Article

A Possible Quantum Model of Consciousness Interfaced with a Non-Lipschitz Chaotic Dynamics of Neural Activity (Part I)

Elio Conte [1,2]*, Nunzia Santacroce[1] & Antonio Federici[2]

[1]School of Advanced Int'l Studies for Applied Theoretical and Non Linear Methodologies of Physics, Bari, Italy
[2]Department of Pharmacology and Human Physiology, University of Bari- Italy;

ABSTRACT

A model of consciousness and conscious experience is introduced. Starting with a non-Lipschitz Chaotic dynamics of neural activity, we propose that the synaptic transmission between adjacent as well as distant neurons should be regulated in brain dynamics through quantum tunneling. Further, based on various studies of different previous authors, we consider the emergence of very large quantum mechanical system representable by an abstract quantum net entirely based on quantum-like entities having in particular the important feature of expressing self-reference similar to what occurs in consciousness. The properties of such quantum-like mind entities are discussed in detail. A quantum-like model of conscious experience is also discussed. It is shown that such quantum mechanical entities are able to arrange themselves alternatively on the basis of the subject story, memory, and pain-pleasure in response to an external stimulus, thus giving the subject the possibility to response to the stimulus on the basis of his emotion as well as cognitive state. Finally, we discuss the possible connections between the quantum-like model introduced in this paper and the chaotic behaviors often identified experimentally in studies on brain dynamics.

Part I of this article contains: Introduction; 1. Non Lipschitz Terminal Dynamics of Single Neuron Activity; and References; 2. Quantum Mechanical Properties of Neuron Dynamics; and 3. A Quantum Model of Consciousness I.

Key Words: quantum cognition, role of quantum mechanics in explaining consciousness, quantum wave function collapse, synaptic connection and quantum tunnelling, neurophysiology, neural activity, applied physics, Clifford algebra, non-Lipschitz dynamics.

Introduction

The brain is a macroscopic system containing approximately 10^{10} neurons. Each neuron is essentially a macroscopic device receiving a relevant number of inputs and giving an output as answer. The inputs are essentially currents generated by approximately 10^3-10^4 synapses posed on the dendritic tree, and the output is usually represented by sequences of action potentials carried by the axon. The input currents are generated by ion specific channels in the membrane which change their conductance in response to chemical neurotransmitters released by other neurons. Roughly speaking, such currents are integrated in the soma whose voltage rises and decays with the fluctuations in currents. When the soma voltage exceeds a certain threshold, action potentials are generated which are propagated down along the axon. Such a complex

*Correspondence: Professor Elio Conte. E-mail: elio.conte@fastwebnet.it

dynamics can be studied by the simultaneous adoption of quantum and classical non linear methods of physics. The aim of the present work is to build up a model of the role of the basic dynamics of the neuron in the emergence of consciousness and conscious experience, by simultaneously adopting non Lipschitz chaotic dynamics and a quantum mechanical approach.

1. Non Lipschitz Terminal Dynamics of Single Neuron Activity

According to our previous papers [1] and to the fundamental work of J. Zbilut, M. Zak, and D.D. Dixon [2], in addition to classical mechanics where the validity of the Lipschitz condition guarantees the uniqueness of solution of a given differential equation for a given initial condition, and thus a substantially imposed deterministic characterization of the dynamics of the system in consideration, a new dynamics, called terminal dynamics, arises for the special kind of non linear differential equations violating Lipschitz condition. The equilibrium points in terminal dynamics are terminal attractors or terminal repellers, and they represent singular solutions having new interesting properties regarding in particular their instability. After reaching terminal attractors or repellers the dynamics of the system becomes independent on the initial conditions, and it acquires an expected ability to overcome the rigid determinism, thus becoming able to adapt itself with great flexibility to any required change, also depending on external conditions. As a consequence the traditional deterministic approach to basic mechanisms of living systems collapses near the equilibrium points of terminal dynamics, and a new chaotic regime may be delineated, called [2] a non deterministic chaotic dynamics.

We have adopted in this paper a model of terminal dynamics applied to the single neuron [details are given in 1,2]. For it an equation may be written in the following manner

$$\frac{dx}{dt} = sen\omega t sen^{\frac{1}{3}} \frac{\pi}{k} x \qquad (1)$$

where ω and k are constants. The equilibrium points are at $x_n = nk$ ($n = 0,1,2,....$) where Lipschitz condition is violated. We have a dynamics of the neuron with different terminal attractors and such attractors are converted into terminal repellers each time we have a change in the sign of the Lipschitz constant from $L = -\infty$ to $L = +\infty$. Owing to the presence of the controlling function $sen\omega t$, in the (1) L oscillates in sign with period ($2\pi / \omega$).

At the singularities the neuron is driven. If we consider a vanishingly small input $\varepsilon(t)$ that is added to (1), the influence of such an input may be ignored during the deterministic journey of the neuron, when in fact it is stable, but it becomes relevant at the instants of instability occurring near the equilibrium points of terminal dynamics. When such a condition occurs, a string of signs like

$$\varepsilon(t) = +,-,-,-,+,....... \qquad (2)$$

will drive the neuron to fire or not to fire.

2. Quantum Mechanical Properties of Neuron Dynamics

Substantially $\varepsilon(t)$ may reflect some quantum mechanical features in neuron dynamics. Let us consider an input x_i that usually is evaluated with a corresponding weight w_i. Owing to the enormous number of inputs hitting the neuron, these values are usually summed together to form the output y, which is therefore given as function of inputs and weights according to the equation

$$y = \sum_{i=1}^{n} w_i x_i \tag{3}$$

A non linear threshold function at the output, ϑ, will realize a crude but significant model of all-or-nothing potential generated by the neuron . In this case the output is given

$$y = 1(u > \vartheta); \varepsilon(t) = + \quad \text{and} \quad y = 0(u < \vartheta); \varepsilon(t) = -$$
$$u = \sum_i w_i x_i \tag{4}$$

In this framework the inputs x_i represent the action potentials arriving from other neurons via many impinging synapses, the weights w_i representing the effectiveness of the synapses in affecting the activity of the target neuron. The larger w_i the more x_i affects the neuron output. Some of the physiological contributions determining w_i may be, for example, the number of synaptic vesicles which are opened by a single action potential in the presynaptic cleft or the number of ligand-gated channels which are activated in the post synaptic membrane.

