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Evolution of Consciousness

Report on the Agora Workshop in Sigtuna, Sweden, on 11–13 August 2001

Introduction

In order to discuss evolutionary aspects of consciousness, researchers from neuroscience, medical psychology, zoology, biophysics, computer science and philosophy were convened for the workshop, *Evolution of Consciousness*, at the research centre Agora for Biosystems, August 11–13, 2001 in Sigtuna, Sweden. The workshop took place in immediate conjunction with the conference *Consciousness and Its Place in Nature*, arranged in the series Toward a Science of Consciousness at Skövde University College (reported in Vaas, 2002).

Invited speakers at the Agora workshop were: Bernard Baars (San Diego), Jean-Pierre Changeux (Paris), Rodney Cotterill (Copenhagen), Bent Foltmann (Copenhagen), Peter Melander (Umeå), Björn Merker (Stockholm), Sakire Pögun (Izmir), Antti Revonsuo (Turku) and Sverre Sjölander (Linköping). The meeting was a follow-up of the August 2000 workshop, *Unconsciousness-Consciousness: Tools for Exploring the Transition*, which examined the foundations of ethological, psychological, pharmacological, neurophysiological, physical and computational tools used in the study of consciousness (reported in Århem *et al*., 2001).

The present workshop focused mainly on questions concerning the neurobiological basis of consciousness. For the most part, the discussion concerned mammalian brain physiology (Changeux, Cotterill, Merker, Baars), vertebrate neuroethology (Sjölander), clinical cognitive tests (Changeux) and mathematical models of neural networks (Changeux, Cotterill). Antti Revonsuo discussed the evolutionary origin and role of dreaming and presented a case for his threat hypothesis, according to which dreams are understood as simulations, serving a preparatory role for dealing with threats during waking states. Bent Foltmann

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discussed the evolution and possible adaptive value of advanced forms of consciousness, involving an ability to form internal representations of the external world without direct sensory inputs, and how this capacity may have developed into an ability of abstract thinking.

Philosophical and educational issues were also discussed. Peter Melander discussed the tenability of different hypotheses of the relation between conscious states and activities of the brain — psycho-physical parallelism, epiphenomenalism and the identity theory — in view of the assumption that the ability to produce conscious states is a 'biological function' of the brain. Granted this assumption, he reasoned, psycho-physical parallelism and epiphenomenalism, must be false. Provided that the brain is an adaptation for producing conscious states, he further concluded, having conscious states must have been adaptive and, consequently, the conscious states must have had physical effects. It may be noted here, that also Karl Popper reasons along these lines in *The Self and Its Brain* (Popper & Eccles, 1977). Unlike Popper, however, Melander did not rule out the possibility that conscious processes are physical. On the contrary, he called attention to the heuristic value in science of the principle that anything that has physical causes and physical effects is itself physical.

Sakire Pögun gave an exposition of the widely different ways consciousness is defined and treated in contemporary text books in medicine, neurobiology, psychiatry and psychology. One of the interesting observations, also confirmed by Bernard Baars, was that very little, if anything, is said about consciousness in text books in biological psychology. Pögün also discussed how different authors relate consciousness to various brain circuits and processes, and how different brain states can be affected by, e.g., certain substrates. (For a detailed program with abstracts, see web site, *www.agora.kva.se/meetings/evolconsc01.html*)

Neuronal Structures Required

One of the objectives of the workshop was to shed light on what neural structures may be required for mammalian consciousness. The workshop largely agreed on a tentative minimal neural circuit, comprising cortical premotor and sensory areas, in combination with the anterior cingulate cortex and the thalamic intralaminar and reticular nuclei. Less agreement was reached when attempts were made to describe the role of mesencephalic nuclei, such as nucleus superior colliculus and locus coeruleus. The most detailed structural hypothesis was that presented by Rodney Cotterill, based on his contention that the motor output forms the basic feature of neural systems related to consciousness (see Cotterill, 2001). According to Cotterill, characteristic of a system supporting consciousness is a direct route from muscle spindles to sensory cortex. This hypothesis is of great interest, since it could provide a means for distinguishing between conscious and unconscious brains. Cotterill also demonstrated a computer simulation of his model, illustrated by CyberChild, a feeding (and crying) computer baby.

In general, the neurobiological views discussed were well within the frames of the global workspace hypothesis, presented by Bernard Baars (1988), and

discussed also by Jean-Pierre Changeux (Dehaene, *et al*., 1998). According to this hypothesis, there is a computational space in the brain composed of distributed and heavily interconnected neurons with long-range axons, which are mobilized in effortful tasks. This space connects to a set of specialized and modular perceptual, motor, memory, evaluative and attentional processors.

A possible conclusion of evolutionary significance that may be drawn from this general minimal circuit model is that at least all mammals are conscious, in some sense. They have the neural equipment, a common 'Bauplan', apparently required for human consciousness. There was less agreement about the lower limit for consciousness in the evolutionary scale. Bernard Baars and Rodney Cotterill did not find it fruitful at this stage to discuss consciousness 'below' the mammal/bird border, to include e.g. reptiles. Sverre Sjölander defended a similar position, based on ethological evidence. Björn Merker described findings related to the vestibularis apparatus, that can be used to place the border considerably lower, at the primitive vertebrate class Agnatha (jawless fish). On these grounds, it could even be argued that the large cephalopods (e.g. squids and octopuses) are conscious. Eventually, it might become important to distinguish between different degrees and levels of consciousness, related to the complexity of the nervous system of the respective species.

Neuronal Activity Required

A general view put forward during the meeting was that consciousness is linked to a basic biological adaptation with many survival functions. One of the functions of consciousness would be of a logistic nature. Others include goal-directed behaviour, learning, and decision-making.

Questions about the more detailed location of neurons directly associated with consciousness were less discussed. Indeed, it is one thing to determine the required circuitry and another to determine which neurons are directly involved. The latter is a much harder problem. However, some recent studies were brought up. For instance, studies of binocular rivalry, that suggest sub-regions of the visual circuitry to be critical (inferotemperal fields), and the idea of an interaction between streams of neural activity in cortex suggests a limited region of the neocortex to be directly involved.

Owing to experimental difficulties, the neural processes associated with consciousness were less discussed than the neural structures. At present, this issue is not very accessible for experimental investigations. Jean-Pierre Changeux presented one approach to reach an understanding by constructing mathematical models of neural networks that accomplish specific cognitive tests. His own case was based on the classical Stroop task. Computer simulations of this task showed that workspace activation increases during acquisition of a novel task, effortful execution, and after errors.

Conclusion

In summary, the present workshop was, in our opinion, a successful follow-up of the previous workshop on the unconsciousness–consciousness transition. The meeting was able to bring into focus concrete questions about the evolution of consciousness, and managed to steer clear of the most speculative and abstract attributes of this issue. It succeeded in presenting a more detailed picture of the tentative neural circuitry, required for mammalian consciousness, and in outlining some new avenues towards understanding consciousness by constructing minimal models accomplishing cognitive tasks. Consequently, it was possible to derive a more detailed description of the evolutionary pathways of consciousness. An apparent point of this consensus view was the conclusion that consciousness, as we know it, would be shared by (at least) all mammals.

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