Perspectives

Falsifications of Hameroff-Penrose Orch OR Model of Consciousness and Novel Avenues for Development of Quantum Mind Theory

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Abstract

In this paper we try to make a clear distinction between quantum mysticism and quantum mind theory. Quackery always accompanies science especially in controversial and still under development areas and since the quantum mind theory is a science youngster it must clearly demarcate itself from the great stuff of pseudo-science currently patronized by the term "quantum mind". Quantum theory has attracted a big deal of attention and opened new avenues for building up a physical theory of mind because its principles and experimental foundations are as strange as the phenomenon of consciousness itself. Yet, the unwarranted recourse to paranormal phenomena as supporting the quantum mind theory plus the extremely bad biological mismodeling of brain physiology lead to great scepticism about the viability of the approach. We give as an example the Hameroff-Penrose Orch OR model with a list of twenty four problems not being repaired for a whole decade after the birth of the model in 1996. In the exposition we have tried not only to pesent critique of the spotted flaws, but to provide novel possibilities towards creation of neuroscientific quantum model of mind that incorporates all the available data from the basic disciplines (biochemistry, cell physiology, etc.) up to the clinical observations (neurology, neurosurgery, molecular psychiatry, etc.). Thus in a concise fashion we outline what can be done scientifically to improve the Q-mind theory and start a research programme (in Lakatos sense) that is independent on the particular flaws in some of the existing Q-mind models.

Key Words: Hameroff and Penrose Theory, OrchOR, objective reduction, quantum mind, microtubules, neuron, consciousness

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1. Split-brain

Hameroff overestimates the role of dendro-dendritic processing and the role of gap junctions between neighbouring dendrites as the main mechanism for coherence between cortical neurons, producing entangled quantum coherent "*superneuron*". He wrongly believes that dendritic microtubules somehow affect the axonal hillock potential and after that the axonal firing follows the well-known classical deterministic behaviour as described by the Hodgkin-Huxley equation. Thus Hameroff claims that in dendritic microtubules occur the quantum events associated with consciousness and after that axons manifest purely classical nonconscious activity. It is believed that

> "Consciousness occurs primarily in dendrites, with axons serving to execute and communicate results of conscious dendritic processes" (Woolf and Hameroff, 2001, p.474).

The main theoretical grounding of such extreme position is the finding that some cortical neurons do not have axons.

> "Some cortical neurons have no axons, and extensive dendritic activity may occur without causing spikes. Excitatory postsynaptic potentials below spike threshold (historically considered noise by many neuroscientists) oscillate coherently in the gamma range across wide regions of brain. Although it is widely assumed to be so, initiation of axonal spikes is not necessarily the raison d'etre of dendrites." (Hameroff, 2006a, p. 403).

1.1 Remark

Classical experiments with split-brain human subjects showed that axons in *corpus callosum* are necessary for "united mind" and cutting them by surgery disintegrates the conscious activities of the two cerebral hemispheres producing prodigious Jekyll-Hyde syndrome. After cutting the axons of corpus callosum in the brain there are two minds each one being completely unaware of other's mind existence and each mind taking control over the opposite half of the body. For this discovery Roger Sperry actually took the Nobel Prize in 1981.

Roger Sperry and Ronald Myers discovered the split-brain effect in the early 1960s. Myers (1955) showed that when the cat had its optic chiasm and corpus callosum severed, two independent learning centers were established - one in each hemisphere of the cat's brain. If the cat had its right eye open and its left eye covered and learned to make a simple conditioned response, it was unable to make the same response when the right eye was covered and the left eye was open. It was as if the learning was unable to be communicated to the other side of the brain; thus, it was obvious that information available to one side remained off-limits to the other.

Roger Sperry and Michael Gazzaniga (Gazzaniga and Sperry, 1967; Sperry and Gazzaniga, 1967; Sperry et al., 1969) began a series of studies of split-brain humans, patients who had had the corpus callosum severed as a therapeutic procedure, and the observations of these clinical patients have formed the basis for a number of significant ideas concerning brain function.

The World War II veteran (known in the scientific literature as W.J.) had undergone surgery to alleviate his epileptic seizures. After the surgery W.J. easily named and described colours, letters, and other information flashed briefly to the right side of his visual field; therefore, W.J.'s left hemisphere needed no help handling basic tasks requiring verbal responses. Then the scientists flashed items in W.J.'s left visual field and waited for the responses of his right hemisphere. As the anxious investigators looked on, W.J. acted as though he had suddenly gone blind. He insisted that he could not see bursts of light, boldface letters, or anything else presented to him. Yet his left hand, under the control of his right hemisphere, pushed down on a telegraph key each time a visual stimulus appeared, just as the scientists had instructed him to do.

In later series of experiments it was shown that the right hemisphere has its own mind and can communicate regardless of the fact that it has no control of the speech center located in the left hemisphere and therefore is deprived from the priviledge to speak.

In his Nobel Lecture Roger Sperry (1981) concluded that after commissurotomy:

> "Each of the disconnected hemispheres, not only the left, has its own higher gnostic functions. Each hemisphere in the lateralized testing procedures appeared to be using its own percepts, mental images, associations and ideas. As in the split-brain animal studies, each could be shown to have its own learning processes and its own separate chain of memories, all of course, essentially inaccessible to conscious experience of the other hemisphere."

That is after commissurotomy the human brain hosts not one but two minds!

Here we want to raise the extremely important point - *the binding problem* cannot be solved by classical communication of information (Georgiev, 2003a; Mashour, 2004). Indeed Hameroff (2006a, 2006b) correctly postulates quantum coherence to explain the conscious binding. The conscious mind feels itself as a single unit, it is a holistic entity and does not equal to two persons communicating with each other. You and your friend may communicate and exchange information, but you and your friend do not collectively feel as being one global mind. In non-split-brain humans the

two hemispheres do not equal to two separate minds that communicate like you and your friend. In normal state (non-split-brain humans) there is a "binding" that unites the two hemispheres so that their experience is united into a single experience. So if quantum coherence is postulated to solve the binding problem, then axons must also convey the quantum coherent states. Therefore axons cannot only classically *"execute and communicate results"* as if between you and your friend, axons provably unite consciousness, and if this is achieved by quantum coherence then they must at any rate extend the quantum coherent states. The observation that some cortical neurons do not have axons must not be erroneously interpreted in a way that "axons and axonal microtubules are unconscious classical relay/output pathways only". This is incompatible with the split-brain data.

Additionally we might argue against axonal classicality. The extremely low reliability of terminal button exocytosis of 0.15-0.30 leads either to chaos, or reduces enormously the computational power of brain via need of classical error correction codes, as will be discussed in a subsequent paragraph.

2. Gap Junction Tuneling and Decoherence

Hameroff wrongly believes that gap junctions can sustain coherence between cortical neurons for time of 25 ms. The acclaimed model requires electrons derived from mitochondria, then tunnelled though gap junctions, and transmitted to microtubules via so called dendritic lamellar bodies (DLBs). The coherent states of microtubules extend in both neurons and glial cells.

2.1 Remark

Gap junctions' electrotonically couple neighbouring neurons and they are hexameric channels composed of subunits called *connexins*, or recently described novel proteins called *pannexins*. There is extensive ion flow, and small molecule transfer through gap junctions such as Ca^{2+}, adenosine triphosphate (ATP), or metabolites. Gap junction hemi-channels are also used for non-SNARE dependent release of neuromediators such as glutamate in developing brain. Hameroff strictly agrees that ion superposition across plasma membrane is impossible as noted by Max Tegmark (1999) where he calculates time till decoherence to be only 10^{-23}s. But ions flowing through gap junction will decohere the system in the same decoherence time. Conservatively done numerical estimate by Georgiev (2002) gives decoherence time $t_{dec}=10^{-9}$ s.