According to E.H. Walker [1, 3] the quantum tunneling effect has a role in synaptic transmission, and still according to the studies of F. Beck and of J.C. Eccles [4], the conventional synaptic theory leads to assume that the ultimate synaptic units operate in a quantal way. They are presynaptic buttons that, when excited by arriving action potentials, deliver the total contents of a single synaptic vesicle. An essential feature is that [4] the effective structure of each presynaptic button is a paracrystalline presynaptic vesicular grid with about 50 vesicles that act probabilistically to release the synaptic transmitter molecules from each vesicle. The emission of the synaptic transmitter molecules from each vesicle is quantal, varying from 5000 to 10000. It represents the elementary unit of information transmitted from one neuron to another. A central point in the synaptic theory is that this process is not regulated in a fully deterministic, but in a probabilistic way, in the sense that it seems intrinsically indeterministic the behavior of any single synaptic vesicle or ligand-gated channel when action potentials are arriving. On this basis such a process can be modeled according to the principles of quantum mechanics. In conclusion, quantum tunneling should have a role in synaptic transmission as well as in the effectiveness affecting the post-synaptic neuron activity. This is to say that also the weights w_i may be modeled according to quantum mechanics.

For such a purpose, according to the papers of Dan Ventura and T. Martinez [5], we first introduce a vector

$$w = [w_1, w_2, w_3, \ldots.., w_n] \tag{5}$$

that cannot be characterized in usual classical terms but connecting to a wave function $\psi(w,t)$ in Hilbert space. This wave function will represent the probability amplitude for all possible weight vectors in an abstract weight space with the usual associated normalization condition that holds in quantum mechanics. For any time we will write that

$$\int_{-\infty}^{+\infty} |\psi(w,t)|^2 dw = 1 \tag{6}$$

In order to elucidate, consider, for example, the case of only one input and one output. We have [5] $\pi \leq w_i \leq \pi$, and solving Schrödinger's equation for the case of one dimensional rigid box, we have

$$\psi(w_1) = \sqrt{\frac{2}{a}} \sum_m c_m sen(\frac{m\pi w_1}{a}) \tag{7}$$

with $m = 1,2,3,\ldots\ldots$, and w_1 the single element in (5), and a, the width of the box. A probability amplitude and thus a probability are connected to each possible value of w_1 in each of the possible quantum states in the box.

In the case of two inputs one may write briefly

$$\psi(w_1, w_2) = Asen(\frac{m_1 \pi w_1}{a}) sen(\frac{m_2 \pi w_2}{a}) \tag{8}$$

and the same procedure may be followed in the case of several inputs. It is important to outline here that our model may also exhibit fractal like behaviour. It was recently shown that several quantum models related to chaotic scattering exhibit fractal like structures [6], and recently [7] it was evidenced that fractality emerges in a regular system as result of the choice for the wave function. In [7] the well known Weierstrass function [8] was considered

$$W(x) = \sum_{n=0}^{\infty} b^n sen(a^n x) \, , a > 1 > b > 0 \, , ab \geq 1 \tag{9}$$

That is a known example of a continuous, nowhere differentiable function. It exhibits fractal properties and the box dimension of its graph gives

$$D = 2 - \left| \frac{Lnb}{Lna} \right| \tag{10}$$

We may consider the solutions of Schrödinger equations for a particle in an infinite potential well. The general solutions satisfying the boundary conditions have the form

$$\psi(x,t)=\sum_{n=1}^{\infty}a_n sen(nx)e^{-in^2t} \quad \text{with } \psi(0,t)=\psi(\pi,t)=0 \tag{11}$$

That obviously is similar to (7). In analogy to the Weierstrass function one (see [7]) may construct fractal wavefunctions

$$\psi_M(x,t)=N\sum_{n=0}^{M}q^{n(s-2)}sen(q^n x)e^{-iq^{2n}t} \quad \text{with } q=2,3,.....,2>s>0\,. \tag{12}$$

As discussed in [7], in the interesting case of finite M the wave function $\psi_M(x,t)$ is the solution of the Schrödinger equation and the limiting case

$$\psi(x,t)=\lim_{M\to\infty}\psi_M(x,t)$$

is continuous but nowhere differentiable with the normalization condition given by

$$N=\sqrt{\frac{2}{\pi}}(1-q^{2(s-2)}). \tag{13}$$

It is shown in [7] that not only the real part of the wave function $\psi(x,t)$ but also the probability density function

$$P(x,t)=\left|\psi(x,t)\right|^2 \tag{14}$$

exhibit a fractal nature.

3. A Quantum Model of Consciousness I

The first central problem is to ascertain if consciousness and mind entities are unequivocally admitted in the present framework of contemporary physics. We find that two basic arguments settle in an unequivocal manner that mind entities and consciousness enter in the present physical description of our reality.

The first argument runs as it follows. According to von Neumann [9], there are two basic processes in quantum mechanics. One is represented by the Schrödinger equation, and it is continuous and casual, and, according to R.A. Mould [10], it delineates the basic features that may be found “inside” of a closed quantum system. The second one is the so called collapse of the wave function, and it is often assumed that it happens when the system is measured. It is discontinuous, non local, and it is imposed from the outside of the system through our procedure of inspection and measurement. At this stage a problem arises. A measurement represents a boundary condition placed on a finitely bounded system [10]. Where is that one poses such a boundary condition? Von Neumann showed that the boundary condition is flexible, and the sense of this statement is clear.

