

# The Importance of New Findings of Research on Consciousness for the Treatment of Depression in Elderly

Alicja Różyk-Myrta, Andrzej Brodziak\*, Małgorzata Muc-Wierzoń

Department of Medical Sciences, University of Applied Sciences in Nysa, Poland

## ABSTRACT

The recent resumption of the discussion of Stuart Hameroff's and Roger Penrose's theory, which assume that the perception of qualia is realized by a quantum physics information processing in microtubules and coinciding publication, at the same time of recent progress of the so called conscious electromagnetic information field (cemi) theory prompted the authors to the trial to integrate these theories with the earlier explanations of consciousness. In order to present the intuitive model of interacting components of consciousness, the authors provide short reviews of the 'Orch OR' and 'cemi' theories. This enables them to distinguish three distinct, cooperating processes underlying the phenomenon of consciousness, namely (a) perception, including the feeling of qualia, (b) the realization of mental imagery and (c) the feeling of subjectivity, identity manifested by the ability to self-awareness. The ability to understand the essence of the self-awareness is important for health care professionals, because consciousness disorders are a frequent medical symptom in emergencies, anesthesia and depressive syndromes in elderly. The authors emphasize the usefulness of transcranial magnetic stimulation, as a method of intervention in brain's endogenous electromagnetic field, or more precisely in its element caused by the 'default mode network'. They emphasize also that effectiveness of the use of mindfulness methods in the treatment of depressive syndromes also results from reducing the activity of "Default Mode Network".

**Keywords:** Elderly; Consciousness; Neurons; Brain

## INTRODUCTION

Recently, significant progress has been made in the ability to understand the essence of consciousness. Stuart Hameroff and Roger Penrose with some other researchers continue to promote the theory, formulated before 25 years ago, linking the essence of the phenomenon of consciousness with quantum information processing in the microtubules of brain's neurons [1-19]. Increased interest in this theory results from the discovery of high-frequency vibration in microtubules of neurons [20].

Moreover, after 20 years of slow development of the so called "field theories of consciousness" Johnjoe McFadden published in a reputable journal an extensive explanation of the conscious electromagnetic information (cemi) field theory, citing new experimental data [21-26].

Now it is possible to connect these concepts with our own theory explaining action of neural circuits realizing imagery, it means the recall of mental images from memory. We presented this theory formerly in several papers [27-30]. It enables us to propose now an intuitively understandable model integrating all these concepts, so that the essence of self-awareness is better understood.

Moreover, the clinicians using so called Transcranial Magnetic Stimulation (TMS) method for treatment of depressive syndromes provided new interesting data [31]. Some new findings related to the psychotherapeutic method, like mindfulness techniques contribute also to the greater effectiveness of the treatment of depressive syndromes [32-35].

These new findings prompted us to provide brief overviews of these achievements, which are important for improvement of the treatment of depressive syndromes in the elderly. We present

**Correspondence to:** Dr. Andrzej Brodziak, Faculty of Medical Sciences, University of Applied Sciences in Nysa, Poland, E-mail: andrzejbrodziak@wp.pl

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this progress first by short summary of the most important theories explaining the essence of consciousness.

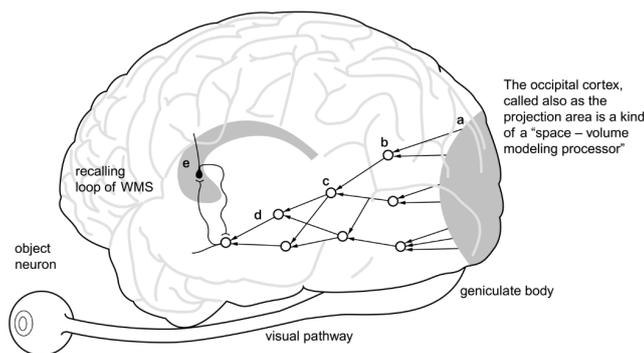
LITERATURE REVIEW

**Neural circuits, which perceive, memorize data, recognize the images and recall them in form of the mental imaginations**

The brain perceives sensory stimuli of various modalities. There are afferent pathways that integrate information: a. visual, b. auditory, c. information about the position of the head and the experienced acceleration (labyrinth analyzer), d. olfactory, e. taste, f. surface feeling; deep (touch, pressure, pain, temperature), and g. articular sensation (position of the limbs).