Another critical issue - the molecular biology is completely messed up. DLBs are found only in the main branch of dendrite. They have never been observed in the dendritic spines that communicate with gap junctions. De Zeeuw et al. (1995) clearly show that DLBs are found tens of micrometers away from the actual gap junction couplings, and that

there is only "correlation" between the existence of gap junctions and existence of DLBs in sense that DLBs might be involved in the biosynthesis of gap junctions, but there is no direct structural link between these.

And last, but not least, the tiny astrocytic/glial projections really couple with neurons through gap junctions, but the connexin proteins are mainly Cx43, while neuronal type is Cx36. Even if this is not a big problem, the obvious problem is that the tiny glial projections are lacking microtubules but are filled with actin filaments. Therefore there seems to be a big morphological difference between the cellular projections coupled through gap junctions - neuronal projections have mainly microtubule-based cytoskeleton, while glial projections have almost exclusively actin-based cytoskeleton lacking microtubules.

3. The Dendritic Lamellar Bodies

Hameroff severely mismodels the actual gap junction coupling between neurons suggesting a highly fictious structural construction with mitochondrion and dendritic lamellar body (DLB).

> "The dendritic lamellar bodies are tethered to small cytoskeletal proteins anchored to microtubules, and it is suggested that the mitochondria within the bodies provide free electrons for tunneling, forming a tunneling diode pair or Josephson junction between cells" (Hameroff et al., 2002, p.163).

3.1Remark

The described by De Zeeuw et al. (1995) dendritic lamellar bodies are located in dendrites and are possibly derived from smooth endoplasmatic reticulum or Golgi apparatus. DLBs are composed of stack of cysternae that lack ribosomes. In some cases DLBs are attached to mitochondrion. There is however big misunderstanding when it comes to the links with gap junctions. The DLBs are located always in bulbous parts of the main dendrite and the correlation between DLBs and gap junctions was suggested by the fact that antibody for gap junction protein cross-labels the DLBs. Thus De Zeeuw and co-workers concluded that DLBs are somehow involved in the synthesis of gap junctions (De Zeeuw et al., 1995, p. 1602). Also the DLBs are not located in the dendritic spines, which contain the gap junctions; therefore the distance between DLBs and gap junctions is several micrometers. Another striking comment by De Zeeuw and coworkers is that the bulbous structure of the dendrite that contains the DLB does not contain neither microtubules, nor neurofilaments. This is explicitly stated so that readers are not lead into delusion - DLBs should be involved in the synthesis of gap junctions, but there is not structural link between DLBs and gap junctions. The "correlation" is based on biogenesis of gap junctions. The original figure with the original

caption on the DLB morphology is provided on the next figure.

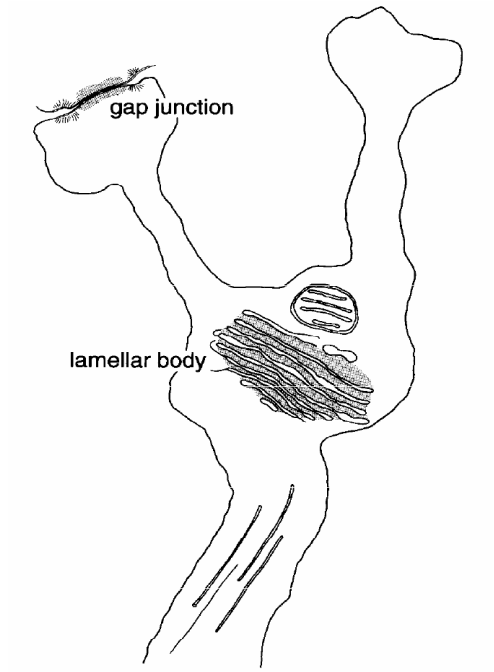

Figure 1. Drawing of a serial reconstruction of a portion of a dendrite containing a DLB. The bulbous appendage with the DLB does not contain a gap junction while the dendritic spine originating from that dendrite does. Note also that the appendage with the DLB does not contain any microtubules or neurofilaments, whereas the dendrite that gives rise to this appendage does contain these neuronal elements (original caption by De Zeeuw et al., 1995).

We conclude that one of the main reasons for choosing gap junction tunneling, instead of coherence through the synaptic cleft, is the extremely short distance between the neuronal membranes at the gap junctions that is just 4 nm. However the imaginary construction done by Hameroff extends tens of micrometers and completely destroys the idea of suitable distance for electron tunneling. The decoherence time of gap junctions has been already discussed above.

4. Glial Role in Consciousness

Hameroff believes that glial cells should be involved in consciousness because they number will increase the computational power of brain, and since glial cells are coupled with neurons via gap junctions.

4.1. Remark

In many neurologic disorders (syringomielia, epilepsia, etc.), there is a death of neurons and concomitant growth of glial cells. But glial cells cannot compensate for neuronal loss.

The involvement of glial cells in cognitive processes as memory storage devices has been suggested in the dawn of neuroscience and has been continuously fuelled with “new data” by researchers of astrocyte biology (Ng et al., 1992; Temburni and Jacob, 2001). Today the evidence is that glial cells are only trophic cells for the very capricious neuronal cells, which need extremely narrow range of physiological parameters for their proper function. Small deviations in glucose concentrations, pH, ionic concentrations, etc., are not tolerated by neurons, and although neurons do not die, unconsciousness follows in tens of seconds. Of course glial cells are subject to the common molecular transduction pathways but every cell in the body is involved in some form of processing of classical information. Every physical change in the cell is a form of classical “memory trace” for past events so for the unexperienced researcher who has not

faced seriously with the problem of consciousness it is easy to confuse the classical "memory traces" that result from irreversible processes, with the "cognitive memory storage". Indeed the engrams of consciousness should be physical, but it is impossible to localize a physical change in brain and then claim that this is necessarily a "cognitive memory trace". So far it has been observed that injury of neurons leads immediately to cognitive memory loss, while the initial stages of autoimmune diseases against glial cells (e.g. multiple sclerosis) are not assocaited with serious cognitive loss. The cognitive deficits appear later in the evolution of the disease when the neurons are also damaged. Therefore there is evidence that neurons solely are responsible for consciousness and cognitive function, while glial cells are only trophic and protective cells.

Extending of consciousness through other cell types such as glial cells, fibroblasts, even connective tissue, blood vessels, immune cells, etc. is of no real purpose for solving the enigma of consciousness. To add more problems and to make more hypotheses than necessary is too bizarre, and against the aesthetic notion for a theory to be as simple as possible, but not simpler than needed. Neuronal morphology and biology is so complicated and many times richer in details than glial biology that it is "insult to neurons" to make their function in hosting consciousness shared by glial cells as well.

5. Subjective Time Flow and Gravitational ORs

Roger Penrose speculated that the psychological arrow of time, should be coupled with the cosmological time arrow, and that possibly our consciousness and the "felling of passing time" could be born by the occurring gravitational objective reductions (ORs).