In principle, the line separating the "inside" from the "outside" of the system, can be drawn in any finite way that excludes the laboratory observer. Still according to Mould [10], this means that an external measuring device in a given experimental condition, can be thought instead to be inside the system only considering the experiment to be arranged differently. Not only we may include a macroscopic instrument inside and includable in quantum mechanics, but it can appear to be in superposition with itself. In brief, any usual laboratory arrangement can be placed inside as well outside of a given quantum mechanical system owing to the previously mentioned flexibility of system's boundary that von Neumann outlined. As Mould deepened in detail [10], if any closed physical system is finitely bounded and if nothing inside of the system is capable of interrupting the Schrödinger process, there must exist something that has the capability to interrupt such a process.

This is something that finally cannot be included in the system by a simple operation of extension of the boundary of the system. The answer of von Neumann and Mould [9,10] was that this something is the consciousness. In our opinion, in this manner consciousness enters unequivocally in the domain of quantum mechanics in the sense that for the first time quantum mechanics, a physical theory, includes also consciousness and mind entities in its ontological architecture. According to Mould [10], we must accept the notion that there exists a mechanism which evolves as a quantum mechanical superposition under the Schrodinger equation, and which dissolves at some critical points into a reduced state and an associated conscious experience.

The non-Lipschitz dynamics outlined in the previous section gives a strong analogy to this mechanism. The second argument suggesting an unequivocal presence of consciousness and mind entities in the present framework of quantum mechanics may be outlined as it follows. This time, according to D.M. Snyder [11], we will speak about the so called "knowledge factor" or the "mental creativity" as was defined by Epstein in 1945 [12]. According to these authors and others [13], the change of the wave function that we have called here the collapse of wave function is not due fundamentally to a physical cause. This change is unequivocally linked to the knowledge attained by the observer of the circumstances affecting the physical existent to be measured. In brief, quantum mechanics is fundamentally a theory concerned with the knowledge of the physical world. It is not concerned with the description of the physical world in a manner that is independent of the thinking living being. Cognition and the physical world are strongly linked in the framework of quantum mechanics, and cognition is an expression of mind entities.

To prove this thesis, according still to Epstein [12] and to Snyder [11], one may consider the Gedanken experiment that was proposed by R. Feynmann et al. [14] regarding the distribution of electrons passing through a wall with two suitably arranged holes, A and B, to a backstop where the positions of the electrons are detected. It is well known that we may integrate the standard experiment inserting a strong light source so that the distribution of electrons from each hole is seen. The argument is well known [11,12]. The standard thesis is that the physical interaction between the light source and the electron is necessary to destroy the interference. However, where the light illuminates only hole A, electrons passing through hole B do not interact with photons from the light source, as discussed in detail in [11,12]. However, interference is destroyed in the same manner as if the light source illuminated both holes A and B. In particular, agreeing still with Snyder [11], the distribution of electrons passing through hole B at the backstop, indicates that there has occurred a change in the wave function of these electrons, even though no physical interaction has occurred between these electrons and photons from the light source.

As said, Epstein in 1945 and more recently Snyder maintained that these kinds of effects on the physical world in quantum mechanics cannot be ascribed to physical causes, and are associated with the presence of the "knowledge factor" or to the mental certainty of the thinking observer for which possible alternatives to the physical existent occurs. The entity responsible for the change in the wave function for the electron headed for holes A and B, and which is not illuminated at hole A, is the knowledge of the observers as to whether there is sufficient time for an electron to pass through the illuminated hole. Knowledge thus enters, unequivocally, in the framework of quantum mechanics and it pertains to cognition that is one of the basic foundation of consciousness.

These conclusions pertain to the standard manner to conceive the approach of quantum mechanics to mental entities. However, we retain that some recent results have given new light about such matter.

First of all consider that von Neumann, formulating his theory of quantum measurement, introduced two basic postulates that are well known as basic von Neumann postulates of quantum measurement.

Rather recently we have given what we retain to represent an important contribution in this direction. By using two shown theorems in Clifford algebra we have given proof of such basic von Neumann postulates. In other terms we have passed from the regime of postulates, thus admitted as true and from the outside, not derived from the standard quantum theory, to the new regime in which these postulates have been demonstrated also proving that they pertain to the inner scheme of quantum mechanics. This result has given a final inner coherence to quantum theory explaining for the first time, also if only in a mathematical manner, that quantum wave function occurs.

The second result relates the actual structure of quantum mechanics. By using a Clifford algebraic formulation of quantum mechanics, we have realized some basic logic statements. Von Neumann showed that logic derives from quantum mechanics. Using such algebraic formulation , and according to Orlov, we showed the vice versa. It is quantum mechanics that derives from logic. This is to say about the logic origin of quantum mechanics. In other terms, quantum mechanics relates our mind entities. In particular we have evidenced that there are stages of our reality i9n which we no more may consider matter per se. There are stages of our reality in which matter no more may be separated from the cognition that we have about it.

In conclusion quantum mechanics is a Two faces God Giano looking from one side to matter and from the other side to the abstract entities of our mind. As a rule such two faces no more may be considered to be separated at some stages of our reality.
We retain that these are the basic advances that enable us to attempt to formulate a preliminary evidence of existing consciousness based on the essential role of quantum mechanics. We give citation of Our and of Orlov contributions in ref. [32].

In conclusion, we have introduced basic arguments that are unavoidable in order to conclude that quantum mechanics connects consciousness and that the wave function of quantum mechanics is a direct expression of our cognition when interfaced with the physical reality. We are convinced that the counterpart of this conclusion must obviously respond at a neurophysiological level. In other terms, if our premises are correct, we cannot escape admitting that quantum mechanics is directly involved at the level of the neurophysiological mechanisms that are present in the brain. They must operate with a strong link with terminal dynamics that we introduced in (1) and in (2). The equations (5-8) gave the first indication of such an existing connection of quantum mechanics with neurophysiological mechanisms. Obviously, one must also outline here that such a connection gives only a preliminary and rough scheme of the system under our discussion where, in substance, a larger number of physiological mechanisms are involved in addition to those under our present analysis.