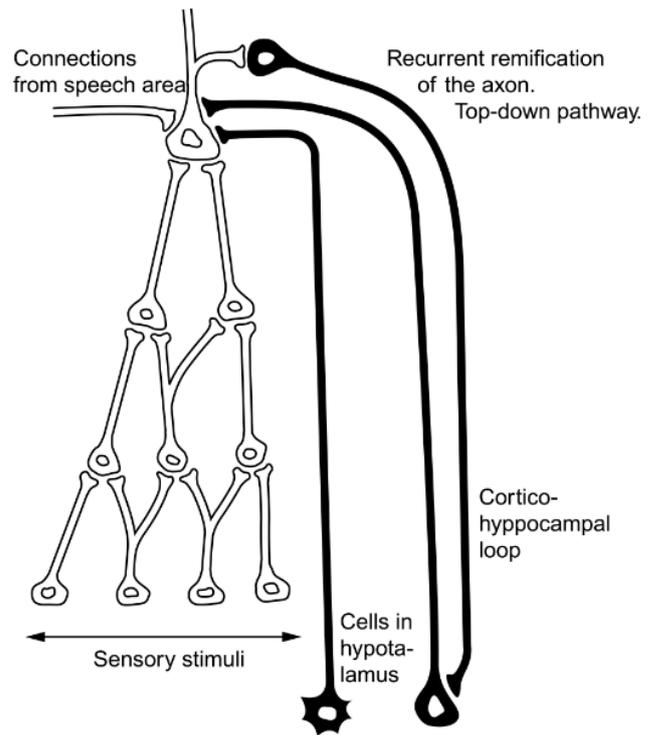
The general principles for information processing are similar across all kind of afferent pathways, going from receptor cells upwards. The natural image falling on the surface of the receptor is always processed in parallel, so that its various aspects are perceived simultaneously (e.g. size, shape, color and surface texture of a certain object).

At the top of certain hierarchical structure integrating information about a specific aspect of the image hitting the receptor cells, a group of so-called object neurons can be distinguished. The existence of such supreme neurons representing certain specific objects was detected by Gross and Mishkin [36,37]. The visual pathways are anatomically bent, what is illustrated in Figure 1. The first few floors of the visual pathway run upwards to the occipital cortex, where the image is encoded by neurons that register the existence of a line segments with a certain angle of inclination. The integration of data is then performed by pathways placed in the temporal lobe of the brain.

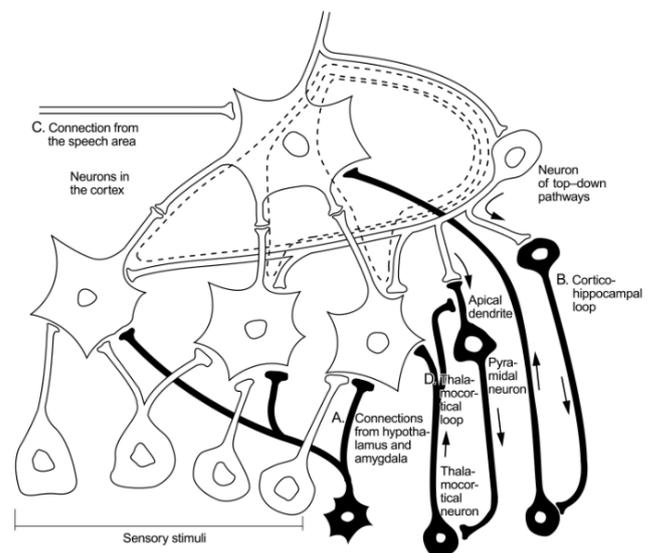


**Figure 1:** The visual pathways does not end in the occipital region, but is prolonged by superior structures placed the anterior part of the temporal lobe, where so called ‘object neuron or concept neuron’ can be found. These neurons are connected with the recalling loop of the working memory system.

