

Consciousness; Its seat: Present and Future and Medico legal Perspectives

B.V.Subrahmanyam¹, S.V.Phanindra², G.V. Nagi Reddy³, K.S.V.K. Subba Rao⁴,
Amit Agarwal⁵, K. Krishna Murthy⁶

Abstract

Every doctor knows about unconsciousness. However how many of us contemplate on Consciousness? It appears that the concept of consciousness and the seat of Consciousness have been eluding the professionals, scientists and the spiritualists. With the advent of MRI and Conceptualization of consciousness at the cellular and microtubule levels a positive outlook appears to be on an even keel in the understanding of consciousness. The present paper tries to deal with these issues.

Key words: Consciousness, Quantum Theory, Microtubules

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Introduction:

Whereas, we are at ease in talking about unconsciousness, coma and may be death, it is still an enigma for us to actualize what is consciousness. In this paper we present the state of understanding of consciousness and its future possibilities and its medico legal perspectives.¹

What is consciousness?

The best way we can define consciousness is ability to interact with environment. There are various angles to consciousness. They are neurological psychological philosophical and religious ones. In the words of Maxvelman and Susan Schneider. Anything that we are aware of at a given moment forms part of our consciousness, making conscious experience at once the most familiar and most mysterious aspect of our lives! William Lycan mentioned types

of consciousness that are identifiable, organism consciousness, control consciousness, event consciousness, introspective consciousness, subjective consciousness and self-consciousness state.² According to William Lames normal human consciousness consists of a serially time ordered, organized, restricted and reflective awareness of self and the environment. It is an experience of graded complexity and quantity. Missing from this definition is the intimate linkage between arousal level, which indexes both unconscious and conscious brain states including stages of sleep from unconscious stage slow-wave sleep to the conscious imagery of rapid eye movement (REM) sleep, levels of responsiveness across the range of disorders of consciousness, and variations in the effects of anesthetics from coma to light sedation and the core neuropsychological components of normal awake, conscious brain function that provide the contents of consciousness, is a range of specific functional types of attention intention, memory, awareness and mood-emotion.³

¹ Medico legal consultant, ²Professor, Forensic Medicine & Toxicology, ³Professor of Cardio thoracic surgery,

⁴Professor of Neurosurgery, ⁶Professor of Psychiatry

^aNarayana Medical College & Hospital, Nellore – 524003, A.P. ^bMedical College, Bharatpur Nepal

Correspondence: Dr. S.V.Phanindra,

Tel: +91 8008511603

Email:phanindrasangam@gmail.com

The various levels of consciousness disorder are:

- Coma
- Vegetative state
- Minimally conscious state
- Acute confusion state
- Disorders of consciousness (DOC) arise from direct perturbations of neural systems that regulate arousal and awareness and indirectly from disruptions in the connections between these systems.
- Distinct clinical syndromes have been identified, but behavioural features often fluctuate and cross diagnostic borders within individual patients, probably reflecting aberrant dynamic changes in corticothalamic neuronal activity.
- Novel applications of functional neuroimaging and electrophysiological techniques have been employed to detect covert signs of conscious awareness improve outcome prediction, and establish brain – computer interfaces to augment communication ability.
- Recent empirical evidence suggests that treatment intervention aimed at neuromodulation can accelerate recovery and enhance outcome during both the acute and chronic phases.
- A paradigm shift should change the pervasive nihilism that continues to complicate patient management, family adjustment medico legal issues and healthcare policy in relation to DOC.⁴

Creating and maintaining the conscious state:

Much recent effort has focused on the neurobiological underpinnings of the conscious stage, beginning with experimental studies isolating the roles of several core brainstem, basal forebrain and hypothalamic systems in supporting variations in neuronal firing patterns across the entire corticothalamic system in relation to different levels of arousal. The awake conscious state is fundamentally identified with highly energy demanding activity

within the corticothalamic system. These energy demands derive strongly from complex, high-frequency neuronal firing patterns associated with depolarization of cortical, thalamic and striatal membrane potentials.⁵