Let us examine now the second important connection. It was obtained by E.H. Walker [3] who, as we said in the previous section, based synaptic connection on quantum tunneling that is one of the fundamental processes in quantum mechanics. We outline here again that also J.C. Eccles and F. Beck [4] suggested the same mechanism also if with some modifications with respect to the standard Walker's formulation. Note the important feature that the theoretical results that were elaborated by Walker, gave also a very satisfactory agreement with the experimental data.
To introduce the argument, we must show, as discussed by Shepherd and Jacobson in 1991 and Agnati and Fuxe [15,16], that neuroscience is still based on the Cajal and Sherrington's (CS) paradigm that states that the intercellular communication relevant for the integrative task of the central nervous system is the interneuronal communication that takes place if and only if the source cell and the target cell are connected by means of a synaptic contact. In 15 years of research activity, some groups [15] have developed an alternative theory that is based on the two classical opposites of interneuronal communication, the Cajal Sherrington's paradigm on one hand and the Golgi's paradigm [16] on the other hand. According to this theory, any cell in the central nervous system can contribute to the integrative brain behaviors. In brief, not only interneuronal communication must be considered but also other forms of intercellular communication should be considered in the brain.

In his studies E.H. Walker [3] opened the possibility of an actual channel of communication. Brain may contain propagator like molecules that, distributed through the brain, could be used by a tunneling electron as stepping ones enabling it to make transitions from one synapse to another distant synapse. One may consider two synapses molecules with some "adhesive" other molecules (propagator like molecules).When the charge has first arrived on the molecule at the synapse, its wave function will be located entirely in that molecule. Starting the tunneling process, the wave function will begin to enter the propagator molecule and so forth. The process will continue until the wave packet will spread through all the space that it is enabled to occupy. Long range quantum mechanical effects will be induced. In detail, the quantum tunneling repeated through the potential wells of several propagator-like molecules, separating two synaptic molecules, will assure the wave packet spreads throughout the brain.

In brief, the emerging conclusion seems to be that a signal may flow from one neuron to another also if they are not in close proximity. In this manner a cell can participate in an assembly of functionally interconnected cells as long as it can release signals that are decoded by other cells of the assembly. An equivalent scheme was given in studies of associative neural networks. These authors, and in particular M. Perus, [17] investigated the quantum mechanical tunneling between patterns considering the relatively stable minima of the configuration energy space of the networks. The patterns represented the macroscopically distinguishable states of the neural nets and the tunneling represented a macroscopic quantum effect. The authors considered the minima of approximately equal depth. The repeated tunneling represented so a random walk implying quantum fluctuations and thus they were reduced to a dynamics that may be modeled by the Pauli master equation. In the corresponding formulation of the present paper we have that the local minima are represented from the transmitting and receiving, distant synaptic molecules of the neurons, being instead the patterns identified from the adhesive or propagator molecules that, as previously seen, assure communication between distant neurons. In this manner, according to [17], in the neurophysiological scheme that we have delineated, the neurons may be seen as attractors realized through specific brain patterns identified by repeated tunneling processes.

We may still follow the basic configuration given in [17], in particular, we have to give two different kinds of time. One may consider that the quantum tunneling pertains initially to the synaptic molecule k_1 and then, through repeated tunneling, the synaptic molecule k_2 is reached. We have stochastic quantum jumps or, equivalently, an nondeterministic transition, for example, $k_1 \rightarrow k_2$. In k_2 the quantum process may continue tunneling to involve k_3 and so on. Otherwise, from it the process may also turn back to k_1. A time, $\tau_{stable,}$ will characterize the sequence of tunneling steps while the tunneling process will take a time that we will call $\tau_{tunneling.}$ still according to [17]. If $P_{ij}(t)$ represents the tunneling probability from the initial state (neuron) i to final state (neuron) j, $\tau_{tunneling}$ will represent the time interval in which such a probability becomes unity. Obviously, the sequence of the transitions represents a stochastic process consisting of a random walk. This dynamics may be modeled by a Pauli master equation

$$\frac{dP_i}{dt} = \sum_{i(i \neq j)} W_{ij} P_i - \sum_{i(i \neq j)} W_{ji} P_j \tag{15}$$

where P_i represents the probability of finding the tunneling particle at the neuron i at the time t while W_{ji} is the tunneling velocity through the adhesive molecules, and it is given by

$$W_{ji} = \frac{dP_{ji}}{dt} \tag{16}$$

One interesting feature is that, using (15), some specific models may be introduced to explain and to account for memory dynamics, storage, and recognition in brain functioning. In fact, as also pointed out in [17], one may consider the most simple interesting case in which

$W_{ij} = W_{ji} = W =$ constant

but one we may also introduce specific models for each W_{ij} involved in the sequential tunneling processes in order to characterize brain patterns and to account for memory factors and plasticity in the whole brain dynamics. This is the problem of recognition and memorization of patterns in the brain. We may acknowledge here the basic role explained by adhesive or propagator molecules. Let us remember the well known Hebb learning rule [18]. It states that if two neurons are both active or both inactive, then the synaptic connection between them is strengthened. Otherwise, if one is active and the other is inactive, then their mutual synaptic connection is weakened. Thus the adhesive or propagator molecules may have their active role. As seen in (15), the probability for tunneling is dependent from the amplitudes of the barriers interposed among the two neurons wells and characterized by W_{ij} . Memorization and recognition are realized by the propagator molecules that, when operating with respect to unlearned and unmemorized brain patterns, have a lower value of W and this enhances tunneling probability and tunneling .velocity.

Let us state now a rough definition of consciousness to which we make reference in the present work. Consciousness is that human entity on whose basis the human subject has perception of himself and of his environment. The deriving model of consciousness is becoming now evident. The reason is that, following the previous arguments, we obtain on one hand a network made by neurons and we will call it Neural Networks. It is entirely based on neurophysiological processes. From the other hand, we have also an Integrated and Complex Quantum Mechanical Network that is entirely based on the wave functions characterizing the previously mentioned quantum tunneling. The synaptic tunneling model that happens between adjacent as well as among distant neurons, will produce an abstract integrated and complex quantum mechanical network that will be overlapped onto the real neuron network dictated by the neurological mechanisms. We have in substance a quantum like nervous system or, if we like, a "virtual" nervous system that will direct the behavior of the real neurological nervous system.

