# HIERARCHICAL NEURAL NETWORKS AND BRAINWAVES: TOWARDS A THEORY OF CONSCIOUSNESS

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**Abstract.** In this paper a comparative biocybernetical analysis of the possibilities in modeling consciousness and other psychological functions (perception, memorizing, learning, emotions, language, creativity, thinking, and transpersonal interactions!), by using biocybernetical models of hierarchical neural networks and brainwaves, is given. It is pointed out that contemporary artificial neural networks are not able to model most of psychic functions, primarily owing to their nonhierarchical architecture. On the other hand, some biocybernetical models of hierarchical neural networks are very encouraging - which is not surprising having in mind that information processing in the central nervous system is achieved through hierarchically organized and interconnected neural networks. However, for modeling most of psychological functions (perception, memorizing, learning, emotions, language, thinking, and especially consciousness, creativity, and transpersonal interactions), the brainwaves combined with complex biophysical ionic neural networks are necessary. This demonstrates that such a broad modeling of psychological functions requires application of subtle biophysical hierarchical neural networks with embedded ultralowfrequency brainwave activity. The implications of these investigations on the diverse scientific fields, including radical shifts in understanding fundamentals of philosophy and religion, are also pointed out.

*Key words: hierarchical neural networks, brainwaves, ionic structures, altered and transitional states of consciousness, theoretical psychology, biophysics, relativistic & quantum physics, comparative approach.*

## INTRODUCTION

The prevailing scientific paradigm considers information processing inside the central nervous system as occurring through hierarchically organized and interconnected neural networks. For instance, the visual information is firstly hierarchically processed at the level of retina (from the photoreceptory rods and cones, to the ganglion cells), to be then hierarchically proceeded within the levels of primary, secondary, and tertiary sensory and interpretatory cortical regions (all of them being additionally constituted of hierarchies of several neural networks) [1]. Interconnections within neural networks and between the neighboring neural networks in this hierarchy are achieved by synapses (one neuron having approximately 40000 synaptic connections with neighbors), which can be excitatory or inhibitory. During the learning process, apart from the brain's hierarchy of neural networks, a significant role in

global distribution and memorizing (over the whole cortex) of hierarchically processed information is played by brainwaves [2].

Along with the development of experimental techniques enabling physiological investigation of interactions of hierarchically interconnected neighboring levels of biological neural networks, significant contribution in establishing the neural network paradigm was given by theoretical breakthroughs in this field during the past decade [3].

The contemporary sequential (von Neumann's) computers have a clock $\sim 10^{-9}$ s, while an average generation time of the neuron action potential is $\sim 10^{-3}$ s. Although this activation rate of the semiconducting processing elements is $\sim 10^6$ times higher, the brain is superior in some complex tasks, such as the image processing and recognition, orientation and movement in the space of changeable characteristics, speech recognition, etc. The reason for great possibilities of the brain lies in the parallel information processing.

Besides, as the number of neurons within the brain and the number of their interconnections are constant, knowledge is distributed within synapses, and new information is added by adjusting the strengths between neurons. Also, some parts of information do not occupy some local positions, but are distributed across the brain regions. Thus a damage of a neuron, or even a group of neurons, does not deteriorate performances of the system, while in most of sequential computers a damage of a part of processing unit causes either an interruption of the whole system or irreversible loss of the information.

In contrast to sequential computers, in which a central processor unit controls all internal activities and has an access to the memory, the brain control is achieved locally. Behavior of every neuron in the brain depends only on its previous knowledge and the input environment, so it can be said that the output of any neuron is a function of locally available information.

Neural networks, to emulate brain function, have many good properties: parallel functioning, relatively quick realization of complicated tasks, distributed information, weak sensitivity on local damages, as well as learning abilities, i.e. adaptation upon changes in environment, and improvement based on experience.

These good properties of neural networks have inspired many scientists to propose them as a solution for most problems: with sufficiently big network and adequate training, the networks could accomplish an arbitrary task, without knowing a detailed mathematical algorithm of the problem. Currently, such expectations are far from realization. To date the real solution is in finding corresponding network topology and training rules for every particular task [3].

One of the first and most significant concepts in the field of neural networks is the Hebb's biological learning law [4], according to which the more frequently activated synapses are strengthening, while those ones less frequently activated are weakening. In neurocomputing this rule is now known as a Hebb's learning rule.[a]

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[a] For a neural network architecture called the linear associator [3], consisting of the input layer (having $n$ neurons) and the output layer (having $m$ neurons), in which every output neuron is interconnected with all input neurons, with some weights or adaptive coefficients $w_{ij}$ ($i = 1,2,...,m$; $j = 1,2,...,n$) - mathematical representation of the Hebb learning law can be written in the matrix form

$$W = y_1 x_1^T + y_2 x_2^T + ... + y_L x_L^T, \quad (L \leq n) \tag{1}$$

where the weight matrix obtained this form after L training pairs of input and output vectors: $(x_1,y_1)$, $(x_2,y_2)$, ..., $(x_L,y_L)$. The vectors $y_k$ i $x_k$ are matrices columns with components $y_{ki}$ ($i = 1,2,...,m$) and $x_{kj}$ ($j = 1,2,...,n$), while $x_k^T$ are matrices rows obtained by transponing matrices columns $x_k$. Eq.(1) is called the outer product sum formula for the weight matrix $W$, implying that during successive learning with the vector pairs $(x_k,y_k)$ the incremental changes to $W$ is of the

In general, apart from the input layer (which only distributes input data to the following layer), the neural network can have several hidden layers, which precede the input layer. In this respect, holds Kolmogorov's mapping neural network existence theorem: Any continuous function $f(x^{(n)}) = y^{(m)}$ can be exactly implemented by a three-layer neural network having $n$ neurons in the first (input) layer, $2n+1$ neurons in the middle (hidden) layer and $m$ neurons in the last (output) layer.