5.1 Remark

It was reported by Georgiev (2003b) and already known from neurological practice, that there are human subjects (e.g. after stroke, or other neurological disorders) that suffer from *time agnosia* - they cannot consciously realize the time flow, nor can judge duration of time intervals. It has been argued that these patients do not feel passage of time, and numerous psychophysiological experiments have confirmed the known by everybody fact that the same objective time interval, subjectively can be experienced as "too fast" or "too slow" depending on the situation, the company, and other factors. Thus the existence of patients with time agnosia clearly shows the possibility for a subject to be conscious, without having associated feeling of time flow. Therefore if ORs (producing "objective time flow") are responsible for consciousness, they cannot be also cause for subjective feeling of time flow. Otherwise time agnosia would be *a priori* impossible, which is not the case.

However a much more general concept should be stressed upon.

Georgiev (2004) have pointed out that the spatial extention of the brain does not produce "feeling of 3 dimensions", and this can be generalized by the statement that the physical characteristics of the brain (mass, temperature, etc.) do not produce associated "feeling of mass", "feeling of temperature" etc. Thus it is conceptually flawed to suppose that objective passage of time itself should produce subjective feeling of passing time.

The suggestion that ORs produce the fundamental consciousness is discussed in a separate paragraph, where we disagree that fundamentalism and emergentism as approaches towards consciousness should be used together.

6. Microtubule's 25 ms "Coherent Freezing"

One of the most frustrating features of the Orch OR model is the fact that microtubules should be coherent for 25 ms in order to perform their cognitive function. Every Orch OR event needs microtubule isolation from the cellular environment to prevent decoherence for 25 ms. This putative isolation is postulated to occur via acting gelation.

6.1 Remark

All protein enzymatic/catalytic function occur at dynamic timescale of 10-15 picoseconds and this fast dynamics should have survival value in order the biological complexity within the cell to be effectively organized against the destructive action of the thermodynamics arrow, which implies increase of entropy in time. Therefore the proteins within cells must be fast enough to counteract the increase of entropy (at the expense of metabolic energy), so that all entropic errors in function be repaired/corrected, all waste products be eliminated, etc.

Microtubules have certain enzymatic functions through their C-terminal tails in controlling the MAP attachment sites, and kinesin walk. Why then microtubules and tubulin do not use the fast picosecond dynamics done by all proteins? Classical (irreversible) events like attachment/detachment, motor protein control, reaction catalysis, need necessarily collapse of the wavefunction, in order the state to become irreversible. If the state is quantum coherent, then everything is reversible, everything is in superposition and indeed no "real" time flow has occurred, because there are multiple space-times in superposition. Therefore no "output" by the microtubules could be achieved without collapse of the wavefunction. In order to have "output" from microtubules an objective time flow (irreversible evolution) is needed, so ORs must occur in picoseconds.

Illustration of the difference between the quantum coherence and the irreversible time flow composed of discrete events (collapses, or ORs) could be the movie analogy - in the quantum coherent case, you have just one picture with many superposed images one over the other, so no time flow occurs, while in

the irreversible classical time flow you can watch a movie in which every cadre is replaced by another one in time, there is both motion and time flow, the pictures are dynamic, not still.

Emerges the embarrassing question - why if all proteins in the cell counteract the increase in entropy (i.e. the "cellular movie is going on"), the microtubules for that time are "frozen" in motionless coherent picture. After microtubules decide to "unfreeze" and "give order" to the cellular protein interior at such long millisecond intervals could they really be able to organize the cellular functions? Isn't it better if the microtubules control everything at picosecond time scale, as well as produce conscious events in 10-15 picoseconds?

The psychophysiological question, "If we are indeed 100 GHz quantum processors why we do not feel that our conscious flow is so fast? ", is answered by Georgiev (2003b) in extremely fascinating fashion - we do not feel that our conscious flow is so fast because our conscious steps do not produce associated experience of time flow at all. The evidence from patients suffering time agnosia suggests that consciousness occurs without co-producing a subjective feeling of time.

7.Photon Capturing in Retina

Hameroff and co-workers (St. Hilaire et al., 2001) suggested that coherent states of photons in retina could be transmitted to the brain cortex, and that microtubules could capture photons directly. Indeed this is one of the 20 testable Orch OR predictions proposed by Hameroff.

7.1 Remark

Color blindness is result from defect of *opsin genes* in retinal neurons (retinal cones), and there is extensive evidence that visual image processing occurs in the layers of the retina at the level of amacrine, and bipolar cells. Particular importance in neurophysiology is paid to the phenomenon of *lateral inhibition* that is responsible for the effect of sharpening (i.e. increasing the contrast of) the boundaries of percepted objects. This effect is responsible for the feeling of travelling rabbit on the skin of your forarm under discrete skin stimulation, and is implicated in the function of all analysators (sense organs); for details we refer the reader to the excellent exposition of that matter by Georg von Bekeshy (1961) in his Nobel lecture on hearing.

Therefore if the visual pictures enter the brain cortex in the form of electric impulses it is impossible the quantum information (coherent states) of photons to be delivered to the brain cortex. The fact that visual information enters the brain cortex in the form of electric excitations has been used by Dobelle (2002) to input through implanted electrodes in the visual cortex of a blind man captured by camera visual information. Thus if the visual information is to be classically processed by the lateral inhibition mechanism at the level of

neuronal membrane generated electric excitations, the idea of Hameroff and co-workers is theoretically doomed to failure from the very beginning. Indeed St. Hillaire (2003) in a personal communcation confessed that the predicted by Georgiev (2002b) failure of the whole experiment indeed did occur.

8. Microtubule A-lattice in Brain Cortex

Based on modelling of microtubules as ferroelectric lattices done by Tuszynski and co-workers, Hameroff suggested that possible good prediction of Orch OR is to bet on existence of A-lattice microtubules in brain cortex, compared to the B-lattice microtubules observed elsewhere *in vivo*. This is also one of the 20 testable Orch OR predictions proposed by Hameroff.

8.1 Remark

The ferroelectric model has no any biological advantage, and is also insensitive for local electric fields. What is more B-lattice for microtubules was proved/observed directly by freeze fracture electron microscopy both for *in vitro* assembled microtubules and for microtubules isolated from various brain regions (Kikkawa et al., 1994). So far there is no observed case of *in vivo* microtubules with A-lattice.

Indeed the tubulin lattice of microtubules was found to be irrelevant for the recently proposed information processing by the C-terminal tubulin tails operating in an interplay with the local electromagnetic field (Georgiev et al., 2004, Georgiev and Glazebrook, 2006).

9. Is Tubulin Bound GTP "Pumping" Possible?

Hameroff and co-workers (Hagan et al., 2002) insisted that indeed GTP cycle of tubulin bound nucleotides might support a "pumping process" whose energy might be used for microtubules in order to achieve Fröchlich type of coherence.

9.1 Remark

It has been shown that α-tubulin bound GTP never hydrolyzes in assembled microtubule, while β-tubulin bound GTP hydrolyzes to GTP soon after the incorporation in the microtubule wall. After that the successive α-tubulin subunit occludes the preceding β-tubulin nucleotide binding pocket and neither exchange of GDP for GTP, nor phosphorylation of the β-tubulin bound GDP is possible. Therefore tubulin bound GTP pumping cycle cannot occur in stable microtubules (Georgiev, 2003c). Alternatives for energy supply should be found (see specific proposals in Georgiev et al., 2004; Georgiev and Glazebrook, 2006a).

10. Bionic Vision and Dobelle's Breakthrough

In Hameroff-Penrose Orch OR the microtubules are suggested to be screened from external electromagnetic fields.