In this integrated quantum mechanical network, the consciousness is represented. In particular, such a virtual and integrated network or, equivalently, such a virtual nervous system will consist essentially of wave functions and thus of information, of signs and symbols that in detail will realize also basic logic operations such as YES- NOT functions, or also XOR functions.

E.H. Walker [3] previously discussed this model with the particular role of propagator like molecules, but our main aim in this paper is to evidence the manner in which such an interface between neural network from one hand and integrated quantum mechanical network from the other hand, is actually realized.

As we demonstrated in a previous paper it is the spin that develops an essential role [1]. The preliminary question to which we are related is to indicate if actually the spin has or not a role in brain dynamics. In order to strengthen this argument, we would consider here some results that were previously introduced. It is not our aim to expose in detail such an important theory that we discussed also in [1], but we will limit ourselves to explain only some features which are important that for our purposes. Starting with 2002, some authors [19] studied the possible role of neural electron spin networks in memory and consciousness, and with respect to this problem they also discussed the general problem of anesthesia. They evidenced that obviously we have not a commonly accepted theory on the manner in which anesthetics work and that we may at least identify two main schools: one, the Lipid theory [20], admitting that anesthetics dissolve into cell membranes and produce perturbations resulting in a depression of ion channels and receptors involved in brain functions; the second, the protein theory [21], indicating instead that anesthetics directly interact with membrane proteins as ion channels and receptors involved in brain functions. In substance, these authors [19] evidenced that both experimental and theoretical studies indicated that many general anesthetics cause changes in membrane structures, and they added the fundamental elaboration that, since both O_2 and general anesthetics are hydrophobic, general anesthetics may cause unconsciousness by perturbing O_2 pathways in neural membranes and O_2-utilizing proteins such that the availability of O_2 to its sites of utilization should be reduced.

The articulation of this argument leads the authors to consider the possible roles of neural electron spin networks in memory and consciousness. They considered nuclear spins inside neural membranes and proteins. They evaluated that free O_2 and NO are the main sources of unpaired electron spins in neural membranes and proteins, are transitioned to metal ions and O_2 and NO bound/absorbed to large molecules. Free radicals produced through biochemical reactions and excited molecular triplet states induced by fluctuating internal magnetic fields produced largely by diffusing O_2. They concluded that these spin networks could be involved in brain functions. We recommend the reader to deepen all the basic features of such a theory by reading the papers given in [19]. It is relevant that such authors considered a simple two electron spin system in neural membranes demonstrating that the large neural electron spin networks inside the membranes can form complex modulated structures through action potential driven oscillations of exchange and dipolar couplings and g-factor and spin-orbital couplings. They argued that the neural spike trains of various frequencies can directly input information carried by them into these electron spin networks. They indicated that the fluctuating internal magnetic fields are produced by unpaired electrons such as those carried by O_2 and NO and spin carrying nuclei such as H^1, C^{13}, P^{31}, and still they calculated that the maximal magnetic field strengths produced by the magnetic dipoles of the unpaired electrons of O_2 and of NO and H^1 along the axes of such dipoles assume values of, respectively, 3.71 (0.003), 1.85 (0.0018), 0.002 (0.000003) T for distances ranging from 1 to 10.0 A˚ [19].

We consider that the dynamics of membrane structures is determinant in synaptic transmission. If synaptic transmission, as previously said, involves a quantum mechanical mechanism such as quantum tunneling, existing high values of the magnetic field strengths as induced by O_2, NO, and H^1 as previously calculated in [19], we have to conclude that quantum mechanisms involved in synaptic transmission will be also spin dependent. In conclusion, in [1] we suggested that synaptic connection and transmission is regulated by a mechanism of spin dependent quantum tunneling .We will expose in a following paper the details of our elaboration, but we may anticipate here some result. According to Walker [3], we have a quantum mechanical potential barrier tunneling by electron across the cleft. The electron transfer is made between two macromolecules, probably lipid-proteins lying in the presynaptic dark projections of Gray and the postsynaptic density at the cleft. Considering quantum mechanics we have a particle (the electron) with a given kinetic energy and moving for example along the y axis and interacting with a barrier of given height and width and centered at y=0. Owing the physical processes previously mentioned, a small magnetic field B, pointing in the z direction, will be confined to the barrier. For the previous arguments, the particle (the electron) will carry spin s=1/2 and the incident particle will be polarized, for example, in the x direction. As the particle will enter the barrier, it will start a Larmor precession and when the particle will leave the barrier, the precession will stop. The polarization of the transmitted and reflected particle may be now compared with the polarization of the incident particle. In the absence of a magnetic field, it is easily given, while, in the presence of the magnetic field, we will have two transmission probabilities along the z direction, T+ and T-, corresponding respectively to spin values $S_z = \pm\frac{h}{2}$. As mentioned, we will publish in detail all the features of such a formulation. The basic key here is that we will have a mean value of spin S_z that will be connected directly to the values of the transmission probabilities according to the following formula:

$$< S_z >= \frac{h}{2}\frac{T_+ - T_-}{T_+ + T_-} \qquad (17)$$

This equation is obviously evident in its derivation but it has here of relevant importance for the arguments that we are developing. Admitting the primary role of the spin in synaptic connection, we link and interface, by (17), the close physical mechanism of neuronal activity represented by the synaptic connection with spin dependent quantum tunneling and terminal dynamics and, on the other hand, the abstract field of the probabilities, probability amplitudes and quantum mechanical wave functions. For details see also our previous paper given in [1].

To conclude we have to consider here still two important features. As indicated, the idea to introduce propagator like molecules was initially discussed by E.H. Walker [3] who suggested that RNA molecules could serve as a propagator vector in the brain .To support this conclusion one may claim the experimental results that were initially obtained by F.R. Babich in 1965 [22] but that were subsequently confirmed also more recently by other authors [23].