That means that any mapping $x^{(n)} \xrightarrow{\ f\ } y^{(m)}$ does not require more than one hidden layer, although for practical reasons in the case of a large $n$, instead of one hidden layer with $2n+1$ the neurons, the two or more hidden layers with much less neurons is being used! Depending on the number of layers and learning rules (with or without supervisor), there are several types of practically used neural networks [3,6]. The past practical experiences with training of artificial neural networks imply the necessity for learning not to last too long, and not to have too many hidden neurons within the network, as this gives rise to overtraining of the network and tendency to memorize the input/output vector pairs only, without generalization (learning) - with no capability to recognize some new input vector for which not being previously trained.

However, the brain consists of $\sim 10^{10}$ neurons but simultaneously it is very flexible, which clearly implies its somewhat different organization in respect to artificial neural networks. Really, although the artificial neural networks appeared as a concept of duplication of biological neural networks, many of the commercial networks do not have any essential similarity with the biological ones - which are organized as hierarchical neural networks!

## HIERARCHICAL NEURAL NETWORKS VERSUS BRAINWAVES: PROSPECTS FOR THEORETICAL PSYCHOLOGY

Most of the artificial neural networks have a maximum of interconnections between functionally *nonspecialized* neurons of the neighboring layers, where every neuron of one layer is connected to all neurons of the neighboring layers (so called *massive parallelism*). However, in hierarchical neural networks interconnections between neurons of neighboring layers are much more sparse and localized.

The advatage of a *hierarchical neural network* structure is that the functionally *specialized* neurons of each layer process only a limited amount of information from the previous layer.

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form $y_k x_k^T$, which is the outer (direct) product of the vectors $y_k$ and $x_k$. If the vectors $(x_1, x_2, ..., x_L)$ are orthonormal

( $x_i^T x_j = \delta_{ij}$, where $\delta_{ij}$ is the Kronecker delta: $\delta_{ij} = 1$ if $i = j$ and $\delta_{ij} = 0$ if $i \neq j$) - then

$$y_k = W x_k, \qquad (k = 1,2, ...,L) \qquad (2)$$

or in other words, the linear associator network will then perform the desired input/output transformation. It is obvious that there must be $L \leq n$, because of the dimensionality of the $x_k$ vectors: the maximum possible number of orthogonal vectors in $n$-dimensional vector space is $n$. This is a consequence of the linearity of the vector space, i.e. transformations (1) and (2)!

To transcend this limitation, i.e. to enable that neural network can learn and recognize much more vectors (L) with respect to the number of input neurons ($n$), it is necessary to apply nonlinear transformation $y_k = W^{nel} x_k$! Contemporary neural networks, which came out the shadow of artificial intelligence after a 15-year quietness owing to Hopfield's papers [5], usually use some nonlinear transformation ($S$) of the linear combination ($\Sigma_j$) of input signals ($x_{kj}$) and weights ($w_{i\,j}^1$) of neurons:

$$y_{k\,i}^1 = S\left( \sum_{j=1}^{n} w_{ij}^1 x_{k\,j} \right), \qquad (3)$$

where index k enumerates the pairs of input/output vectors (k = 1,2,...,L), while index i enumerates components of the output vector (i = 1,2,...,$m$) in the l-th layer of neural network (l = 1,2,...).

The total global situation is then pieced together as one ascends from one hierarchical layer to the next.

Such approach requires a spectacularly smaller number of processing elements than would be required by a network with massive parallelism of interconnections between neighboring layers! It should be pointed out that hierarchical neural networks are only appropriate in those situations where the inputs to the network have low-level, intermediate-level, and high-level structures that can be consistently related to one another, as images or sounds from outdoor scenes (random data, however, do not have such structure). That is the reason why biological neural networks are organized as hierarchical networks.

A significant contribution in modeling *biological hierarchical neural networks* was given by Grossberg and his collaborators [7], working on hierarchical architecture adapted for modeling perception of illumination of a visual field, based on the experimental neuropsychological data about the visual feature extractors; the numerical simulations have shown that such a network can recognize different psychological illusions too, related to the problem of surface illumination. By introducing excitatory and inhibitory loops for intra-columnar interactions, as well as inter-columnar feedback connectivity within columnar structure of the visual cortex, Grossberg and Somers [8] predicted electroencephalographic (EEG) $\gamma$-oscillations ($\sim 40$ Hz) of their hierarchical network, generated in response to steady-state-inputs. A generalization of this retinocortical model by Ogmen and his collaborators [9] produced additionally EEG $\alpha$-rhythm ($\sim 10$ Hz) in response to intrinsic-noise sources (in the absence of external inputs), and flash visual evoked potentials (FVEP) of various relative magnitudes and latencies (P40, N70, P100, N130, P170) in response to flash inputs. It should be pointed out that their study makes predictions for network activities that can be translated into EEG signals, providing an important missing link between single-neuron activities and the ensemble properties of the biological neural networks!

A significant contribution in modeling biological hierarchical neural networks was given by Freeman and his collaborators [10] too. By adopting a system of feedback on different hierarchical levels of the network, the neural network which reflects the dynamics of olfaction was obtained. As a result of modeling, strange attractors with multiple "wings" were obtained: the central part of attractor can be interpreted as a basal chaotic electric activity of the olfactory system (simulating the basal brainwave EEG activity without olfactory stimulus), while the wings of attractor can be interpreted as "near-limit cycles", corresponding to quasiperiodic states of the induced brainwave EP activities upon the various olfactory stimuli, implying that EEG enables brain's quicker responses upon stimuli!