The visual imaginary and visual perceptions rely on the same neural substrate [27-30]. The basic structures are depicted in Figures 2 and 3.



**Figure 2:** Two kinds of connections reach so called ‘object neurons’. One of them, going from the side of hypothalamus and amygdale is active in the case of emotional arousal and take part in the consolidation of the long- term memory traces. The second connection constitutes the oscillating loop, which cause that the evoked mental image is aroused for the time necessary for the action of the working memory.



**Figure 3:** Intuitive and symbolic depiction of some layers of the hierarchical structure of neurons integrating sensory information and of three coordinating networks. The traces of long term memory are consolidated under the influence of connections from hypothalamus and amygdale (A). There are consolidated through two mappings: weights of receiving, ascending synapses and synaptic weights of reproducing connections. The second, cortico - hippocampal loop (B) is necessary for temporary recalling of the mental image. The activation of the object neuron by this indexing loop causes the

recurrent reactivation of neurons in lower layers. The dotted line indicate the pathways of repetitive circulations of stimuli in the upper layers of the hierarchical structure, what is the essence of mental imagery. The object neuron can be activated also from the side of speech area (C). Mental imagery is the essence of episodic memory, short term memory and is used for working memory activity. The drawings highlight also the existence of the thalamo cortical loops (D). Neural activity in the period of a deep sleep is limited to the oscillations of thalamo cortical loops reaching only the lower parts of the cortex. The frequency of these oscillations are in the theta and delta range. In this situations only a core element of the imagery process is active. The figure enable to understand why perceptions and imagery stimulate further the oscillations in these loops, what increase the frequency of oscillations. The core element of the imagery process is acting permanently without external stimuli.

A very important phenomenon essential for understanding the nature of creating mental images is the oscillation between neurons of the upper and lower levels of hierarchical structures creating perceptions. To comprehend the importance of oscillations between subcortical structures (hippocamp, thalamus) and the cerebral cortex it is useful to consider (Figure 3). Almost all cortical neurons have recurrent axons. These ramifications are necessary to start top-down pathways to activate the lower levels of the hierarchical structures at the moment of the stimulation of an object neuron from the side of the speech area or during complex mental processes, especially problem-solving. When the neuron of a known object is stimulated, next the activation returns – by means of recurrent axons or generally by reproductive pathways – to lower levels of the hierarchical structure, consolidated previously during perceptions and the learning process.

When such a structure is activated from below by repeated perceptions, the object neuron is further stimulated by the cortex-hippocampal indexing loop. Thus, the structure of a known, recognized object is stimulated from two directions. When the object neuron is stimulated from the speech area, the mental image (a remembrance) is recalled [27-30]. The neural mechanism of the mental imagery consists in the circulation of impulses up and down along superior levels of the hierarchical structure, which is maintained by the cortex-hippocampal indexing loops.

### Quantum computation in brain microtubules

In order to present the contemporary state of considerations on the essence of consciousness, a short review of Stuart Hameroff's and Roger Penrose's 'Orch OR' theory is necessary. Roger Penrose and Stuart Hameroff took into account that neurons have a rich and organized cytoskeleton, with microtubules as the main components.

Microtubules are key structures for maintaining cell form and function. They participate in intracellular transport, cell movements and cell divisions. They are distributed inside neurons, in a characteristic way, mainly in the dendrites and the body of neuronal cells. Microtubules are composed from tubulin protein subunits. The tubulin protein dimers of the microtubules have hydrophobic pockets that may contain

delocalized electrons. The authors of the 'Orch OR' noticed the rapid cyclical processes taking place there. It was a novelty in science, that the authors proposed to consider the hypothesis that microtubules could realize quantum processing. They have claimed that the electrons of mentioned pockets become quantum entangled. So, they assumed that tubulin polymer elements may represent coherent quantum superpositions (qubits).