The second important comment regards an important criticism that could be considered for our present model evidencing that a lot of chaotic rather of quantum behaviors were actually identified in analysis of signals relating to the brain. To respond one considers first of all that in 5-14 we gave some important indications on the manner chaotic behaviors could be explained in the presence of a quantum mechanical dynamics. In addition, it must be added that the process of resonant electron tunneling through potential barriers may give an origin to chaotic behaviors that of course were found in brain signals. Non linear dynamical effects may be generated, in fact, by charge accumulation in the inter barrier spaces as they were also calculated by using the Davydov and Ermakov formulation [24] and outlined also by several authors [25].

We may now formulate our model of consciousness. We must explain how the interface between the neural and virtual or quantum mechanical (wavefunction) net, will originate at some stage a unique quantum mechanical function that will be self referential and able to have perception of itself and of the environment. Let us summarize briefly the conclusions we have reached at this stage. On the basis of the arguments previously developed we have admitted some fixed points:
a) Discussing some previous quantum mechanical experiences we have evidenced that quantum mechanics has profoundly changed our classical view on physics and on our reality. There are

cases in which we cannot avoid considering the "knowledge factor" as an essential component in the dynamics of reality itself. By this way we arrive at the conclusion that some quantum mechanical approaches and formalizations describing reality include unequivocally and prototypically mind-like entities. In particular, as in detail we shall see also through the following elaboration, the basic substrate of quantum mechanics resides in its mathematical formalism which is an abstract language that continuously relates to the role of the logical mind. b) During the past decades studies on the brain have advanced in a considerable way. Many efforts have been devoted in understanding the physiology as well as the structure of the neocortex.

Two basic directives have been substantially identified. In the first case various attempts and considerable advances have been obtained in the field of brain topology, that is to say in the identification of the localization of the specific area and role of brain activity. The second one has focused its attention on the analysis of the mechanisms that are involved with particular attention to the analysis and processing of signals that are involved during brain dynamics. In our opinion from the whole of such interdisciplinary studies it has emerged that the most fundamental process in brain dynamics is memorization. We consider that the neural network transforms a specific external stimulus into a specific pattern. Memorization, recognition of patterns are realized by tunneling processes happening by adjacent as well as by distant neurons that represent attractors in such configurations. The Pauli master equation delineates the time evolution of probabilities in tunneling also characterizing patterns, memorization and recognition.

The neural net stores many patterns simultaneously, each neuron and each synapse participates in several tunneling processes so that the whole macroscopic dimension of the involved quantum process becomes dreadfully high so that it becomes impossible to delineate it by a quantum mechanical formalism. In our opinion, a quantum-like, that is to say, a kind of basic but simplified scheme of quantum mechanics is necessary to delineate it. Let us explain the problem with the aid of an example. As we said [4], there are about 40 vesicles altogether in the paracrystalline structure, but it never happens that more than one vesicle emits transmitter molecules into the synaptic cleft after stimulation by a nerve impulse. This certainly means that the vesicles in the vesicular grid do not act independently. Soon after one vesicle is triggered for releasing its content, the interaction between them blocks further exocytosis. The relaxation time for the blocking process is of the order of femtoseconds [for details see still the 4]. Therefore in the framework of the process we have two basic factors to account for the number of vesicles (about 40 in the paracrystalline structure) and times of the femtoseconds.

With these starting data we may attempt to describe the many-body aspect of exocytosis from only one vesicular grid. In quantum mechanical terms we may attribute schematically to each vesicle in the grid, two possible quantum states, f and i, where i is the state before and f, the state after exocytosis has been triggered. Equivalently we may think a dichotomous quantum observable A that assumes the numerical values +1 or -1 if exocytosis has been triggered or not, respectively. In brief, from the view point of quantum mechanics the problem of characterizing our virtual or quantum mechanical net, does not appear to be so difficult: We need a dichotomous variable A that potentially may assume the values +1 and -1. The actual and impressive problem resides instead when accounting for the dimensions and for the times characterizing our net. Let us consider only one exocytosis and thus only 40 vesicles. Still according to [4], the wave function of N vesicles is then a product of the denumerable states with N=40.

$$\psi(1,2,....,N) = \psi_{i_1}{}^1 \psi_{i_2}{}^2 ....\psi_{i_N}{}^N \quad \text{and } i_j = (0,1) \tag{18}$$

Before exocytosis the wave function has the form

$$\psi_0 = \psi_0{}^1 \psi_0{}^2 ....\psi_0{}^N \quad \text{with N=40}$$

The observation that in response to a presynaptic impulse only one vesicle can empty its transmitter molecules into the synaptic cleft leads to a properly normalized wave function after the trigger for exocytosis that has the following form

$$\psi_1(1,2,.........,N) = \frac{1}{\sqrt{N}}(\psi_1^1\psi_0^2..........\psi_0^N + \psi_0^1\psi_1^2\psi_0^3........\psi_0^N + ... + \psi_0^1.......\psi_0^{N-1}\psi_1^N)$$

with N=40. (19)

This is a very articulated function. Let us add that the most elementary process characterizing brain dynamics involves a number of variables varying at least from 200 – 300 to one million of neurons. To write the detailed wave function and the virtual net that is represented, becomes a complex enterprise that on the other hand will be unable to characterize the unifying moment in which such a virtual net will be represented from only one wave function having some defined and self-referential attributes. The way we must continue, cannot be to represent step by step the increasing complexity of the virtual net as well as of the interfaced brain dynamics while we account for the increasing number of neurons that are employed and the neural patterns that consequently are induced. The way to be pursued is to introduce a formalism that on one hand is able to give the complexity of the net in consideration, but fundamentally, on the other hand, to be able at some point to represent instead the synthesis to which such a virtual complex net arrives at the final stage of its complexity. We think that the quantum mechanics becomes substantially unable to explain such a passage and for this purpose we will use here an alternative scheme that, of course, preserves all the quantum basic features of the theory.