Hierarchical neural networks are also a biological basis of *learning* and *memory*, as the aforementioned types of *perception* require a previous training (learning) of the network, accompanied with memorizing of the information! In the case of olfactory system, Freeman and his collaborators have proposed the following hierarchical mechanism of learning and memory [11]. Excitatory neurons are activated, strengthening their joint synapses in accordance with Hebb's rule [4]: a nerve cell assembly (NCA) is thus created comprising perhaps 1-5% of the total in the olfactory bulb. Thereafter, excitation of any portion of the NCA by receptors sensitive to a particular odor tends to activate the whole assembly.

So, it seems that *learning* in olfactory system is related to generation of corresponding activation of a local cell assembly in the olfactory bulb, while *memorizing* and *recall* is related to the whole bulb. The very activation of only a part of the odor-specific receptors results in hierarchical activation of the local cell assembly, followed by activation of the whole olfactory bulb.

The similar is characteristics of the learning process in general [2]: while something is learned, information is hierarchically processed in primary, secondary, and tertiary brain areas, being afterwards spread by brainwaves over the whole cortex; however, when learning is achieved (so called habituation), the same visual stimulus can only be found in the visual system.

This also implies that brainwaves play a significant role in *distribution* of information across the whole cortex, and its *memorizing*. Of particular interest in this process is also extended reticular-thalamic activating system (ERTAS) [12], as a hierarchical system of neural networks which compares currently processed information with the one memorized in the cortex, giving priority and amplifying one piece of information to the conscious frequency levels of $\alpha$, $\beta$, and $\gamma$ brainwaves; the rest of information remain nonamplified at unconscious frequency $\delta$ and $\theta$ levels (it should be stressed that the oscillator model of Ellias and Grossberg [13] really predicts EEG rhythmicity in such a way that an increase in the input causes an increase in the frequency of oscillations, and decrease in their amplitude, offering an unified explanation of EEG waves ranging from $\delta$ to $\gamma$). This might basically be also the mechanism of "*emotional coloring*" of some information, and its ascending upon the ERTAS-amplification from the lower-frequency ($\delta$,$\theta$) unconscious form of primordial subliminal thought to the higher-frequency ($\alpha$,$\beta$,$\gamma$) conscious thought! So, it seems that there are two levels of information *coding* and *memorizing* in biological neural networks [14,15]: spatio-temporal level (responsible for spatially distributed memory, through dynamic strengthening and weakening of synapses, in accordance with Hebb's rule) and ultralowfrequency level (responsible for normally conscious and unconscious states and their interactions, through the ultralowfrequency modulation of the first level).

Accordingly, a *thinking* process could be separated in at least two parts: first, the selection of one piece of information out of complete one processed by hierarchical structure of brain's neural networks, and its amplification to the conscious level, and second, the problem solving related to this piece of information. The first process is accompanied by emotional and verbal modulation of information by nondominant (normally right) and dominant (normally left) cerebral hemisphere, respectively [16]. The second process includes the prefrontal region and the associative secondary and tertiary cortical structures [17]. The significant role in this process can belong to brainwaves - through distribution of information across the whole cortex [2], and in transitional states of consciousness [15] (with anticipating creative insights), and altered states of consciousness [15,18] (with intense associative mixing of normally conscious and unconscious contents related to this problem, which can contribute to acceleration of the problem solving)!

A modeling of verbal modulation of information is an important but extremely complex task, still waiting to be fully accomplished in future hierarchical neural networks. However, it seems that basic brain mechanisms responsible for organization of natural *language* are known [19]: (a) Semantic processing (which relates indicant and symbol to the sensory input from which they derive) is carried out by systems which involve the posterior "association" areas that surround the primary sensory areas; (b) Pragmatic processing (which relates sign and symbol to their user) is carried out by ERTAS-like systems which involve the frontolimbic cortical formations of the brain; (c) Syntactic processing (the arrangement of indicants and symbols) is carried out by the motor systems of the brain to which both posterior and frontal cortical formations project. It should be then pointed out that ERTAS-like mechanism of pragmatic processing, in combination with the increase of dominant EEG frequency from $\delta$ to $\beta$ brainwaves [20] during an ontogenesis, implies that the mother tongue is generally

memorized at low-frequency δ and θ levels (later being unconscious in adults), in contrast to second and even further languages in bilinguals and multilinguals which are memorized at high-frequency α, β, and γ levels (later being conscious in adults) - further on implying that second and further languages are being hardly incorporating at unconscious (automatic) levels, save only from contextual learning which enables unconscious processing of contexts. This might provide differences of the language learning in childhood and adulthood, as well as in school and in living environment!

A particularly significant role of brainwaves is involved in modeling the *states of consciousness* - and especially the altered states of consciousness [15,18], as elaborated further on.

**TOWARDS A THEORY OF CONSCIOUSNESS**

The key problem of any future theory of consciousness is how to incorporate altered states of consciousness (REM sleep, meditation, hypnosis, psychedelic drug influence, some psychopathological states, and near-death experiences) within a new paradigm. It should be pointed out that purely *biochemical* mechanisms of the ERTAS are not accelerated up to several orders of magnitude, as the subjective time sense is dilated in altered states of consciousness [21-23] - in respect to the normal awake state.