Large reductions in arousal level in normal individuals involve broad hyper polarization of these neurons via withdrawal of excitatory neuro modulatory influences from cholinergic, noradrenergic and other brainstem, basal forebrain and hypothalamic systems. Such hyperpolarization of cortical and thalamic neurons progressively occurs across deeper stages of sleep (or with broad inhibitory effects of anesthesia), markedly shifts the firing patterns of these neuronal populations and influences the overall pattern of corticothalamic dynamics toward more-synchronous and dynamically stereotyped waves of activity compared with the more spatiotemporally differentiated patterns associated with the wakeful conscious state.^{5, 6}

The mechanistic link between consciousness and the more depolarized, activated and spatiotemporally complex activated state has not been formulated. Nonetheless, several key requirements have been proposed, particularly with respect to the types of brain activity that correlate with conscious brain states, the timescales of specific neurophysiological processes that are consistent with psychophysiological measurements of awareness, and the role of global availability of information across the brain. Experimental studies that focus on contrasts between no conscious and conscious processing of information in normal individuals demonstrate that conscious brain activity is typically associated with widely distributed brain regions within the prefrontal and parietal cortex, the sensory areas of which show synchronous activity and late amplification of activity. Such processes are posited to be necessary for an abstract distributed dynamic activity, known as the global workspace, to have access to sensory or

internal cognitive representations and maintain activation over hundreds of milliseconds.^{6,7}

Measurements of Consciousness:

Metric test

The line between consciousness and unconsciousness is generally very clear. In people with brain injuries who can neither talk nor move, the differences are harder to define. Neuroscientists have now devised a single metric of brain activity to distinguish between different states of consciousness and guide medical treatment for people with brain injuries. The metric relies on the idea that consciousness involves widespread communication between different areas of the brain, with each region performing specialized functions. Loss of consciousness during sleep or anesthesia, or from brain injury, may be caused by the disengagement of brain regions from one another.

By now we are aware that everything in the universe is made out of energy. Quantum physicists discovered that physical atoms are made up of vortices of energy that are constantly spinning and vibrating. Matter is energy, and human consciousness is connected to it, human consciousness can influence its behavior and may even re-structure it. When a scientific theory cannot cope with the question of the very origin of the universal matter and energy, how could it ever grasp and explain the phenomenon of consciousness which is evident in living beings?

Mind is no longer an accidental intruder into the realm of matter; we may have to see it as the creator and governor of the realm of matter. The universe is immaterial –mental and spiritual. (R.C.Henry, *The Mental Universel*. Nature 436:29, 2005).⁷

The Science of the Heart: The heart generates the largest electromagnetic field produced in the body. Researchers have analyzed the spectrum analysis of the magnetic field that's produced by the heart, and results have shown that emotional information is encoded into this electromagnetic field so, by shifting our

emotions, we are changing the information that is encoded into the electromagnetic fields that are radiated by the heart. This can impact those around us. When we are feeling emotions of compassion, love, gratitude and understanding the heart beats out a very different message.

Electromagnetic test

Neurophysiologist Marcello Massimini of the University of Milan in Italy and his colleagues, found that electromagnetic stimulation of conscious persons brain sets off a cascade of activity and generates unique responses in different brain regions. In unconscious people, this activity either fails to spread, or there is little variation in the responses from different brain areas. The researchers present a mathematical measure to quantify the extent and richness of response to the stimulus — a mild electromagnetic pulse applied through the scalp. They applied the technique to 52 people in Italy, Belgium and the United States between 2005 and 2009. In healthy participants; the metric was high during wakefulness, and cut by about half during anesthesia-induced unconsciousness and in some stages of sleep.