According to the authors of the theory, the basic process underlying consciousness are the cycles of increasing synchronization (orchestration, coherence) Orch and subsequent decoherence by the OR operation. Synaptic signals stimulate the orchestration process. When the threshold is reached, a so-called objective reduction and a so-called "confirmation of the state" occur. The process moves to the axons of the neurons and the data is passed on. The "Orch OR" theory suggests that quantum computations in brain neuronal dendritic-somatic microtubules regulate axonal firings to control conscious behavior. The theory assumes that the consciousness process is discrete rather than continuous and results from the occurrence of so-called "conscious moments" occurring at a frequency of about 30-90 Hz. Stuart Hameroff, if quoted literally, puts it as follows: "The 'Orch OR' theory attributes consciousness to quantum computations in microtubules inside brain neurons. Quantum computers process 'superpositions' of possibilities (quantum bits or 'qubits') which unify by entanglement, evolve and compute, until reduction, or 'collapse' to definite output states".... These orchestrated oscillations entangle, compute, and terminate ('collapse of the wavefunction') by Penrose objective reduction ('OR'), resulting in sequences of Orch OR moments with orchestrated conscious experience. Each Orch OR event selects microtubule states which govern neuronal functions [1].

Readers of the arguments of Roger Penrose and Stuart Hameroff will encounter difficulties in understanding of all papers on quantum physics. As we know, physicists have unresolved disputes in the field of this theory regarding the problem of the so-called reduction of the wave function or state vector. It should be recognized that Roger Penrose proposes several personal beliefs in the framework of the "Orch OR" theory.

Instead of talking definitely about obtaining coherence like in Bose-Einstein condensations, the authors talk about "orchestration". Roger Penrose also defines his own concept of wave function reduction, which he calls as "Objective Reduction" ('OR'). Moreover, he raises the problem that "understanding" of 'Orch OR' processing "cannot be explained by any computational system and must derive from some 'non-computable' effect".

Roger Penrose and Stuart Hameroff initially made an attempt to convince their readers that the states of coherence that condition quantum operations, such as in Bose-Einstein condensation, are possible in ordinary temperature ranges, not only at temperatures close to absolute zero [6]. In the later stages of theory development, its proponents raised the possibility of existing inside of microtubules rather of so called Frohlich condensate, a hypothetical substance characterized by coherent oscillation of dipolar molecules [10].The researchers reasoned

that this kind of condensate would magnify nanoscopic quantum effects to have large scale influences on the brain. It seems to us, that for readers with biological and medical education, some intuitive approximation of these considerations is needed. It is important to have such an intuitive, approximate explanation because the mentioned characteristics of the processes taking place in microtubules are useful to fill a gap in the rational explanation of conscious sensations known to us.

The discussed theory makes possible to understand intuitively where this "feeling of qualia" comes from in animate nature of all species. Figuratively speaking, the theory defines a possible explanation of how a "bright, colorful, panoramic, sometimes sound replica of the outside world" arises in our minds. It should be however emphasized, that many species produce this "replica of the outside world" in their nervous systems, but only a few species recognize themselves in the mirror. The theory therefore does not explain where the feeling of what we call "I" comes from.

### **A short review of the Conscious Electromagnetic Information field theory (cemi)**

One of the basic assumptions of the author of the conscious electromagnetic information field theory (cemi) is the statement that the essential integration of data in order to obtain a comprehensive result is only such an action that build something spatially, not only through a sequence of events in time [26]. To make this conclusion intuitively understandable, one can use the example of a building, created in space, according to an architectural design and technical project. The sequence of actions performed according the project must add in any next step something in a physical spatial structure, so that a certain physical construction arises.