The only mechanism that can account for the extremely dilated subjective time base in altered states of consciousness is the relativistic *biophysical* one, if only the "subjective" observer can be associated with an EM field of the ultralowfrequency (ULF) brainwaves which can move through the brain with relativistic velocities, as it was extensively elaborated in our biophysical model of altered states of consciousness [14,15]. However, it is necessary that complete information (both conscious and unconscious) be permanently coded from neural network to brainwaves, as a spatio-temporal pattern resulting from changes of the synaptic interconnections in the neural networks of the brain.[b]

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[b] To be more specific, the ionic medium supporting propagation of the brainwave ULF ionic currents must be inhomogeneous [14,15], to ensure that the "subjective" observer (associated with the EM component of reference ULF brainwaves), moving through the part of medium of greater $\varepsilon r$, could register time-dilated information from faster EM component of brainwaves moving through the neighboring part of medium of lower $\varepsilon r'$. Then, at every moment the "subjective" observer is associated with the EM component of brainwaves in the dialectically "denser" medium, and the whole such system behaves like some "center of consciousness". The informational content of such "subjective" observer is continuously replaced by a new incoming EM component of brainwaves. So, we have permanently some "stream of consciousness". More precisely, for inflowing information (in the form of ULF brainwave ionic currents, coded in spatiotemporal patterns from the brain neural networks) to be recognized by the structured ionic medium, that medium itself must have a form of some kind of "optical" neural network - thus the "subjective" observer being associated with the EM component of brainwaves in dielectrical "condensations" (of greater $\varepsilon r$), behaving like "distributed centers of consciousness", this presumably being the basis of yogic chakras [14]; in that context, it seems that other esoteric notions [24,25] such as subtle body (manomaya, lingasarira, manovijnana, ka, psyche, astral body, psychic body ...) and mental body (vijnanamaya, suksmasarira, manas, ba, thymos, mind, noetic body ...) are biophysically inevitably associated with a partly displaced (from the body) ionic acupuncture system, and an EM component of ULF ionic currents embedded within it, respectively; along the same line the qi (prana, pneuma, ether, "bioenergy", ...) can be biophysically associated with ions, implying also physiological significance of the ions in air, out of them the positive ions having an exciting influence (yang) and the negative ones an inhibiting influence (yin) [26]. It should be also added that ionic acupuncture currents, and accompanied EM fields, have both ultralowfrequency (ULF) and microwave (MW) components, i.e. the MW component is modulated by the ULF component: in support to the ULF nature of ionic currents in acupuncture channels, one can cite the resonance ULF (~ 4 Hz) stimulation of the acupuncture analgesia endorfin mechanism [27]; on the other hand, the evidence for the MW component of ionic acupuncture currents is provided by resonant MW (~ 50-80 GHz) therapy, efficient even in very serious diseases [28]. According to former Soviet inventors of the resonant MW therapy, Sit'ko and his collaborators, acupuncture system is

It should be also pointed out that it might not be quite accidental that consciousness is related to the EM field of ULF brainwave ionic currents, as the intensity of irradiated ULF EM field is extremely low (intensity I of the field of frequency f, irradiated from a dipole source of linear dimensions d, has a dependence $I \sim f^4 d^2$ [32]), giving rise to consciousness localized around the body.

The model perfectly fits with the narrowed-down limits of conscious capacity in normal awake state (when brainwaves are predominantly located in the brain tissue with relative dielectric permittivity $\varepsilon_r \gg 1$), and very extended limits in altered states of consciousness (characterized by low-dielectric $\varepsilon_r \approx 1$ states, when the relative velocity between the "objective" laboratory reference frame and the "subjective" one is highly relativistic, $v = c_o \sqrt{\varepsilon_r} \approx c_o$, where $c_o$ is a velocity of EM waves in vacuum) - due to biophysical relativistic mechanism of *dilations of the subjective time base*.[c]

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a dynamic structure, differentiated at the locations of maximums of three-dimensional standing waves, formed as a result of the reflection of coherent microwave ($\sim 100$ GHz [29]) Fröhlich excitations of molecular subunits in the cell membranes and proteins - supported also by other investigations which have demonstrated that differentiation of the intercell "gap junctions" (of higher density at acupuncture points and meridians) is slightly sensitive to voltage [30]; in that context the explanation for efficiency of this method should be sought: some disorders in the organism give rise to deformation in the structure of electrical field of the organism in MW region, which influences some changes in spatial structure of the acupuncture system, and consequently its resonant frequency, resulting in some disease; during the therapy, applying the MW sound at corresponding acupuncture point the excited acupuncture system of the patient is relaxing to the previous healthy condition, while reaching its normal frequency response upon the wide spectrum MW source - and following to physiological mechanisms of the acupuncture regulation [31] organism biochemically overcomes the disease. Then, the biophysical process of holistic healing might be generally related to appropriate artificial or biotherapeutic corrections of the disordered ionic distributions and concentrations within the acupuncture system of the healee, either by transfers of ions or EM information patterns in MW and ULF domains - responsible for normal functioning of acupuncture system and overall health.

[c] By attaching the "objective" reference frame to the brain (i.e. laboratory) which moves relatively to the "subjective" reference frame with velocity $v = v = c_o / \sqrt{\varepsilon_r}$ (where $c_o$ denotes the propagation velocity of the EM field in vacuum, and $\varepsilon_r$ the ULF relative dielectric permittivity of the denser ionic structure where brainwaves propagate), the relativistic relation between the time intervals [33], from the viewpoint of the inertial "subjective" observer ( $v = c_o / \sqrt{\varepsilon_r} = const$ ), is [15]

$$\Delta t^{subj} = \frac{\Delta t_o^{obj}}{\sqrt{1 - \dfrac{v^2}{c^2}}} = \left. \frac{\Delta t_o^{obj}}{\sqrt{1 - \dfrac{\varepsilon_r'}{\varepsilon_r}}} \right|_{\frac{\varepsilon_r}{\varepsilon_r'} \approx 1} \gg \Delta t_o^{obj} \tag{4}$$

where $c = c_o / \sqrt{\varepsilon_r'}$ denotes the propagation velocity of the incoming EM field inside the neighboring part of ionic structure with lower dielectric permittivity ($\varepsilon_r' < \varepsilon_r$). This could account for the striking dilations of the subjective time base ($\Delta t^{subj}$) in comparison with the objective time measured by the laboratory clock ($\Delta t_o^{obj}$), in altered states of consciousness, if $\varepsilon_r / \varepsilon_r' \approx 1$. This condition can be achieved only in a low-dielectric weakly ionized gaseous structured medium (with $\varepsilon_r \approx \varepsilon_r' \approx 1$), as the brain is a highly nonhomogeneous structure where $\varepsilon_r$ could range from $\varepsilon_r \geq 2$ (characteristic of biopolymers) across $\varepsilon_r \approx 81$ (characteristic of free tissue water to $\varepsilon_r \sim 10^5$ (characteristic of cell membranes, with striking polarization of the volume ion density within the porous cell wall, strongly depending on metabolic cell processes [31]).