The metric was low for people clinically diagnosed as vegetative — wakeful, but unaware and unresponsive. In two study participants with locked-in syndrome, fully aware but able to respond only minimally, the metric was high. In people with brain injuries that were diagnosed with intermediate states of consciousness were found in the two extremes. These distinctions help physicians to determine when and how aggressively to pursue different treatment options. The metric can also be used to monitor how well treatments are working. None of the people with brain injuries recovered during the course of the study, so researchers could not determine long-term changes in the measure. On some healthy participants, the measure was used to track changes between wakefulness and varying degrees of sedation induced by anesthetic.

Functional brain imaging

Adrian Owen, a neuroscientist at the University of Western Ontario in London, Canada, has pioneered the use of functional brain imaging to diagnose levels of consciousness in people with brain injuries. This technique requires the use of magnetic resonance imaging and the active concentration of the patient. (Massimini's method is easier to apply, and does not require anything of the patient.)

ORCH-OR THEORY

Hameroff and Penrose propounded the Orch OR theory (orchestrated objective reduction). It is an attempt to place consciousness within the empirical sciences as a fundamental concept in science. This is in contrast to emerging phenomenon approaches or spiritualistic/ dualistic concepts (Orch OR theory linked this phenomenon to numerous enigmatic features and observations ranging from the intelligent behavior of single-cell organisms to anesthesia.) The central postulate of the Orch OR theory is that the site of action of consciousness is located within the brain's microtubules (MTs) which operate at the interlace between classical neurophysiology and quantum gravitational forces. This is very challenging as at present the gold standard in neuroscience is functional MRI and its spatial resolution is on the 1 mm scale while temporal resolution is on the 1 s scale. This order of magnitude is higher than the 1 nm and 1 ns scales of tubulin's size/time operational dimensions as studied by molecular biophysicists, let alone the quantum gravity effects hypothesized by Orch OR to be occurring on the Planck scale of space-time geometry (10^{-35} m: 10^{-44} s).⁸ That means there is a huge gap between the present experimental capabilities and the Orch OR theory poses the greatest challenge to the acceptance of these tenets. Divorcing consciousness from life forms puts it back into the spiritual/dualistic type of reasoning which Orch OR rejects.

How can one account for metabolism taking place in neurons, which would be a minimal requirement for making Orch OR account for life? The emphasis based on the gravitational interactions is difficult to accept within conventional physics. The time tested approach to solving equations of motion (in both classical and quantum physics) is a perturbation method where the first approximation is given by the strongest forces and then these solutions are subjected to the next weaker force, etc., giving a reasonable representation of reality by mathematical convergence of approximate solutions.

Computer-like neural correlates of consciousness involves neuronal circuits oscillating synchronously in thalamus and cerebral cortex. Higher frequency oscillations (collectively known as coherent 40 Hz) are suggested to mediate temporal binding of conscious experience (e.g. Singer et al 1990; Crick and Koch, 1990; Joliot et al, 1994; Gray, 1998). The proposals vary, for example as to whether coherence originates in thalamus or resonates in cortical networks, but thalamo-cortical 40 Hz stands as a prevalent view of the neural-level substrate for consciousness.

How neural firings lead to thoughts and feelings? Conventional (functionalist) approaches fall short on the mind's enigmatic features. These include: 1) the nature of subjective experience, or qualia, our inner life (e.g. Nagel, 1997; Chalmers, 1996) 2) binding of spatially distributed brain activities into unitary objects in vision and a coherent sense of self 3) transition from preconscious processing to consciousness, 4) non-computability (Penrose, 1989; 1994; 1997), and 5) free will.⁹

Marshall (1989) suggested that coherent quantum states known as Bose-Einstein condensation occurred among neural proteins (c.f. Penrose, 1987; Bohm and Hiley, 1993; Jibu and Yasue, 1995). Pre-conscious to conscious transitions was identified by Stapp (1992) with collapse of a

quantum wave function in pre-synaptic axon terminals (c.f. Beck and Eccles, (1992). In another proposal, protein assemblies called microtubules within the brain's neurons are looked upon as self-organizing quantum computers (orchestrated objective reduction Orch OR) e.g. Penrose and Hameroff, 1995; Hameroff and Penrose 1996a; 1996b; c.f. Hameroff 1997; 1998a; 1998b; 1998c; 1998d).¹⁰