Quoting Johnjoe McFadden's: "Neural networks, on their own, cannot be responsible for physically integrating conscious information because, like integrated circuits, they integrate information only temporally, not physically... There are, however, physical systems that encode information integrated over space in a single moment of time. We know this form of information as force fields... In this sense, the field represents an algorithm in space, rather than the algorithms in time that are implemented by Turing machines. The EM field's information is complex information that is physically bound... only energy fields are capable of integrating information in space; so, I proposed that consciousness is information physically integrated, and causally active, encoded in the brain's global Electro-Magnetic (EM) field..." [26]. McFadden remarks also that "The periodic discharge of neurons firing or action potentials generates EMF waves that propagate out of the neuron... where they overlap and combine to generate the brain's global EM field that is routinely measured by brain scanning techniques such as electroencephalography (EEG) and magnetoencephalography (MEG). The human brain therefore possesses around 100 billion EMF transmitters" [26]. According to McFadden's theory, consciousness appears when there is a massive synchronization of neuronal activity. For the continuation of the inference of this article, it is important that

McFadden emphasizes the importance of repetitive oscillations in neuronal circuits.

He writes that "it has been recognized in many studies, that conscious neuronal processing tends to be associated with re-entrant circuits, essentially closed loops of neuronal activity whereby neuronal outputs are fed back into input neurons. The function of these re-entrant circuits remains controversial, but they could be analogous to amplifier circuits in electronics that boost and phase-lock oscillations by feeding outputs back into inputs" [26].

He quote also the list of key "signatures of consciousness", namely among others: (i) a sudden ignition of parietal and prefrontal circuits; (ii) sudden burst of high-frequency oscillations; and (iii) exchange of bidirectional and synchronized messages over long distances in the cortex [26].

### **Three different elements of the phenomenon of consciousness**

The cognitive processes performed by the human nervous system are extremely diverse. Moreover, the function of the brain consists of very complex processes, carried out synchronously by various systems and centers of the brain. Many contemporary studies assess this synchronism of action by defining the so-called connectivity. In order to adequately describe what takes place during these periods of time when we are aware, it is necessary to distinguish, in our opinion, at least three separate processes. For the purposes of creating a comprehensive explanation of the consciousness the reminded above theory of Roger Penrose and Stuart Hameroff can be used to describe the "feeling of qualia". We propose to call this process briefly and intuitively as the emergence in our minds of "a bright, colorful, panoramic, sound replica of the outside world". The perceiving of the outside world, together with sensations of qualia, occurs through experiencing a discrete sequence of so-called "conscious moments", which takes place while perceiving and receiving information about the world.

However, thought processes continue also when we do not focus on the experiences of the outside world, for example when we think to find a solution to a problem. It is necessary then to use imaginations. We have described, in details, in chapter 2 the recall of memory data. In order to explain the mental imagery, it is necessary, however, to point to the essence of the neural circuits operating at that time, which we tried to illustrate, reproduced from our previous papers [27-37]. Our theory of neural circuits realizing imagery is recognized by many researchers [38]. It remains, however, to define what is this {experiencing, observing} element of our psyche, and it means the structure representing the subject, in other words what is defined by the word "I" and in the psychoanalytical theories by the word "ego". It is related to the phenomenon that some primates have the ability to self-recognition [39,40]. Some indications for the trial to say what is the "structure representing the subject" comes from introspection. The feeling of "I" arises on the basis of autobiographical memory [41]. In order to feel "I", it is necessary to remember "who I am". This, however, is determined by the remembrance of the biographical path.

Since we described in chapter 2 a model of a hierarchical structure, realizing the mental image of a certain object, it suffices now to state that the feeling of "I" arises when there is a perception of one's own body and surroundings, and then an overlay on it of imagination of oneself, it means the activation of the self-image. In order to efficiently imagine yourself, it is necessary to be able to imagine own past and remembered images of own surroundings, what allows also to imagine own foreseeable future.

In our earlier articles, we emphasized that the basic mechanism of the self-consciousness consists on the self-excitation (re-entrant processing) of neuronal circuits in cerebral subcortical structures and thalamo-cortical pathways [42-44]. Probably at the beginning of ontogenetic and phylogenetic development, not by reason of external stimuli from external world, but because of the structural necessity of "conscious information processing systems", the neural circuits are formed which triggers themselves.

Recognition of Rodolfo Llinas and Georg Northoff's inference as convincing opened the door to consideration of Qiu's and Hales's hypothesis, which assumes that on the basis of the electric pulses circulation, a secondary magnetic field is generated [23,24].