This relativistic mechanism also enables the *dream-like* mixing of the normally conscious and unconscious contents in altered states [15,18], due to the relativistic Doppler mapping of EM component of the "objective" ULF brainwaves power spectrum on the zero-degenerate frequency [d] "subjective" one.[e] This could be the biophysical *mechanism of dreams*, which particularly implies their psychological significance: in dreams one has continuous access and more efficient "subjective" integration of normally conscious and unconscious contents, giving rise to integration and growth of human personality (otherwise divided into conscious and unconscious associative "ego" states), which results in alleviation of emotional conflicts [15,18]. Then *meditation*, as a prolonged altered state of consciousness, enables more efficient "subjective" integration of human personality, but it is inevitably accompanied by a decay of ultradian rhythm, governing alterations of normal and altered states of consciousness (of periodicity ~ 1.5 - 2 hours, in both waking and sleeping [38]). However, if a person bears strong internal psychic conflicts i.e. "ego states", the result of such a prolonged meditation will be integration of human personality around foregoing several "ego-states", with undesirable result of multiply divided (instead of well integrated) personality; competent teachers of meditation are fully aware of these perils, and do not recommend its accelerated practice to psychically weak persons (for whom the main priority being a *reprogramming* of psychic conflicts [39]).

Biophysical nature of the *low-dielectric* ($\varepsilon_r' \approx \varepsilon_r \approx 1$) structure has also been analyzed: this structure could be related to partly displaceable (from the body) unhomogeneous ionic acupuncture system, which can conduct ULF brainwave currents ~ $10^{-7}$ A, inside the conductive channels of the initial ionic concentration ~ $10^{15}$ cm$^{-3}$, with a tendency of

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[d] This does not diminish the rate of "subjective" information processing, as this process is not serial but parallel (both in spatiotemporal and frequency domains), being enhanced on "subjective" level by greatly enlarged temporal resolution due to extremely dilated "subjective" time base in altered states of consciousness.

[e] The relativistic relation between the frequencies [35] measured in the two reference frames, moving away from one another ($\alpha = \pi$), is [15]

$$f^{subj} = f_o^{obj} \left. \frac{\sqrt{1 - \dfrac{v^2}{c^2}}}{1 - \dfrac{v}{c}\cos\alpha} \right|_{\alpha = \pi} = f_o^{obj} \left. \frac{\sqrt{1 - \dfrac{\varepsilon_r'}{\varepsilon_r}}}{1 + \sqrt{\dfrac{\varepsilon_r'}{\varepsilon_r}}} \right|_{\frac{\varepsilon_r}{\varepsilon_r'} \approx 1} \ll \ f_o^{obj} \tag{5}$$

which describes the striking relativistic Doppler shift of the excited "objective" brainwave frequency ($f_o^{obj}$) down to the vanishing "subjectively" observed brainwave frequency ($f^{subj} \approx 0$ Hz) in low dielectric ($\varepsilon_r \approx \varepsilon_r' \approx 1$) altered states. This can account for the mixing of conscious and unconscious contents in the altered states of consciousness, as five main frequency bands of both the spontaneous (EEG) and evoked (EP) brainwave activities, $f_{o\gamma}^{obj}$ (30-50 Hz), $f_{o\beta}^{obj}$ (13-30 Hz), $f_{o\alpha}^{obj}$ (8-13 Hz), $f_{o\theta}^{obj}$ (3,5-8 Hz), and $f_{o\delta}^{obj}$ (0,5-3,5 Hz), the first three of them predominantly corresponding to normally conscious states [36] and the last two corresponding to normally unconscious states [37], for $\varepsilon_r / \varepsilon_r' \approx 1$ start merging from the viewpoint of the "subjective" reference frame: $f_\gamma^{subj} \approx f_\beta^{subj} \approx f_\alpha^{subj} \approx f_\theta^{subj} \approx f_\delta^{subj} \approx 0$ Hz. Although the "objective" brainwave power spectra in such states do not differ significantly from the spectrum of the alert state, the essential difference appears in the "subjective" brainwave power spectra; for the sake of comparison, in the alert state the brainwaves are predominantly located in the brain tissue (with $\varepsilon \gg 1$), when a differentiated "subjective" spectrum exists: $f_i^{subj} = f_{o\,i}^{obj} \sqrt{1 - \varepsilon_r'/\varepsilon_r} \big/ \left(1 + \sqrt{\varepsilon_r'/\varepsilon_r}\right)$, $\quad i = \gamma, \beta, \alpha, \theta, \delta$.

deterioration during a period of $\sim$ 1 hour [14,15]. As a consequence of the deterioration process, the displaced part of the ionic acupuncture system can be finally "emitted" together with the informational content of the embedded ULF EM waves [14,40]. Even the conditions for ULF EM field localization are not fulfilled at the end of deterioration process, as then ULF brainwave currents can flow through the surrounding weakly ionized ($\sim 10^4$ cm$^{-3}$) atmosphere,[f] which significantly enlarges linear dimensions of the dipole source and therefore the intensity of irradiated ULF EM field. Even *long-range interactions* of this type are energetically supported by existence of extremely low attenuation at ULF frequencies due to "Schumann resonances" of the earth-ionosphere cavity, well matched with EEG-spectrum [42]. The above mechanism has probably been of adaptational significance for animal species, in highly efficient global spreading of surviving-important novel information [43]. Inside the human population, it seems that the Maharishi effect is providing evidence [44] for the above possibility - which can be biophysical basis of Jung's *collective unconscious* [45]. In that context, it could be said that ionosphere represents a dynamic collective memory of all biological species, which is continuously being refreshed by biological units with periodicity and phase of their ultradian rhythms, having continuous backward influence on the living world globally. Such global information processing on the ionospheric level is enabled by inhomogeneities in its ionic structure due to local variations of the Earth's magnetic field, implying that ionosphere behaves as a giant "optical" neural network, with ionic channels of greater conductivity in respect to local environment.