Penrose views the bubbles are unstable, with a critical objective degree of separation resulting in instantaneous reduction to classical, no separated states. Objective reductions are events which reconfigure the fine scale of space time geometry.¹¹

Microtubules are functionally organized by webs of protein polymers-the cytoskeleton. Major components of the cytoskeleton are microtubules, self-assembling hollow crystalline cylinders whose walls are hexagonal lattices of subunit proteins known as tubulin. Microtubules are essential for cell movement, cell division (mitosis) and establishment and maintenance of cell form and function. In neurons, microtubules self-assemble to extend axons and dendrites and form synaptic connections. Microtubules help maintain and regulate synaptic strengths responsible for learning and cognitive functions. Microtubules are traditionally considered as purely structural components. Recent evidence has demonstrated mechanical signaling and communication functions as well. Microtubules interact with membrane structures and activities by linking proteins (e.g. fodrin, akkyrin) and second messenger chemical signals.^{12, 13}

Microtubule subunit tubulins undergo coherent excitations, in the giga Hz range by a mechanism suggested by Frhlich. O. Penrose and L. Onsager. Frhlich excitations of tubulin subunits within microtubules have been suggested to support computation and information processing (Hameroff and Watt, 1982; Rasmussen et al., 1990), The coherent excitations are proposed to clock computational transitions occurring among

neighboring tubulins acting as cells as in molecular scale cellular automata. Dipole coupling among neighboring tubulins in the microtubule lattice act as "transition rules" for simulated microtubule automated exhibiting information processing, transmission and learning.¹⁴

As the human brain contains about 10^{11} neurons, nanosecond microtubule automata offer about 1027 brain operations per second. However even a vast increase in computational complexity won't by itself address the difficult issues related to consciousness but Quantum coherent states and quantum computation with objective reduction (Orch OR) appear to address the same. Macroscopic quantum states in brain microtubules would have to somehow avoid environmental decoherence and still communicate with the environment. Nature may have solved this problem with alternating phases of isolation and communication.¹⁵

Microtubules and other cytoskeleton components are embedded in cytoplasm which exists in alternating phases of 1) "sol" (solution, liquid), and 2) "gel" (gelatinous, solid).¹⁶

Unlike chemical synapses which separate neural processes by 3050 nanometers, gap junction separations are 3.5 nanometers, within range for quantum tunneling. Widespread unevenly distributed high levels of gap junctions appear in thalamus and cortex. Thalamocortical networks of gap junction connected neurons with sol-gel phases coupled to synchronized 40 Hz activity could transiently isolate quantum state across large brain volumes.

Quantum computing with objective reduction-The Penrose-Hameroff Orch OR model

Conformational state of individual tubulin proteins in brain microtubules are sensitive to internal quantum events (e.g. London forces in hydrophobic pockets) and able to cooperatively interact with other tubulins in both classical and quantum computation.

Classical phase computation (microtubule automata) regulates chemical synapses and other neural membrane activities. Quantum coherent superposition supporting quantum computation emerges among London forces in hydrophobic pockets of microtubule submit tubulins (e.g. in a manner described by Frohlich, 1968; 1975). In this phase, quantum computation among tubulins evolves linearly according to the Schrodinger equation (quantum microtubule automata). Acting elation and a condensed charge phase surrounds isolates and insulates microtubules during the quantum phase. The proposed quantum superposition/computation phase in neural microtubules corresponds to preconscious (implicit) processing, which continues until the threshold for Penrose's objective reduction is reached. Objective reduction ((OR)-a discrete event then occurs, and post OR tubulin states (chosen non-computably) proceed by classical microtubule automata to regulate synapses and other neural membrane activities. A sequence of such events gives rise to a stream of consciousness. Probabilities and possibilities for pre-conscious quantum superpositions are influenced by biological feedback including attachments of microtubule associated proteins (MAPs) which tune and "orchestrate" quantum oscillations. We thus term the self-tuning OR process in microtubules "orchestrated" objective reduction Orch OR.¹⁷