10.1 Remark

In a breakthrough neurosurgical operation Dobelle (2002) was able to implant electrodes directly in the visual cortex of a blind man, who lost his vision as a result of accident. The electrodes were connected to a bionic camera that transmitted the visual image in the form of electric pulses. Each electric pulse created sensation of bright spot called "phosphene" and the totality of such "phosphenes" creates the visual input. Thus the blind man called Jerry, was able to navigate in unknown environment such as the subway, with the use of the bionic vision.

Dobelle's achievements are based on classical work of Penfield who showed that electric stimulation of the brain cortex is able alone to elicit conscious experience. This is in agreement with all the current medical knowledge from clinical neurology, where the sensory information is delivered to the cortex in the form of electric impulses through thalamus.

Hameroff-Penrose Orch OR theory has the big shortcoming of supposing that microtubules are insensitive for the local electric field. We believe the possible quantum model of microtubules that should account for consciousness should benefit from microtubule sensitivity to local electromagnetic fields. This issue was addressed in a pioneering work of Georgiev (2003d) that was refined into a QFT model with electromagnetic sine-Gordon solitons coupled with the C-terminal tubulin tails projecting out of the microtubules; see Georgiev (2004a), Georgiev et al. (2004), and Georgiev and Glazebrook (2006a) for detailed discussion on the topic.

11. Output at the axonal hillock

Hameroff believes that dendritic microtubules solely are responsible for conscious Orch OR events, and that the output of the microtubule gravitational OR event is to affect somehow by unknown mechanism the axonal hillock potential. After that the Hogkin-Huxley dynamics of the axon is classical (deterministic) and the communication with other neurons is ensured.

11.1 Remark

One of the major concerns is that each axon ends up with about 10 000 synapses for a cortical neuron. The probability for exocytosis and neuromediator release at each terminal button (hence reliability of synaptic transmission) is only 0.15-0.30. Therefore it seems that if there is no subneuronal control of the synaptic release at random only about 3 000 of the synapses of the cortical neuron will "fire", while 7 000 of them will be "silent". Thus it is not clear how the Orch OR will prevent the huge chaos as expected due to synaptic failures.

12. Machine-Brain Interfaces and Thought Control of Robot Arm

Hameroff-Penrose Orch OR model completely leaves out the possibility for

microtubules to control the process of neuromediator release except indirectly through control of axonal spiking. If the microtubules indeed controlled only the axonal hillock potential (by yet unknown mechanism) then for each axonal terminal you would better bet that the exocytosis will not occur (you have 70% chance to guess) instead of relying on neuromediator release (the chance is only 30%). Since neuromediator release is followed by predictable postsynaptic electric activity of dendritic tree, it seems that within Orch OR the microtubules cannot control the pattern of electric excitations of the cortical neurons (that is because the randomness introduced by synaptic failures is disastrous, and, in order to be avoided, a subneuronal control is needed).

12.1 Remark

Carmena et al. (2003) in a breakthrough neurosurgery have implanted electrodes in the monkey's cortex that measure the cortical neuron potentials, and then send them to computer that processes the measured data by a certain software program. According to the measured electric excitations of the cortical neurons, the computer deterministically controls a robot arm. The amazing thing is that monkeys in time were able to learn how to move "by thought" the robot arm for their own purpose. After the entire connected computer was just a transmission device operating in fully deterministic manner, in the same way the transmission of a car is navigated. You don't need to know how exactly all machinery of your car works, you only need to know that it operates deterministically and what you have to learn is what kind of commands you must output in order to control the car. In the case of monkeys this happens by try-and-error mechanism. What is particularly amazing is that in the beginning the monkeys moved the robot arm with associated movement of their arms, however in time the parasitic movement of the monkey arms disappeared.

Recently the experiment has been proved successful in humans. Thought control of computer linked to the brain cortex of paraplegic human through machine-brain interface has been achieved by Hochberg et al. (2006) and the method remains the only possibility to restore the independence for humans with paralysis.

What is the important conclusion from such experiments? Of course they point towards the essential place where your mind outputs its orders - namely the consciousness is able to control the neuronal excitations. This could happen if the mind controls exocytosis at synapses and thus neuromediator release. Following exocytosis the excitation of the postsynaptic dendrite is considered a deterministic event as a result of neuromediator binding to postsynaptic ligand gated ion channels. Since microtubules cannot control directly the

function of the voltage-gated ion channels (the channels are voltage-gated, not microtubule-gated), they should control them indirectly - through control of the release of neurotransmitters (synaptic exocytosis). Particular support for the suggested interpretation (for mind control of electric excitations via control of the exocytosis) is the observation that in time the monkeys can eliminate the parasitic motion of their arms. This means that the electric excitation is there to be captured by the electrodes, yet when the electric signal arrives at the terminal buttons of the pyramidal tract (axons that output the motor information from the cortex to the □-motoneurons in the spinal cord), it does not release neuromediator.

13. Axonal processing of information

Hameroff is silent on the possibility for axo-axonal gap junction couplings with 200 Hz activity that ensure axonal couplings and possibilities for induction of axonal spike in gap junction coupled silent axon with smaller diameter than the firing one. Indeed in Orch OR all this is not relevant because axons are not involved in conscious processes. Mentioning of 200 Hz gap junction activity within Orch OR will be somehow contrasting with the 40 Hz gap junction activity proposed by Hameroff.

13.1 Remark

It seems unfair to have contraposition dendritic vs. axonal microtubules, dendritic vs. axonal computation. We think that none of these extreme points of view stressing on priority of only one type of neurites is acceptable. Indeed there is undisputable evidence for axons to "integrate mind", and for the split-brain studies Roger Sperry took Nobel Prize in 1981. So both dendrites and axons should be involved in cognitive processes.

Another frustrating observation is the logical mess - in Orch OR the dendritic microtubules are accounting solely for consciousness, while the axonal microtubules are not endorsed with the priviledge to be conscious. But why such unjustice - these are parts of a same neuron and exclusion of axonal microtubules from mind processes decreases the mind computational power? On the other hand glial cells are involved in conscious activity (in order to increase the computational power of mind), but they are completely different cell type that has the primary duty to ensure the trophic needs of neurons. Orch OR in its current form is a bad cell biology with nothing positive for the model except the fact that is completely scandal.

14. Synaptic Failures and Neuromediator Release

The probability for exocytosis at a CNS synapse varies in the range 0.15-0.30. The randomness/chaos from such a "lottery" is enormous number. For a small neuron with only 1000 synapses of which 30% fire and 70% are silent the randomness is 1 to 10^{263}. This means that there are 10^{263} possibilities for the decision which 300 synapses from the total 1000 will fire. If

the exocytosis is not subneuronally controlled then any of these 10^{263} possibilities will have equal chance to occur, and the chaos in the brain function seems to take disastrous dimensions. We also have stressed that Orch OR cannot resolve the problem with synaptic failures because it insists on microtubule output at the axonal hillock, hence no effect on synaptic boutons.

14.1 Remark

One can repair the above problem with synaptic failures assuming that the presynaptic cytoskeleton is performing quantum computation, as recently advocated by Georgiev, 2002c and reviewed in Georgiev et al. (2004), Georgiev and Glazebrook (2006a).