McFadden's observation that a manifestation of conscious processes consists, in particular, on the circulation of impulses in parietal and prefrontal circuits is in line with the long-known observations that damage to these areas of the brain causes identity disorders, it means disturbed ego feeling [45]. This is confirmed by the conclusions from the applications of Transcranial Magnetic Stimulation (TMS) targeted to the medial prefrontal, cingulate and medial parietal cortical regions [31].

### Data on current TMS applications in the treatment of depressive syndromes

The method of transcranial magnetic stimulation is used to treat depressive syndromes since 15 years [31,46,47]. The effectiveness depends on where the application of stimuli is targeted using so-called navigation methods implemented on the basis of fMRI images [48]. The data related to the optimal location of the sites that should be chosen for TMS to be effective in treating severe depression have led to discoveries that are important for a better understanding of the essence of depressive syndrome and significance of the default mode network. DMN consists of many anatomical structures. The most important are the posterior cingulate cortex (PCC), precuneus, medial prefrontal cortex (mPFC), angular gyrus, dorsal media prefrontal cortex (dPPP). It occurs that the application TMS for the treatment of the depression is effective when stimulation is targeted to centers of so called 'default mode network' (DMN). These centers of the brain are active when the person is not focused on the outside world during sleep and during daydream or mind-wandering. The network activates in a default mode, when a person ceases to search for solutions, when stop to be engaged in any task. DMN is also activated in some thought processes related to the past, to the future, to autobiographical remembrances and even to moral and social judgments [31]. That the application of TSM stimuli results in a reduction

in over-activity of DMN subsystems [31]. The findings about the key role of the altered function of the 'default mode network' (DMN) in depressive syndrome supports the theory, which has been developing since the 1990s, that one the basic process underlying self-consciousness consists in the self-excitation of neuronal circuits in cerebral subcortical structures and thalamo-cortical pathways (thalamo-cortical re-entrant processing). One of the precursors of this theory was Rodolfo Llinás, who formulated the theory of thalamocortical-resonance (oscillation) [42]. Georg Northoff developed this theory and distinguished several levels of so-called 'neural prerequisites' and 'neural substrates' of self-consciousness [42]. According to him, one of the necessary factors, though not sufficient for self-consciousness, is neuronal oscillation in the brainstem and midbrain [19]. Recognition of Rodolfo Llinás and Georg Northoff's reasoning as credible also opens the door to serious consideration of Hales and McFadden's theories, which assumes that secondary electromagnetic field is likely to be generated on the basis of the electric impulses circulation [43,44].

### Recent progress in understanding of significance of mindfulness method in the treatment of depressive syndromes in elderly

Recently, many studies have been published presenting the results of research on the importance of mindfulness techniques and in the treatment of depression [32-34]. Not only the results of randomized controlled trials have been published, but also theoretical considerations regarding the mechanisms of influence of these techniques [35]. An important observation is that methods that intensify mindfulness works by reducing DMN activity. This is in line with the data presented on how TSM influence DMN system.

### CONCLUSION

The ability to understand the essence of the phenomenon of consciousness is important for health care professionals, as consciousness disorders are a frequent medical symptom in emergency situations, anesthesia and especially in depressive syndromes in the elderly. The integration of discussed theories of consciousness enables a binding answer to the questions about the essence of self-awareness. Only the multi-level, hierarchical data processing reaching the centers located in the parietal and prefrontal areas make possible to pass the mirror test successfully. It turns out, that for a convincing description of the phenomenon, in addition to enumeration of material substrates, it is necessary to admit the role of an energy equivalent in the form of a specifically shaped electromagnetic field. The TMS method of intervention in brain's endogenous electromagnetic field, or more precisely in its element caused by the 'Default Mode Network' (DMN) is already useful in treatment of depressive syndromes and borderline personality disorders. The effectiveness of the use of mindfulness methods in the treatment of depressive syndromes also results from reducing the activity of "default mode network".

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