Let us delineate the basic scheme of our approach. We are convinced that the discovery of non commuting observables existing in entities of our reality [26] and identified for the first time through the introduction of quantum mechanics that of course also postulates the superposition principle and existing potential states in Nature, has represented the highest conceptual moment in the story of humanity. Let us return to consider the dichotomous variable A previously introduced to represent that exocytosis happened or not for a single paracrystalline structure. Our starting point is that our virtual-quantum net may be described on the basis of dichotomous variables as the previous A, yes/not or equivalently +1/-1 variables as mind like entities in the manner previously specified in a. As such they must be expressed as abstract mathematical entities having a quantum like direct correspondence and analogy. Therefore, our aim is to introduce an algebra, that is to say a very rough scheme of quantum mechanics that however preserves some basic features of this theory, in particular, the non commutativity of observables and the quantum like potential states that usually are introduced in this theory.

To respond to such requirements, let us introduce three basic algebraic elements e_i , $i = 1,2,3$, having the following basic features:

1) $e_i^2 = 1$ and 2) $e_i e_j = -e_j e_i = i e_k$ with $\text{i, j, k} = 1,2,3$, $\text{ijk} =$ permutation of 1, 2, 3 and $i^2 = -1$.. (20)

We see that the axioms 1) and 2) introduce the two basic requirements that we invoke for quantum mechanics: potentiality and non commutativity. The first axiom in fact introduces an abstract entity, e_i, but at the same time fixes that its square is 1. This is to say that to each e_i with $i = 1,2,3$, under particular conditions in such an algebra , may correspond or the value +1 or the value -1. For each e_i we have the potential for it to correspond to one of such possible numerical values. The second axiom introduces non-commutativity for e_i ($i = 1,2,3$).

We know that in the usual quantum mechanics the 1) and the 2) are representative of a well known quantum observable, the spin, but here it is assumed only in analogy, and we consider only that 1) and 2) characterize a well known algebraic structure with the addition of the unity element $e_0 = 1$, and we consider that a quantum like dichotomous observable is connected to such basic elements. In particular, we may observe [1, 24] that, if to one of the e_i , $i = 1,2,3$, under suitable algebraic conditions may correspond a numerical value , say +1 or -1 , we may also correspond to e_i, their mean values, $< e_i >$ considering the probabilities for +1 or for -1 values, and writing

$$< e_1 > = (+1)p(+1) + (-1)p(-1)\ , \ < e_2 > = (+1)p(+1) + (-1)p(-1)\ , < e_3 > = (+1)p(+1) + (-1)p(-1) \quad (21)$$

where $p(+1)$ and $p(-1)$ represent the probabilities for +1 and -1 values, respectively, with $p(+1) + p(-1) = 1$. The quantum like features of this algebra may be synthesized in the following equation that we discussed in our previous work [1, 24] :

$$< e_1 >^2 + < e_2 >^2 + < e_3 >^2 \leq 1 \quad (22)$$

In this manner all our virtual or quantum mechanical net may be represented by such a rough quantum mechanical scheme considering the previous dichotomous variable represented by such basic elements and their algebraic rules.
First of all we have to observe that the given basic elements e_i are abstract mathematical entities in our algebra and as such they remain. To lower this level of abstraction that, as clearly evidenced by the simultaneous reading of axioms 1) and 2) is very high, we may consider an

isomorphic operation. In fact, we may introduce the well known Pauli matrices at order n=2 as representative for the basic elements e_i. This is an important operation since, from on one hand, it helps us to identify some hidden features of our algebra, and, on the other hand, it introduces for the first time the possibility of a self-referential operation that , as is well known, in mathematics as well as in science in general, is retained (and we agree) of the greatest importance in order to characterize the basic features of mind entities and thinking. Let us proceed with the aid of an example. Let us suppose that in the operation of progressive description of the net, we have arrived at a level of description of such a virtual (quantum) net that two dichotomous variables A and B are actually required in order to characterize it since two tunneling processes have actually the probability to happen or, in any case, two dichotomous variables are actually required in order to characterize its behavior. We may use the matrix representation of the basic elements e_i and we may realize some new algebraic elements given by the direct product of matrices. In this case, we will have new basic elements in the following manner:

$$E_{oi} = I \otimes e_i \quad \text{and} \quad E_{io} = e_i \otimes I \quad \text{being} \quad I \quad \text{the unit matrix, } i = 1,2,3. \tag{23}$$

Note that E_{0i} and E_{i0} will satisfy the same rules that were given in 1) and 2) for e_i. In detail we will have that

$$E_{0i}^2 = 1 \;,\quad E_{0i}E_{0j} = iE_{0k} \;,\quad \text{and} \quad E_{i0}^2 = 1 \;, \text{and} \quad E_{io}E_{jo} = iE_{k0}\,. \tag{24}$$

It is important to observe that we will have also that $E_{0i}E_{jo} = E_{j0}E_{i0}$ for any (i, j) and $i = 1,2,3;\ j = 1,2,3$.

As required, we have now two dichotomous variables, E_{0i} and E_{i0} , $i = 1,2,3,$ to describe our virtual (quantum) net. Let us consider still that e_i are the basic elements of our algebra given at order n=2 in our isomorphism while E_{0i} and E_{i0} are the same basic elements but at order n=4.

Note that for the first time we have also introduced a self referential mathematical formalism. To explain such a referential mathematical operation ,let us return to our basic algebraic scheme but outlining what V.A. Lefebvre [27] recently outlined . As we know, the central topic of Western philosophy, starting with John Locke, was the problem of representing mentally one's own thoughts and feelings. Actually, it is a very difficult concept to represent. It and this is the reason to use here a pictorial representation, the same figure that V.A. Lefebvre introduced to describe his formulation [27]. Tentatively we may express self attitude through the reflexion. A subject having reflexion may be conceived as a miniature human figure with the image of the self inside his head. We recover it here in the following fig 1. It represents with care the subject with reflexion. We prefer to call it the picture of a subject having perception of itself. In fig.1, following V.A. Lefebvre, we may say that inside the subject's inner domain, there is an image of the self with its own inner domain. An image of the self is traditionally regarded as the result of the subject's conscious constructive activity.