If one does not like the idea for presynaptic cytoskeleton controlling the exocytosis there remains the "ugly" classical possibility to assume a classical error correction code that enormously decreases the computational activity of brain. In such an "ugly scenario" not every synapse should be considered as a "bit" but a group of say 10 or 15 synapses will constitute a "bit". In this case it would be enough only one of those 10-15 synapses to fire in order for the whole bit to have value 1. This can be achieved if all these synapses end only on a single postsynaptic neuron and there is the requirement that the postsynaptic spines of those synapses be coupled with classical *OR-gates*. Such possibility is extremely "ugly" from biological perspective and seems to contradict the fact that dendritic spines perform all kind of computational gates including *AND-gates*, which are hardly to be implemented if this huge error correction code was operating. These classical error correction codes seem to be in contradiction with the precise subneuronal (molecular) control of individual synapses, which have their own memory through enzyme sequestration like CaMKII, local ribosome and mRNA clustering and local protein synthesis under active spines.

15.G-proteins and MAP-2 Phosphorylation

One of the main conjectures by Woolf and Hameroff (2001) is that the dendritic microtubules input the information coming from extracortical neurons in the form of neuromediator pulses with the help of G-protein coupled cascades that affect the MAP-2 phosphorylation status. One of their estimates is that the time needed for such a process is 250-500 milliseconds and this should be comparable to each conscious step.

15.1 Remark

The G-protein effects are much slower (utilize greater timescales) than the direct electric depolarizations. While it means that the onset of the G-protein coupled effects is delayed, it also means that the decay of the effect is protracted in time. Therefore once triggered such a G-protein cascade needs a longer time to be turned off. The main principle is that the

G-protein after its activation triggers second order and third order messengers in the form of kinases or phosphatases that amplify the signal in a form of chain reaction. Hereafter it will be difficult for the chain reaction to be turned off. The electric excitations in contrast have faster dynamics and can be dissipated ("turned off") for shorter time.

In Orch OR seems that there is some problem with the interpretation of the classical Penfield results that showed clearly that electric current itself is evoking conscious experience when applied to the brain cortex (Penfield, 1954a; 1954b; 1955). Also it is not seen direct link between Orch OR and the applications of Penfield's discovery by Dobelle (2002) who implanted directly the electrodes connected with bionic camera in order to recover the vision in blind human subject after neurosurgery.

Although the Hameroff-Woolf's scheme is based on the dual action of *neuromediator*, namely to activate both ion channels and G-protein coupled receptors, in the case of direct electric input to the cortex it is necessary explanation how the *electric current* itself induces conscious experience. But if this piece needs to be integrated in the theory then it seems that Hameroff-Woolf's theory in its current form is *incomplete* because it ignores (does not explain) how the electric currents (generated by ion channels when activated by neuromediator) are inputted to microtubules. There is also additional problem with the Hameroff and Tuszynski proposal for screening/isolation of microtubules against external electric fields (Hameroff and Tuszynski, 2003) because direct input will be impossible.

16. Microtubule Screening by the C-terminal Tails

Hameroff and Tuszynski (2003) propose extremely bizarre screening of microtubules against external electric fields by double Debye layers organized by the C-terminal tubulin tail (CTT) presence. The main idea is that CTTs "shield" the microtubule against external electric fields. The suggestion however is based on misapplication of Debye-Hückel theory of charge screening in electrolyte.

16.1 Remark

If microtubules are responsible for consciousness but are insensitive to the electric excitations of neurons, then the Penfield's and Dobelle's experimental results proving the role of electric processes as direct input resources of conscious experience would be left outside the theory of quantum consciousness.

Second much more important result stems from the main mathematical derivation of the Debye-Hückel theory itself. It is approximation in a model in which is assumed Boltzmann distribution of ions in the solution and one of the critical steps is the electric neutrality of the electrolyte (see detailed exposition in Georgiev and Glazebrook, 2006b). Since

during electric excitations the ion flow across dendritic membrane is electrogenic, the electrolyte of the cytosol is no more electroneutral and the Debye-Hückel approximation might not be valid, and it is not at all evident why microtubules should be insensitive for external electric field as generated by the electric excitations. Indeed the electrosensitivity of microtubules could be modelled exactly through the CTTs that Hameroff wrongly believes are responsible to shielding. If neuronal electric excitations are modelled within quantum field theory (QFT) as proposed by Jibu et al. (1994, 1996), Jibu and Yasue (1997), it can be shown that electromagnetic sine-Gordon solitons could propagate within the neuronal cytosol (Abdalla et al., 2001), and these solitons could be coupled with conformational change in the CTTs (Georgiev and Glazberook, 2006a).

17. Freud and Subconsciousness

One of the main ingredients of Hameroff's Orch OR is the emergence of conscious processes out of subconscious ones. The quantum coherence leads to *subconsciousness*, while the Orch OR event is *a conscious occasion*. Hameroff's attempt is to somehow inbuild in the Q-mind model the Freudian psychoanalysis and Freudian scheme for the structure of human psyche being *Ego* (conscious) + *Id* (subconscious) + *Superego* (conscious).

17.1Remark

Freudian psychoanalysis (Freud, 1899; 1901; 1905a; 1905b; 1913; 1914; 1920; 1923; 1927) has been a subject of extensive critique, and it was shown that psychoanalysis hardly can be called a science; see Popper (1982) and *the demarcation criterion*. There is nothing that is forbidden from occurrence in psychoanalysis, and amazingly the analysis done by the psychoanalyst hardly could be subject to any counter-argument or revision. Typical example could be if you do not agree with the conclusions of your psychoanalyst that you have *Edip's complex* ("subconscious desire to make sex with your own mother"), your argumentation will be taken as evidence that your "subconsciousness is resisting the actual realization by you that you have this sexual complex", and the psychoanalyst will never assume that your denial maybe is evidence that his theory is wrong. Freudian theory is thus immunized against any form of critique, because it does not forbid anything, and could explain everything concerning the functioning of the human psyche.

There has been extensive biological work to show that "subconsciousness" is result of extracortical neural substrates such as thalamus. Therefore the modern biological approach is that "subconsciousness" is brain activity outside your consciousness, while your consciousness is solely result of your brain

cortex activity (classical or quantum one). However in the modern neurobiological approach towards psychoanalysis the term "subconsciousness" is already unnecessary, misleading, and "dangerous". Simply this is not qualitatively different state from consciousness. "Freudian subconsciousness" in modern terms is "extracortical neuronal activity" therefore no qualitative transitions from subconscious to conscious activities should take place in your cortex. The cortex is either conscious, or unconscious (e.g. during anesthesia), and extracortical neuronal impulses become conscious when they enter the cortex. Thus Freudian state transition from subconscious mind state into conscious mind state is no more necessary. The mind is always conscious (tautologically), and only the physical signal carrier of information undergoes dynamics i.e. it is outside or within the mind.

Example of extracortical activity may be neuronal impulse entering from the periphery towards the spinal cord that will trigger sensation of pain when it reaches the brain cortex. This entering pain impulse may be blocked with *local anesthetic* (spinal anesthesia) before it goes to the brain cortex. So spinal anesthesia acts by making all pain impulses remain outside the brain cortex - i.e. they are blocked somewhere on their way from the body to the brain cortex, and this block happens at the level of spinal cord neurons. You don't experience these pain impulses, but nevertheless they may affect the body functions.

Block of sensory impulses can be done higher in the sensory pathways at the level of thalamic neurons, or the communiation of thalamic neurons with brain cortex. For example *radiatio optica* is composed from axons of thalamic neurons that enter the visual cortex. If they are cut, despite of the fact that your eyes "see" the visual image, and your thalamus as well "sees" the image, you are not consciously aware of that because your brain cortex i.e. visual cortex cannot input this visual information. But your thalamus is center for triggering various vegetative responses, so the "thalamic seeing" could lead to extracortical/unconscious triggering of vegetative responses or other reflexes like blinking of the eyes (this is wrongly called "subconscious" in Freudian psychoanalysis).