It should be noted that some peculiar *spatial* relativistic effects in altered states of consciousness (when $\varepsilon_r \approx 1$) are predicted by the model [15]: the weakly ionized gaseous neural network, with embedded ULF brainwave currents, enables that even long "objective" distances can be "subjectively" recognized *contracted*, implying that such displaced ionic neural network can optically perceive an environment *extrasensory*, as reported by reanimated patients. Even most peculiar *spatio-temporal transpersonal interactions* are predicted in *transitional states* of interchange of normal and altered states of consciousness (when brainwaves traverse from high-dielectric ($\varepsilon_r \gg 1$) to low-dielectric ($\varepsilon_r \approx 1$) state or vice versa, the relative velocity $v = c_o \sqrt{\varepsilon_r}$ of "subjective" reference frame being therefore subjected to abrupt change in short transitional period $\tau \sim 0,1$ s, with "subjective frame" acceleration $\sim c_o/\tau$ $\sim 10^9$ m/s$^2$) - due to the relativistic generation of so-called wormholes in highly noninertial "subjective" reference frame - fully equivalent, according to Einstein's Principle of equivalence, to extremely strong gravitational fields where generation of wormholes (or Einstein-Rosen space-time bridges, whose entrance and exit could be in very distant space-time points) is theoretically predicted [46]. It should be pointed out that apart from the EM field, the displaced part of ionic acupuncture system (in the form of ionic neural network, having the "optical" sensory function), must also be tunneled in previously "mentally addressed" distant

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[f] Further deterioration of the points of displaced part of the ionic acupuncture system makes the whole ionic system homogeneous, and "proper time" ("subjective" time) for photons in dielectrically homogeneous medium is identically zero [33], thus preventing any "stream of consciousness" (in contrast to situation for nonhomogeneous low-dielectric medium, when "subjective" time is highly dilated; cf. footnote c) - bringing the ultimate transpersonal state of thought-free consciousness (nirvana, samadhi, satori, enlightenment [24]). Objectively, the whole ionic system is completely open for information exchange in ULF domain, bringing a sense of oneness with the surrounding world, and subjectively, this is the state of empty consciousness, although the brain neural network can be still very active. This state lasts very shortly in nontrained persons, but can be presumably prolonged in yoga-like trained persons. The lost part of the ions (of the initial concentration $\sim 10^{15}$ cm$^{-3}$) is insignificant in comparison with that which exists in the body ($\sim 10^{20}$ cm$^{-3}$ [41]), and can even be regenerated during the breathing process in $\sim$ 1 h.

exit in space-time [g] - reminiscences on passing through some tunnel being actually reported by many patients reanimated from clinical death [23]!

This could be a biophysical mechanism of the so-called *astral projections* of consciousness, they presumably being the basis of most psychic phenomena [48] - being actually described by rare practitioners as not subjected to spatio-temporal limitations [25,49,50] - providing also explanation for their transitional nature and poor reproducibility: they last only ~ 0,1 s, and spontaneous conditions for them are achieved only every 1.5 - 2 hours, with periodicity of ultradian rhythms which govern the interchange of normal and altered states of consciousness [38]. However, it should be noted that the non-low-dielectric barriers in interaction with the low-dielectric barriers can induce transitional states (not limited by ultradian rhythms!), thus barriers helping in overcoming themselves in such induced transitional states - quite opposite to normal experience in usual mechanical interactions – enabling even their deliberate control and prolongation [25,49]! The aforementioned transitional states are presumably also the basis of *religious experiences*: in particular, it seems that efficiency of *prayer* in self-healing of interior psychological conflicts (caused by some previous interpersonal fights) might be the consequence of similar biophysical transpersonal interactions of the persons in conflict in transitional states of the praying person, accompanied by *mutual reprogramming* of interior conflicts (as a germ of the future interpersonal fights, as well as of potential psychosomatic and psychological disorders); that might provide an explanation for extraordinary efficiency of prayer accomplished shortly before sleeping (which is recommended by all religious traditions), with direct mental a dressing on the person in conflict, or energetically more efficient indirect mental addressing via ionically abundant disembodied archetype structures [38].

The predicted transitional states of consciousness could also be the biophysical basis of *anticipation*[h] in intuition, precognition and deep creative insights - which could be easily put

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[g] To support this, one can cite the technique adopted by "psychics" when they want to exert some distant influence: they always intensely visualize the person or place, as mental targets! On the other hand, this could be deeply connected with the role of consciousness in quantum theory of measurement, where consciousness with its act of observation affects the final collapse of the initial wave function into one of possible probabilistic eigenstates - which implies that the collapse could be related to generation of a local Einstein-Rosen bridge in highly noninertial processes of interactions of microparticles with measuring apparatuses [15], equivalent to strong gravitational effects of crucial importance for this process [47], cf. footnote i).