Each instantaneous Orch OR event binds superposed information encoded in microtubules whose net displacement reaches threshold at a particular moment: a variety of different modes of information is thus bound into a now event. As quantum state reductions are irreversible in time, cascades of Orch OR events present a forward flow of time and stream of consciousness.¹⁸

Five features of consciousness are 1) the nature of subjective experience, 2) "binding" in vision and sense of "self" 3) transition from pre-conscious processing to

consciousness, 4) non-computability and 5) free will.¹⁹

Democritus described empty space as a true void whereas Aristotle saw a background "plenum" filled with substance. Maxwell's 19th-century "luminiferous ether" sided with Aristotle but attempts to detect the ether failed and Einstein's special relativity agreed with Democritus: empty space was an absolute void. However Einstein's general relativity with its curved space and distorted geometry reverted to a richly-endowed plenum the space time metric.²⁰

Planck-scale spin networks could provide Whitehead's basic field of proto-conscious experience, Shimony (1993) has suggested Whitehead occasions are quantum state reductions. Penrose objective (quantum state) reductions are bubble-like separations and collapses in fundamental space-time geometry extending downward to the level of spin networks. Orch OR events could be Whitehead occasions of experience.²¹

Planck scale spin networks encode protoconscious ("funda-mental") experience (qualia) as well as Platonic values. Particular configurations of quantum spin geometry convey particular varieties of proto-conscious experience, meaning and aesthetics. The proposed Orch OR events occur in the brain, extending downward to processes in an experiential Planck scale medium. The basic idea is that consciousness involves brain activities coupled to self-organizing ripples in fundamental reality.

Orch OR process may be an emergent phenomenon in quantum geometry mediated through London forces in hydrophobic pockets of tubulin and other proteins. Binding is potentially resolved by the unitary nature of quantum states (e.g. Penrose, 1987). Binding is a feature of Bose-Einstein condensates among certain of the brain's neural proteins. In the Orch OR model, an instantaneous event binds superposed information whose net mass/space time displacement reaches threshold at a particular moment, Different

modes and time scales of information are bound into a unitary “now” event.

Transition from pre-conscious processing to consciousness

In Orch OR preconscious processing is equivalent to the quantum superposition phase of quantum computation. Potential possibilities interact and then abruptly self-collapse a slight quake in space time geometry. As quantum state reductions are irreversible, cascades of Orch OR events present a forward flow of subjective time and “stream of consciousness”.

For example during 25 milliseconds of pre-conscious processing quantum computation occurs with information in the form of qubitsl superposed states of microtubule tubulin subunits within groups of neurons. As threshold for objective reduction is reached, an instantaneous conscious event occurs. The superposed tubulin qubits reduce to definite states, becoming bits. Now, you recognize that she is Coro!! (An immense number of possibilities could be superposed in a human brain's 10^{19} tubulins).^{22, 23}

The ORch OR model suggests that quantum coherent superposition occurs in microtubules which are immediately surrounded by an insulating charge condensation and encased (cyclically) in acting elation. Cyclical isolation allows for alternating phases of communication (input/output) and isolated quantum computation.²⁴

Quantum coherence occurs in microtubules. Microtubule quantum coherence requires isolation by cycles of surrounding acting elation. Macroscopic quantum coherence occurs among MT in hundreds/thousands of distributed neurons and glia linked by gap junctions. The amount of neural tissue involved in a conscious event is inversely proportional to the event time.