Our conclusion is that there is no any need of accounting for "subconscious" processes in the (quantum) physical theory of mind. Any such process if being a "real" process and thus having effect on bodily functions, could have "extracortical" neural modelling. So postulating a consciousness being at the fundamental level of Universe at the quantum level, does not need neither associated "fundamental subconsciousness", nor any threshold for consciousness to occur. This is consistent with the evolutionary approach suggested by prof. Chris C. King (1989, 1991, 1996,

1997, 2003a, 2003b, 2004) for the early prebiotic evolution of molecules in the primary ocean on Earth. In this scenario every molecule manifests a form of "free will" in quantum transactions in the primary ocean, and the whole process of evolution of life, now can be seen as a growing complexity of conscious choices (panpsychism). Of course the quantum states of single molecules cannot be as rich as macroscopic quantum states realized in brain. So in a sense the experience is always there, but its complexity evolves with evolving life systems that could have harvested mechanisms to sustain macroscopic quantum coherence entangling billions of protein molecules in the cellular cytoskeletons of millions neurons.

18. Emergent vs Fundamental Experience

In Orch OR model there is bizarre mixture of "fundamental consciousness" that "emerges" at OR events. The whole approach is *over-complicated* for the sake of satisfying some old and mainly non-scientific Freudian concepts.

18.1 Remark

We suggest a direct fundamental experience/consciousness manifested by quantum systems. Thus we think of the quantum events/collapses as "decisions" done by the experiencing quantum system, not as "events producing consciousness". In this new framework the OR event will be "decision making", not "experience creating" event. If consciousness is irreducible phenomenon at the quantum level there is no need for it to "emerge" from "subconsciousness" which is a pseudo-scientific Freudian concept.

19. Thalamo-cortical 40 Hz

Hameroff's Orch OR is based on the idea that thalamocotical 40-80 Hz activity is somehow responsible for consciousness.

19.1 Remark

We agree that the b -EEG is a good indicator of consciousness, and that the correlation between- EEG and consciousness is reliable enough to serve monitoring function in controlling the depth of anesthesia, etc. However we do not see why thalamus should be involved in conscious experience, nor why if experience is a fundamental ingredient of reality should be created by any "form of activity".

Indeed if quantum coherence is responsible for "conscious binding of experience" then it does not matter whether the sensory stimulus is present in thalamus, or in cortex. The whole system manifests quantum wholeness and the sensory stimulus should be already present in the conscious experience. This was the fundamental preliminary argument raised by Georgiev (2002b) against the possibility for coherent sates in retina, which are simultaneously coherent with the brain cortex, as responsible for vision. If this were the case, then the neural impulses will be useless to carry information to the cortex. Indeed

already at the very moment your retina has detected the photon, due to quantum coherence and conscious binding between the retina and the brain cortex you must have experienced the visual information. Otherwise if there is no such quantum coherence between the retina and the brain cortex, there is no mechanism to account for coherent transfer of the state of the photon seen by the retina. All quantum teleportation schemes need both quantum and classical channel. Without quantum Einstein-Podolsky-Rosen channel (existent quantum coherence) there is no possibility for quantum teleportation of unknown quantum state, such as the state of the incoming photon. And last, if you deny to use the quantum coherence for binding of experience, then why to use a quantum approach towards consciousness at first place.

If the quantum coherence is responsible for "binding of conscious experience" one can conclude similarly that thalamus is not involved in consciousness because the sensory impulses must be realized already when they enter in the thalamus, and not later when they are delivered to the brain cortex. For example in the surgical severing of radiatio optica the brain cortex "sees nothing", and you are not consciously aware of the visual information, but the thalamus is "seeing" the visual image. Therefore since cortico-thalamic connections/axons are not severed, and you can imagine that other thalamic areas are not severed - so they deliver sensory information to the brain cortex, there should be still possible "binding" of the perceived by the thalamus information with the perceived by the cortex information, via the quantum coherence mechanism.

Solution of all these problems outlined above as imposed by facts from the clinical neurology, can be found only if one also believes the conclusion of clinical neurology that only and solely the brain cortex is responsible for your consciousness (at least this is the main theory in European post-communist countries, and in Russia; Western science is most tolerable and has allowed for various attempts to involve extracortical regions in conscious awareness, yet all this is self-controversial and we do not see any use of it). So if the brain cortex is solely responsible for consciousness and the quantum coherence is maintained and shared only between brain cortical neurons, then there will be no problems with the hypothesis that quantum coherence leads to "conscious binding of various experiences".

Remains to be explained the correlation between the 40 Hz thalamocortical activity (b -EEG) and consciousness. Well, the obvious thing is that sensory information from the surrounding environment is delivered always through thalamus, except for olfaction. Therefore when consciousness is wakening up it will need sensory input from thalamus. To have consciousness

only without any external sensory information is useless because all normal activities are interesting, only when done in communication with the external world. But it is possible to be conscious, and not to be interested in external sensory information. For example mediating tibetian budhists may try to isolate themselves from the surrounding sensory input. In this case communication of consciousness residing within the brain cortex with thalamus is not necessary and slower waves are measured. So our explanation is somehow inverted. Consciousness is the cause for b EEG through interaction with thalamus in order to deliver sensory information. The b EEG is not responsible for consciousness but result from the interaction of your consciousness with the environment. Our thesis is confirmed by the fact that mediation or other conscious experiences might happen without -EEG.

We conclude that 40 Hz as the needed objective time for a conscious step to occur is wrong and useless prediction. All evidence is against. Also this opens possibility for consciousness to be 100 GHz phenomenon, as proved originally by Georgiev (2003b). This is an amazing proof since Q-mind theory with 100 GHz quantum consciousness will not lead to psychophysiological paradoxes. Now the road for Q-mind theories is open down to smaller time intervals needed for coherence/time until decoherence, and the original objections by Tegmark (1999) and others, for brain being “hot, wet and noisy”, are meaningless. The necessary Bose-Einstein condensation can be achieved for 10-15 ps that is the timescale of protein dynamics/catalysis solely by means of energy pumping (Georgiev and Glazebrook, 2006a).

20. The Actin Gel-Sol Cycles

The actin gel sol cylces in Orch OR serve the function to shield the coherent microtubules for 25 milliseconds.

20.1 Remark

The fact that NMDA receptor triggered actin dynamics (contraction, polymerization/depolymerization) is responsible for change in dendritic spine shape is observed by special video-microscopic technique. This has great effect in synaptic transmission, and the generated postsynaptic potentials. However we do not see any purpose this to be relevant to microtubule shielding. Actually the spine is filled with scaffold protein cytoskeleton, and microtubules from different spines couple only indirectly by these scaffols proteins. So actin filaments and other scaffold proteins may be quantum coherent link between microtubules of neighboring neurons. Indeed there is no theoretical possibility for interaction of microtubules between neighbouring neurons without any scaffold protein being the link between the microtubules. In Orch OR such “linkage” was supposed to occur by gap junctions, but the ionic flows through gap junctions lead to problems with

decoherence in Orch OR scheme. In recent work we were able to show that the synaptic environment is better for microtubule coupling between neighboring neurons, plus there is ensured direct output on neuromediator release, thus solving the problem of control of the electric excitations, and the synaptic failure problem. See Georgiev (2002a), Georgiev et al. (2004), Georgiev and Glazebrook (2006a).