[h] According to the computer experiments with random number generators [51], only nonactualized possible futures can be anticipated (more accurately for a priori greater probabilities of their realization), in accordance with quantummechanical viewpoint. In that context, what is actually anticipated in transitional states of "individual consciousness" might be the evolved state of "collective consciousness" $\Phi(t)$ in some future moment t [15] (to which "individual consciousness" $\varphi_k$ has access, being the constitutional part of "collective consciousness", $\Phi(t) \sim \prod_k \varphi_k(t)$),

which is quantummechanically described by deterministic unitary evolution governed by Schrodinger equation (or Dirac equation in relativistic case). However, the anticipated state $\Phi(t)$ could be redefined by changing initial state $\varphi_k(t_o)$ of "individual consciousness", thus leaving room for free will and the possibility for influence on the future: then, by changing initial state of "collective consciousness" $\Phi$ one can influence probabilities $|a_i|^2$ of realization of corresponding states $\Phi_i$, i.e. possible objective states $\Psi_i$, as the composite state of "objective" system and "collective" observer is a superposition of all possible composite states, $\Psi\Phi = \sum_i a_i \Psi_i \Phi_i$ (cf. also the footnote i); this is particularly true if the state $\Phi \sim \prod_k \varphi_k$ is very sensitive to small changes of initial conditions, which is the case for the brain and corresponding state $\varphi_k$ of "individual consciousness", described by deterministic chaos [52]. In this respect, it is quite possible that strong preferences in individual or collective futures exist, governed by karmic interpersonal

under control by "mental addressing" on a chosen problem, shortly before a waking-sleep transitional state! On awaking, the brain would then amplify the dream concerning the solution of the problem addressed, giving to it the priority in respect to other processed information during the sleep phase. The information obtained in this way is usually mixed through associative coupling with other conscious and unconscious pieces of information during the following REM-sleep periods - having therefore some symbolic form, which has to be decoded through introspective analysis of the dream. Naturally, to solve some scientific, technical or artistic problem in this way, it is necessary for the person to be expert in the field, in order to articulate the solution obtained in corresponding scientific, technical or artistic "language".

Finally, if the EM field of ULF ionic currents represents sophisticated internal display (related to consciousness) of neural network information processing, it seems that consciousness is not privilege of humans - but can be also a characteristic of higher animals. Even more, if microtubular cytoskeletal structures have neural network-like electrical activities on subcellular level, it seems that consciousness can be descended down to the cellular and even subcellular level [55]. Naturally, the conscious content displayed in such EM internal displays depends on the complexity of corresponding neural network information processing at different levels, from subcellular to brain ones. Furthermore, as the EM field is only one out of four manifestations (electromagnetic, gravitational, weak and strong nuclear forces) of the unified physical field [56], it can be tentatively generalized that the unified field itself may be internal conscious display for various physical processes at different structural levels, from macroscopic cosmic to microscopic subnuclear ones [44]. As a consequence, one could conjecture that Nature itself has consciousness at different structural levels, both animate and inanimate, as it is widely claimed in esoteric traditional knowledge. In that context, all local consciousness might be interconnected (through previously described interactions in altered and, especially, in transitional states of consciousness) making a giant cosmic informational network with collective consciousness, implying the crucial significance of *morals*, both on the level of thoughts and feelings [15]!

Although such nonlocal pantheistic idea of consciousness is rather bizarre, it can naturally help in resolving the fundamental problem of the *wave function reduction* in the quantum theory of measurement, where in an act of measurement (including finally the very act of conscious observation of the act of measurement) the macroscopic measuring apparatus (including consciousness as a "subjective" observer) makes reduction of the initial wave function into one of the possible eigenfunctions of the system.[i]

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loads, as it is claimed in Eastern tradition [53]; along the same line, it might also be possible that spiritual cleansing (by prayer or some other esoteric technique [39]) is an efficient mechanism for changing initial state of several interrelated "individual consciousness", and hence "collective consciousness", thus changing anticipated preferences for both individual and collective futures [25,54].

[i] The problem of the wave function reduction (collapse) in an act of measurement is "orthodoxly" interpreted in quantum theory of measurement as the discontinues change induced by the observation of a quantity with eigenstates

$\Psi_1$, $\Psi_2$,..., in which the initial wave function $\Psi = \sum_i a_i \Psi_i$ will be changed to the state $\Psi_j$ with probability $\left| a_j \right|^2$. The

collapse of the wave function and the assignment of statistical probabilities do not follow from the Schrodinger equation - they are consequences of an external a priori metaphysics, which is allowed to intervene at this point and suspend the Schrodinger equation, or rather replace the boundary conditions on its solution by those of the collapsed state function. The problem of quantum theory of measurement has not been consistently resolved to date, and has been the subject of many serious theoretical efforts, from the very beginning of Quantum mechanics [57]. In one of the most recent approaches, Penrose [47] proposes gravitationally induced wave function reduction: actually, gravitational field of the state of observing apparatus $\Phi$, with all possible observable outputs $\Phi_i$, must be also involved in the

**CONCLUSION**

In Table 1 a comparative presentation of the possibilities in modeling consciousness and other psychological functions (memorizing, learning, emotions, language, creativity, thinking, and transpersonal interactions!), by using biocybernetical models of hierarchical neural networks and brainwaves, is given. It is obvious that such a broad modeling of psychological functions requires application of subtle biophysical hierarchical neural networks with embedded ultralowfrequency brainwave activity, thus incorporating good properties of both the neural networks and the brainwaves models.