A critical degree of cytoskeletal assembly (coinciding with the onset of rudimentary consciousness) has significant impact on the rate of evolution.^{25, 26}

The Hameroff-Penrose form of orchestrated objective reduction is related to the fundamentals of quantum mechanics and space-time geometry hence the connection between the basic structure of the Universe and biomolecular processes. Relating these effects to neurons might appear an unjustified self-inflicted limitation. Consciousness is a property and a manifestation of life.²⁷

The potential for reconciling science and consciousness was first glimpsed during the quantum revolution a century ago when several of the greatest physicists, including Schrodinger, Heisenberg, Planck, and Pauli, surmised that consciousness might be so fundamental that it can't be gotten around. Penrose and Hameroff, begin with the brain as a testable locus of the mind, the standard materialist position. The Penrose-Hameroff claims that “spiritual” systems are dual. It posits the cosmos as the play of consciousness, which undergoes transformations into what we perceive as matter and energy, by inserting platonic values from mathematics.²⁸

Hameroff and Penrose theory has three components: Objective Reduction, Orchestration, and a quantum mechanical re-interpretation of neurophysiology leading to Quantum Computing in the Brain. Hameroff and Penrose try to make the match, explaining (though not algorithmically) quantum-mechanical fluctuations as due to small alterations in the gravitational field. Such tiny differences in space-time structure can have large effects, for they entail subtle but fundamental influences on the very rules of quantum mechanics:

The medico legal angle

The question of consciousness semi-consciousness and unconsciousness become important issues in relation to assessing the criminal responsibility. The Indian law as well as laws many countries presume that for every criminal act there must be criminal mind (*mens rea*) and such a state of mind can exist only when the person is

conscious. Hence persons with altered levels of consciousness in conditions like automatism; somnambulism, somnolentia etc. are not held responsible for crimes committed by them. When person is drunk and perform an unlawful act in a stage of altered consciousness he will not be responsible for criminal act if the intoxicating agent was administered without his knowledge. However so such immunity is offered to a hypnotized person.

A misdiagnosis case of consciousness may contribute to premature withdrawal of life-sustaining care and lead to a case of medical negligence. While behavioural assessment of DOC remains the gold standard, neuroimaging permits objective documentation of CNS damage after acquired brain injury. Individual patients are conscious (locked in) or unconscious (VS). Fronto parietal midline structures are thought to be important for internal, stimulus-independent or "Self" consciousness, whereas lateral frontoparietal cortices seem to be critical for external or sensory awareness. In the absence of a full understanding of the neural correlates of consciousness, deficient cortical activation to external stimuli does not necessarily prove the absence of consciousness.

Valid Consent must be taken in all cases of Consciousness disorders like Locked in syndrome, vegetative states, unconsciousness where there is no response for verbal stimuli and there is no conscious and aware verbal communication. In other cases where the consciousness was sufficient enough to legally constitute competency, patient's own voluntary informed consent or voluntary informed refusal should be recorded.

Conclusion

In conclusion we may say that a new direction integrating quantum physics and consciousness is in the horizon. A quantum leap is essentially required to reckon with the reality regarding the seat of consciousness. The Medicolegal issues

related to consciousness disorder must be critically reviewed and weighed in the light of the present knowledge regarding the consciousness integrated with quantum mechanics and functional neuroimaging

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Table 1. Characteristic clinical features of disorders consciousness (DOC)

Disorder	Arousal and attention	Cognition	Receptive language	Expressive language	Visual perception	Motor function
Coma	No sleep - wake cycles	None	None	None	None	Primitive reflexes only
Vegetative state	Intermittent periods of wakefulness	None	None	None	Inconsistent visual startle	Involuntary movement only
Minimally conscious state	Intermittent periods of wakefulness	Inconsistent but Clear-cut behavioral signs of self-awareness or environmental awareness	Inconsistent one-step command following	Spontaneous and limited to single words or short phrases	Visual pursuit Object recognition	Localization to noxious stimuli Object manipulation Automatic movement sequences.
Post traumatic confusion state ACS	Extended periods of wakefulness	Confused and disoriented	Consistent one step command following	Sentence-level speech, often confused, perseverated Reliable yes-no responses	Object recognition	Functional use of common objects.
Locked-in syndrome	Normal sleep-wake cycles	Normal to near-normal	Normal	Aphonic	Normal	Tetraplegia