If the actin is "shield" then it cannot be used for mediating of coherence. However the evidence is that in muscle contraction actin uses quantum coherence (Hatori et al., 2001). Yet the mechanism in muscle contraction as well as the mechanism in spine contraction is the same - just myosin/actin action.

Also the microtubule insensitivity to local electromagnetic field is bad for the theory, and indeed after the revision of the dynamic timescale of consciousness being 10-15 ps, the proposed within Orch OR actin gel-sol cycling will be unnecessary to account for microtubule shielding.

21.Libet's "Delayed Experience"

Stuart Hameroff suggests that the described by Libet back-referral of time must imply that consciousness uses quantum coherence - during the quantum coherent period indeed the future and past co-exist together and future events might affect the outcome of past events.

21.1 Remark

As noted by Pockett (2002) it is always easier to read the conclusions of the articles and to skip the boring reading of the technical part that describes the actual setup of the experiment. However if one struggles to understand the principles underlying the brain function then a careful study of the data is needed. Here we briefly summarize some of the most quoted results by Libet and point out obvious flaws in the interpretation of the experimental data.

As a grounding fact of most of the Libet's conclusions is taken the observation that direct stimulation of the brain cortex with electric current elicits conscious sensation only some time after the start of the electric current. It was shown that the electric current I must have some threshold magnitude I_0. If $I<I_0$ the electric current may be continued for a long time without eliciting any conscious sensation. If $I=I_0$ the conscious sensation occurs approximately 500 ms after the start of the electric stimulation, and if $I>I_0$ the conscious sensation occurs faster than 500 ms in such a fashion that higher current elicited conscious sensation faster. With the used higher intensities of the currents the minimal period for duration of the current that elicited conscious report was approximately 200 ms. Libet interprets the I_0 as "normal" stimulus and then suggests that consciousness occurs with delay of 500 ms. There is nothing "normal" however in opening the skull of

a human and delivering electric impulses to his brain with electrodes dipped in saline. Also Libet completely forgets about neuronal fascilitation - there is possibility for electric excitations to sum over time, so that subthreshold agitations finally result in a spike. From such a perspective it is highly plausible that at the beginning of the electric train with I_0 the subthreshold currents summated, so that only after 500 ms some relevant to induce conscious experience neuronal activity has been induced by the electrode. There seems nothing to be explained here, as all this is well known is modern neuroscience.

Based on misunderstanding of this first series of experimental data, Libet and colleagues perform a second experiment that is maybe the most quoted in the scientific literature experiment. A patient is delivered an electric stimulus with current I_0 for duration of 500 ms, while at the same time a suprathreshold skin stimulus on his hand is delivered 200 ms after the onset of the electric current I_0 delivered to his somatosensory cortex. It was reported that the hand stimulus is experienced before the sensation that resulted from the electrode stimulation. Libet then concludes that this is surprising because the skin stimulus would have been experienced with delay of 500 ms that summed up with the 200 ms delay from the onset of the current I_0 gives us delay of 700 ms. This prediction fails however Libet does not consider it as evidence that his pet hypothesis for delay in consciousness of 500 ms is false, but ridiculously claims that a novel explanation is needed (i.e. back-referral of time). Of course that taking into account that there is no any such delay in consciousness, the skin signal will need only about 80 ms to reach the brain cortex, so if the onset of the current I_0 is labeled as t_0 then it follows that the experience of the skin stimulus will be at time t_0+280 ms, while the direct current delivered to the cortex will evoke conscious experience only after some fascilitation takes place at time t_0+500 ms. Our prediction does not fail, so there is no whatsoever reason to search for exotic explanations such as Libet's hypothesis based on misunderstanding of neurobiology.

Alas, as it often happens in science despite of the fact that Libet's work was pioneering (indeed it is irrelevant to our discussion) he became victim of his "pet theory". It is not so rare in science that researchers prove experimentally their expectations, or if the experimental data does not fit exactly their expectations they misinterpret it i.e. interpret it in "novel" (exotic) way, so that in the end the expectations are confirmed.

And last, a note should be added on the meaning of the term "back-referral of time", that should be understood within the framework proposed of Libet - consciousness occurs with delay of 500 ms after the neural mechanism that generate it, however the consciousness "fills up the gap" by (illusory) assuming that it has triggered itself the neural mechanisms (thus consciousness is epiphenomenon

here). Other possible interpretations of the term "back-referral of time" such as in Klein (2002) are not necessarily incompatible with our views, but they have completely different meaning from the one discussed here.

Our conclusion is that quantum mind theories do not need to specifically resort to Libet's experiments as something extraordinary.

22. Bierman's "Presponse"

Stuart Hameroff provides Bierman's presponse as an experimental evidence for quantum mind theories and Orch OR.

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highly pornographic pictures is higher than the nerural arousal before the other two sets of pictures. Biermann interprets this data as evidence for unconscious fortune-telling called "presponse".

Indeed except for the fact that Bierman felt perverted pleasure to show in his lecture slides "examples" of the pornographic pictures he had presented to his test-subjects thus shocking the auditory, there is nothing else special to be discussed. Severe statistical errors in the manipulation of the data were reported independently by Georgiev (2003f) and Jiri Wackermann (2002)

22.1 Remark

The reported unconscious presponce by Bierman and Radin (1997, 1999) is indeed a mixture of bad statistical manipulation of experimental data plus misunderstanding of neurophysiology. Briefly described the experiment is as follows: subjects are shown in a random fashion pictures divided into three groups: (i) neutral pictures, (ii) fear-inducing pictures and (iii) photos with highly pornographic content. The pictures were shown randomly to a subject and the activity of various brain areas was monitored by fMRI. Then it was shown that the neural arousal as detected by fMRI just before the appearance of the pointing out the possibility that the observed arousal before the pictures with pornographic content might be explained with the *gambler fallacy effect*. If this is accounted for in the statistical analysis, the observed "presponse" will be washed out as an artifact of the bad mathematics used by Biermann.

Below we provide for illustration a nice story suggested by Wackermann (2002) and for full mathematical tackling of the problem we refer the curious reader to Wackermann's paper also.

"Stephen feels a special affection for Phyllis: each Saturday evening he phones her to invite her for a dinner. She is not much impressed by Stephen's person, but she does not want to injure his feelings,

so she invented a convenient strategy. Whenever Stephen phones, she rolls fair dice to determine her response. If the die shows "6", she accepts the invitation; in case of any other outcome, from "1" through "5", she finds a socially acceptable excuse to decline.

Stephen also has his secret habits. On Friday he obtains his weekly pocket money from his father, a constant amount of $10. If Phyllis declines to go for a dinner, he saves the money in a shoe box for the next occasion. If she accepts his invitation, he takes the cash from the box and expends all the money for the dinner with Phyllis.

Stephen's father is fairly scared about his son's unfortunate passion, and secretly keeps track of Stephen's cash reserves. On each Saturday the dad notes the state of Stephen's deposit, and then he observes Stephen's going or not going out. In this way, the father obtains a bi-variate data series which, for example, may look like this:

Having collected enough data points, he submits the data to a simple analysis: he calculates the average state of Stephen's funds separately across successful and failed invitations, and finds that the average money sum on accepted invitations was significantly higher than on rejected invitations! Stephen's father is facing an interpretation problem. Given that Steve did not tell Phyllis anything about his money saving habits, something definitely anomalous seems to be happening. Does Phyllis possess an fortune-telling ability? Was she perhaps scanning by telepathy Stephen's dinners funds? Stephen's father has a moral problem, too. Should he tell his son what he has found, or not? And, if so, what is he going to tell him? "

The example provided by Wackermann is crystally clear - different predetermined behaviors may lead to "pseudo-telepathy" artifacts. Noone will take seriously in the above scenario that Phyllis can foresee the future. Yet, exactly such kind of statistical errors are reported uncritically by various researchers as support to psi-phenomena.

