., Baars, B. J., & Seth, A. K. (2005). Identifying the hallmarks of consciousness in non-mammalian species. *Consciousness and Cognition*, *14*(1), 169-187.
- Edelman, G. M. (2003). Naturalizing consciousness: a theoretical framework. *Proc Natl Acad Sci U S A*, *100*(9), 5520-5524.
- Edelman, G. M., & Tononi, G. (2000). *A universe of consciousness : how matter becomes imagination* (1st ed.). New York, NY: Basic Books.
- Humphries, M. D., Gurney, K., Redgrave, P., & Prescott, T. J. ((in press)). Is there a brainstem substrate for action selection? *Philos Trans R Soc Lond B Biol Sci*.
- Prescott, T. J., Redgrave, P., & Gurney, K. (1999). Layered control architectures in robots and vertebrates. *Adaptive Behavior*, *7*(1), 99-127.
- Seth, A. K. (2005). Causal connectivity analysis of evolved neural networks during behavior. *Network: Computation in Neural Systems*, *16*(1), 35-55.
- Seth, A. K. (in press). The ecology of action selection: Insights from artificial life. *Philos Trans R Soc Lond B Biol Sci*.
- Seth, A. K., Baars, B. J., & Edelman, D. B. (2005). Criteria for consciousness in humans and other mammals. *Consciousness and Cognition*, *14*(1), 119-139.
- Seth, A. K., Izhikevich, E., Reeke, G. N., & Edelman, G. M. (2006). Theories and measures of consciousness: An extended framework. *Proc Natl Acad Sci U S A*, *103*(28), 10799-10804.

- Sporns, O., Tononi, G., & Edelman, G. M. (2000). Theoretical neuroanatomy: Relating anatomical and functional connectivity in graphs and cortical connection matrices. *Cerebral Cortex*, *10*, 127-141.
- Tononi, G. (2004). An information integration theory of consciousness. *BMC Neurosci*, *5*(1), 42.
- Tononi, G., & Edelman, G. M. (1998). Consciousness and complexity. *Science*, *282*(5395), 1846-1851.