



Review

Consciousness in the universe A review of the ‘Orch OR’ theory

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Abstract

The nature of consciousness, the mechanism by which it occurs in the brain, and its ultimate place in the universe are unknown. We proposed in the mid 1990’s that consciousness depends on biologically ‘orchestrated’ coherent quantum processes in collections of microtubules within brain neurons, that these quantum processes correlate with, and regulate, neuronal synaptic and membrane activity, and that the continuous Schrödinger evolution of each such process terminates in accordance with the specific Diósi–Penrose (DP) scheme of ‘objective reduction’ (‘OR’) of the quantum state. This orchestrated OR activity (‘Orch OR’) is taken to result in moments of conscious awareness and/or choice. The DP form of OR is related to the fundamentals of quantum mechanics and space–time geometry, so Orch OR suggests that there is a connection between the brain’s biomolecular processes and the basic structure of the universe. Here we review Orch OR in light of criticisms and developments in quantum biology, neuroscience, physics and cosmology. We also introduce a novel suggestion of ‘beat frequencies’ of faster microtubule vibrations as a possible source of the observed electro-encephalographic (‘EEG’) correlates of consciousness. We conclude that consciousness plays an intrinsic role in the universe.

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1. Introduction: Consciousness in the universe

Consciousness implies awareness: subjective, phenomenal experience of internal and external worlds. Consciousness also implies a sense of self, feelings, choice, control of voluntary behavior, memory, thought, language, and (e.g. when we close our eyes, or meditate) internally-generated images and geometric patterns. But what consciousness actually *is* remains unknown. Our views of reality, of the universe, of ourselves depend on consciousness. Consciousness defines our existence.

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Three general possibilities regarding the origin and place of consciousness in the universe have been commonly expressed.

- (A) *Consciousness is not an independent quality but arose, in terms of conventional physical processes, as a natural evolutionary consequence of the biological adaptation of brains and nervous systems.* This prevalent scientific view is that consciousness emerged as a property of complex biological computation during the course of evolution. Opinions vary as to when, where and how consciousness appeared, e.g. only recently in humans, or earlier in lower organisms. Consciousness as an evolutionary adaptation is commonly assumed to be epiphenomenal (i.e. a secondary effect without independent influence [1–3]), and also illusory (largely constructing reality, rather than perceiving it [4]). Nonetheless, consciousness is frequently argued to confer beneficial advantages to species [5]. Overall, in this view, consciousness is *not* an intrinsic feature of the universe.
- (B) *Consciousness is a separate quality, distinct from physical actions and not controlled by physical laws, that has always been in the universe.* Descartes’ ‘dualism’, religious viewpoints, and other spiritual approaches assume consciousness has been in the universe all along, e.g. as the ‘ground of being’, ‘creator’ or component of an omnipresent ‘God’ [6]. In this view consciousness can causally influence physical matter and human behavior, but has no basis or description in science [7]. In another approach, panpsychism attributes consciousness to all matter, but without scientific identity *or* causal influence. Idealism contends consciousness is all that exists, the material world (and science) being an illusion [8]. In all these views, consciousness lies outside science.
- (C) *Consciousness results from discrete physical events; such events have always existed in the universe as non-cognitive, proto-conscious events, these acting as part of precise physical laws not yet fully understood.* Biology evolved a mechanism to orchestrate such events and to couple them to neuronal activity, resulting in meaningful, cognitive, conscious moments and thence also to causal control of behavior. These events are proposed specifically to be moments of quantum state reduction (intrinsic quantum “self-measurement”). Such events need not necessarily be taken as part of current theories of the laws of the universe, but should ultimately be scientifically describable. This is basically the type of view put forward, in very general terms, by the philosopher A.N. Whitehead [9,10] and also fleshed out in a scientific framework in the Penrose–Hameroff theory of ‘orchestrated objective reduction’ (‘Orch OR’ [11–16]). In the Orch OR theory, these conscious events are terminations of quantum computations in brain microtubules reducing by Diósi–Penrose ‘objective reduction’ (‘OR’), and having experiential qualities. In this view consciousness is an intrinsic feature of the action of the universe.

In summary, we have:

- (A) Science/Materialism, with consciousness having no distinctive role [1–5].
- (B) Dualism/Spirituality, with consciousness (etc.) being outside science [6–8].
- (C) Science, with consciousness as an essential ingredient of physical laws not yet fully understood [9–17].

2. Consciousness, computation and brain activities

2.1. Unexplained features of consciousness

How does the brain produce consciousness? Most scientists and philosophers view consciousness as an emergent property of complex computation among ‘integrate-and-fire’ brain neurons which interconnect and switch at chemically-mediated synapses. However the mechanism by which such neuronal computation may produce conscious experience remains unknown [18,19]. Specific unexplained features of consciousness include the following:

The ‘hard problem’ What is the nature of phenomenal experience, and what distinguishes conscious from non-conscious cognition? Perception and behavior may be accompanied or driven by phenomenal conscious awareness, experience, or subjective feelings, composed of what philosophers call ‘qualia’ [19]. However perception and behavior may at other times be unaccompanied by consciousness. We could have evolved as full-time non-conscious ‘zombies’ performing complex ‘auto-pilot’ behaviors without conscious awareness. How and why do we have phenomenal consciousness, an ‘inner life’ of subjective experience?

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