23. "Shielding" in Orch OR

Hameroff suggests that the possible water lasing by superradiance in and around microtubules could have the function of a shield against environmental decoherence.

23.1 Remark

One of the important questions in the Q-mind models is to explain how neurons can sustain long-ranged quantum coherence in their interiors. Jibu et al. (1994, 1996) have suggested that water molecules manifest lasing effect known as *superradiance*. The dynamical timescale of this process however is 10^{-14}s, and might be too fast in order to have some impact on much slower protein dynamics through which all cellular functions are realized (timescale of 10^{-11}s). Jibu and Yasue (1997) have shown that there is a possibility for "energy pumping" of the water lasing

process which will prolong the coherence time above the timescale of thermal fluctuations (10^{-13}s). That is why Georgiev and Glazebrook (2006a) have further explored the possibility for "energy pumping" in which the water lasing is attained for 10-15 ps. In this case travelling electromagnetic pulses in the form of sine-Gordon solitons might affect the enzymatic function of the C-terminal tubulin tails of microtubules. The model describes the interaction between the electromagnetic field within neurons and the cytoskeleton that is why it is easily accomodating all the results found by Penfield, Dobelle, and others, concerning the role of electric fields and currents in eliciting conscious experiences.

Gilmore and McKenzie (2005) have shown that any quantum coherent process taking part in a biomolecule will suffer a significant decoherence from the surrounding dipole disorder of the solvent molecules. That is why it seems impossible to be realized a quantum theory of brain function without including in the model coherent ordering of water molecules. In other words a quantum coherent process within a biomolecule cannot last for significant biological timescale if the biomolecule is coupled with equilibrium thermal bath.

However is there any rational argument that will force us to model the neuronal interior as electrolyte solution at thermodynamic equilibrium? Certainly not only such argument does not exist, but it is quite the opposite - the neuronal interior is a system far from equilibrium.

Biological systems are systems that evolve far from equilibrium. This is well known in biophysics and indeed the continuous supply of metabolic energy is what keeps the organized neuronal interior. Yet, under such circumstances Fröhlich type of Bose-Einstein condensates could form. Laser functioning is a typical example of quantum coherent process realized at room temperature. Thus coupling of the microtubules or any other protein molecule residing within the neuronal interior with equilibrium thermal bath will be severe biological mismodelling. Most physicists trying to "disprove" Q-mind, do exactly this vicious circle reasoning - they couple the quantum system of interest with an equilibrium thermal bath, and prove what they want to prove (i.e. Q-mind is not feasible *in vivo*? !). Yet, properly pointing out that the neuronal interior is a system far from equilibrium, should invalidate all kind of such flawed critiques. So far, biophysical modelling for neuronal cytosol as system far from equilibrium suggests that Fröhlich type of Bose-Einstein condensation occurs for 10-15 picoseconds, a timescale that is sufficient to account for long-range quantum correlations between the enzymatic function of neuronal proteins (Georgiev and Glazebrook, 2006a).

Therefore in the current Orch OR model Hameroff wrongly suggests that there is an equilibrium thermal bath near

the microtubule, so that the microtubule needs to be shielded. Indeed this is a severe mismodelling also. Once accepting the flawed argument that (i) the neuronal interior is "thermal bath" then one should start to invent (ii) various additional mismodels in order to counteract the wrong supposition (i). Our conclusion is that Q-mind models cannot be properly developed if one does not clarify and resolve this confusion. The supply of metabolic energy makes the neuronal interior a system far from equilibrium and further no shielding mechanisms are needed. What one needs is a proper understanding of the quantum behavior of systems far from equilibrium, and this should be done with advanced mathematics, not by philosophical arguments. A pioneering work in that direction was done already by Fröhlich (1968, 1975, 1984, 1986).

24. Where Act the Anesthetics?

Hameroff suggests that the main action of volatile anesthetics (as well as anesthetic gases) is to cause unconsciousness via binding to the hydrophobic pockets of tubulins. Also Hameroff argues that volatile anesthetics are the most perfect agents to produce unconsciousness that we currently have.

24.1 Remark

The model suggested by Hameroff is certainly interesting; however it is too simplistic to be used as a general approach towards anesthesia. In the following we will raise two particular issues that need to be considered.

The volatile anesthetics have numerous molecular targets: the core SNARE complex, two pore domain potassium channels, calcium and sodium voltage gated ion channels, gap junction hexamers, $GABA_A$ receptors, etc. Therefore it is arguable that microtubules are the primary target that leads to unconsciousness. In this way it is experimentally impossible to find out the primary target of volatile anesthetics without comparisson with the effects of other more selective drugs that have less number of molecular targets. Here is where the role of intravenous anesthetics should be considered i.e. almost all known intravenous anesthetics realize their anesthetic action through activation of $GABA_A$ receptors (with the exception of NMDA receptor agents such as ketamine that lead to "dissociative anesthesia" - a condition manifested with hallucinations, amnesia, and unpleasant post-anesthetic recovery, hence not deserving to be correctly termed "anesthesia"). Thus, it seems that the key towards understanding anesthetic action must involve the GABAergic neuromediation as one of the major mechanisms for producing unconsciousness.

The second issue we would like to stress upon, is the fact that volatile anesthetics are far from being the perfect anesthetics as argued by Hameroff. Indeed the induction is anesthesia is slow

(currently intravenous induction is preferred), the effect within brain is diverse (multiple molecular targets as listed above), and as a consequence the recovery from anesthesia is delayed and associated with unpleasant experiences. Vomitting, nausea, and disorientation are often seen in the early post-anesthetic period, even after perfectly performed volatile anesthetic anesthesia. All this is avoided with the usage of intravenous anesthesia, and a particularly close to perfect anesthetic agent is *propofol* (except that it is relatively expensive). Propofol should be the primary choice in all cases where there is no contraindications for its usage (such as accompanying heart disease, newborn child, etc.), yet, the range of applicability of propofol is growing and if the anesthetist is experienced propofol could be used even in cases where the contraindication is relative. Compared to volatile anesthetics, the time needed for propofol induction in anesthesia is rapid (roughly equal to the circulation time from the place of injection to brain), and the recovery is also rapid (in most cases associated with pleasant experiences, possibly mediated by dopamine receptors). It seems that GABAergic mechanism is very close to the physiologic mechanism generating unconsciousness during sleep; hence usage of selective $GABA_A$ agents predictably leads to better anesthesia compared to volatile anesthetic anesthesia (agents with diverse molecular targets one of which is the $GABA_A$ receptor). Despite of the fact that our notes are sketchy, the key argument is that hardly one could point out solely the microtubule as the main target for producing unconsciousness.

Outlook

As stated in the beginning of this paper the purpose of the current work is to outline a research programme that will put the Q-mind theory on stable scientific grounds. Unfortunately at the present time a lot of pseudo-scientific concepts are patronized under the name “quantum mind” and this has negative effect on the development of the very idea of “quantum effects in brain as explanation of some features of consciousness such as nonlocality and noncomputable evolution.”

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