Especially illuminating are investigations of altered and transitional states of consciousness, which seems to be a key for understanding the very nature of consciousness, which might have significant implications for many scientific fields:

(a) in *medicine* it might give rise to enlightening of many secrets of the brain functioning, as well as of the role of the acupuncture system in holistic health and reprogramming of internal conflicts;

(b) in *psychology* one might understand mechanisms and roles of altered states of consciousness in a growth of personality, control of creativity, as well as transpersonal phenomena usually accompanying these states;

(c) in *biology* it might appear that limits of interactions between individuals are more provisional then widely believed, which would be of significance not only for adaptive mechanisms on the level of whole biological species, but even for deeper understanding of the very significance of morals in human population;

(d) in *physics* an understanding of the phenomenon of consciousness might give rise to deeper understanding of fundamental problems of the observer's role in quantum mechanical act of measurement, which would demonstrate that consciousness, space, time, and matter are more deeply interwoven than widely believed;

(e) in *engineering* an understanding and controlling of transpersonal interactions should significantly change the field of *communications*, with many traditional spatio-temporal barriers radically surpassed, and in *computer sciences* an understanding of the nature of

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superposition of quantum eigenstates ( $\Psi\Phi = \sum_i a_i \Psi_i \Phi_i$ ) - this implying different space-time geometries superimposed; however, when the geometries become sufficiently different (on the Planck-Wheeler scale $\sim 10^{-35}$ m), thus implying ill-defined standard superposition of the matter eigenfunctions in strictly separate spaces - Nature must choose between one of them and actually effects wave function reduction. Moreover, as microparticles are continuously subjected to fantastic accelerations ($\sim v^2 /r \sim 10^{23}$ m/s$^2$ for electrons bounded in atoms, and $\sim 10^{29}$ m/s$^2$ for protons and neutrons bounded in nucleus,...), which can be met also in extremely strong gravitational fields - according to the Principle of equivalence one should expect [15] continuous opening and closing of local Einstein-Rosen bridges, addresses of their exits being related (probabilistically) to one of the possible eigenstates of corresponding microparticles. This process might yet be the mechanism for some sort of the wave function reduction, implying why so important the mental addressing is in transitional states of consciousness, related to "astral projections", described above! It also reveals that Quantum mechanics and the General theory of relativity seem to be deeply interconnected on microparticle level, showing that microparticles are continuously vanishing and reemerging (subjected obviously to corresponding conservation laws) in measurement-like interactions, throwing a new light on wave-particle dualism and other quantummechanical phenomena. In that framework, the role of consciousness in quantum theory of measurement turns out to be extremely important: for instance, in gravitationally induced wave function reduction, the very mechanism for this process could be continuous opening and closing of local microparticles' Einstein-Rosen bridges, addresses of their exits being related (probabilistically) to one of the possible eigenstates $\Psi_i$ of corresponding microparticles - and everything being related to corresponding probabilistic addressing $\Phi_i$ of "collective consciousness" [15]. On the other hand, this nonlocality of "collective consciousness" provides an additional evidence that Quantum mechanics is nonlocal theory - otherwise demonstrated by recent tests of Bell's inequalities [58] and the Einstein-Podolsky-Rosen paradox [59], which suggest that even very distant parts of quantummechanical system (which cannot exchange light signals) can be physically correlated in the act of measurement.

consciousness might give rise to computers with artificial consciousness, functioning on deeper relativistic and quantum principles;

(f) finally, a deeper understanding of the very nature of consciousness and transpersonal phenomena might radically shift our scientific understanding of some ultimate philosophical and *religious* questions, like spiritual and practical significance of imperative moral behavior of every individual - with prospects for a new/old humanism, without meaningless and painful interpersonal, interethnical, and interreligious conflicts.

**Table 1** A comparative presentation of the possibilities in modeling psychological functions by using biocybernetical models of hierarchical neural networks and brainwaves.

| *FUNCTION* | *HIERARCHICAL NEURAL NETWORKS* | *BRAINWAVES* |
|---|---|---|
| CONSCIOUSNESS | - hierarchical extended reticular-thalamic activating system (amplitude and frequency modulation) | - biophysical nature of consciousness;<br>- normal and altered states (REM sleep, meditation…) |
| PERCEPTION | - hierarchical structure (image, olfaction, speech) | - EM "neural networks/ brainwaves" coding;<br>- altered and transitional states of consciousness (ionic neural network as a "sensor") |
| MEMORIZING | - spatial synaptic activation (short-term and long-term memory) | - frequency memorizing for various unconscious and conscious levels;<br>- spatial memorizing of EM field within ionic network |
| LEARNING | - nonlinear neural networks (generalization) | - information distribution (prior habituation) |
| EMOTIONS | - hierarchical extended reticular-thalamic activating system (amplitude and frequency modulation) modulated by minor (right) hemisphere | - conflicts reprogramming (through integration of unconscious and conscious contents in altered states; through mutual transpersonal cleansing of acupuncture systems of conflicted persons in transitional states of consciousness) |
| LANGUAGE | - hierarchical primary sensory and associative secondary areas (semantics), frontolimbic formations (pragmatics), and motor systems (syntactics) mainly modulated by dominant (left) hemisphere | - lower-frequency (unconscious) mother tongue and contextual second language learning, and higher-frequency (conscious) school second language learning |
| CREATIVITY | | - anticipating transitional states of consciousness ("astral projections");<br>- intense associative coupling of conscious and unconscious contents in altered states of consciousness (REM-sleep, meditation, hypnosis…) |
| THINKING | - emotional and language modulation of information;<br>- information processing in associative secondary and tertiary cortical regions, and in prefrontal cortex | - creative aspects of thinking in transitional and altered states of consciousness;<br>- thought ascending upon the ERTAS-amplification from the lower-frequency ($\delta$, $\theta$) unconscious form to the higher-frequency ($\alpha$, $\beta$, $\gamma$) conscious form |
| TRANSPERSONAL INTERACTIONS | | - short-range interactions by EM induction (hypnosis) and/or ionic transfer (healer/healee);<br>- long-range global ULF EM interaction at the end of altered states (Jung's collective unconscious);<br>- long-range directional ULF EM mentally address–oriented spatio-temporal tunneling of the displaced ionic neural network with embedded ULF EM field, in quick transitional states ("astral projections" through wormholes: transpersonal psychic and religious phenomena, "spiritual" healing) |

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