[References at the end of part II]

Article

A Possible Quantum Model of Consciousness Interfaced with a Non-Lipschitz Chaotic Dynamics of Neural Activity (Part II)

Elio Conte [(1,2)*], Nunzia Santacroce[(1)] & Antonio Federici[(2)]

[(1)]School of Advanced Int'l Studies for Applied Theoretical and Non Linear Methodologies of Physics, Bari, Italy
[(2)]Department of Pharmacology and Human Physiology, University of Bari- Italy;

ABSTRACT

A model of consciousness and conscious experience is introduced. Starting with a non-Lipschitz Chaotic dynamics of neural activity, we propose that the synaptic transmission between adjacent as well as distant neurons should be regulated in brain dynamics through quantum tunneling. Further, based on various studies of different previous authors, we consider the emergence of very large quantum mechanical system representable by an abstract quantum net entirely based on quantum-like entities having in particular the important feature of expressing self-reference similar to what occurs in consciousness. The properties of such quantum-like mind entities are discussed in detail. A quantum-like model of conscious experience is also discussed. It is shown that such quantum mechanical entities are able to arrange themselves alternatively on the basis of the subject story, memory, and pain-pleasure in response to an external stimulus, thus giving the subject the possibility to response to the stimulus on the basis of his emotion as well as cognitive state. Finally, we discuss the possible connections between the quantum-like model introduced in this paper and the chaotic behaviors often identified experimentally in studies on brain dynamics.

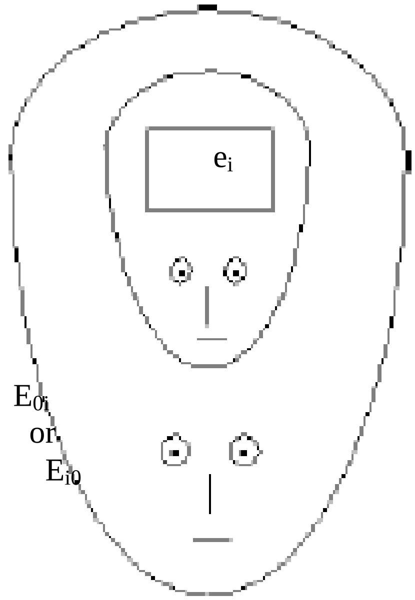
Part II of this article contains: 4. A Quantum Model of Consciousness II; 5. The Quantum Model of Conscious Experience; and References.

Key Words: quantum cognition, role of quantum mechanics in explaining consciousness, quantum wave function collapse, synaptic connection and quantum tunnelling, neurophysiology, neural activity, applied physics, Clifford algebra, non-Lipschitz dynamics.

4. A Quantum Model of Consciousness II

Let us analyze now the mathematical operation given in (23). It is the faithful correspondent of the self-picture given in Fig.1 in which, in fact, E_{0i}, for example, or also E_{i0}, contain in its inside that image of itself that is e_i. We may conclude that, at least for our present possibilities of understanding what the self is and its self-perception represent, we have for the first time identified a basic algebraic scheme and the corresponding mathematical operations to represent it.

*Correspondence: Professor Elio Conte. E-mail: elio.conte@fastwebnet.it



Let us note the value of the mathematical formalism that we have realized. According to (20) and to (24) we have the same algebraic structure and in the corresponding isomorphisms we disclose that it may exist at order n= 2 and at order n=4, respectively. In addition, at order n=4 we disclose to have two basic sets that respectively are given by E_{0i} and E_{i0}. According to (23), by using a simple algebra, we appreciate also the manner in which the two self referential operations are realized. In the first case of (23) we have a matrix representation at order n=4 in which, for E_{0i}, it is the basic representation of e_i to be preserved but with matrix structure as in the unit matrix I while instead in the second case of E_{i0} it is the basic structure of I to be preserved but in a matrix structure like e_i. These are actually the only two possible forms in which the self-referential operation of e_i may be realized. Note that they realize also structural self similarity in passing from order n=2 to order n=4.

We may also attempt to give a more rigorous definition of the self-referential operation. Let us follow A.G. Khromov [28] who recently discussed the problem under the profile of Boolean functions. A given human experience, pertaining for example to thoughts or belief or intention or also to images, consists of contents and awareness of this content. Let us indicate by x, y, z, ... contents of various experiences and let us introduce awareness statements as a, b, c, ...According to Khromov [28], the statements a, b, c,... must be self-referential or auto referential and thus require the introduction of autoreferential definitions. Therefore, n awareness statements are introduced by means of an autoreferential system of n definitions

$$a_i = F_i(a_1, a_2, ..., a_n; x_1, x_2, ..., x_m) \qquad 1 = 1,2,..........., n. \qquad (25)$$

In the case of [25] the F_i are considered to be Boolean functions in a classic framework. For example, the equation

$$a = F(a, x) \tag{26}$$

is the most simple case of single autoreferential definition.

In our case it is

$$E_{0i} = F(e_i, x) \quad \text{or equivalently} \quad E_{i0} = F(e_i, x) \tag{27}$$

Finally we note that, obviously, also to E_{0i} and E_{i0} there is the possibility that they correspond to the numerical values of +1 or -1, respectively, and still we may also introduce their mean values, $< E_{0i} >$ and $< E_{i0} >$, assigning the probabilities for the assumed values of +1 and -1. In addition, also for $< E_{0i} >$ and $< E_{i0} >$ hold (22) rewritten in its proper symbolism.

We may pass also to the case n=8, introducing this time the new basic elements E_{00i}, E_{0i0}, and E_{i00} that will be given by the following self-referential operation

$$E_{00i} = I \otimes I \otimes e_i \quad , \quad E_{0i0} = I \otimes e_i \otimes I \quad , \text{and} \quad E_{i00} = e_i \otimes I \otimes I \tag{28}$$

Such new basic elements respond to the same algebra of e_i given in 1) and 2) of (20), and precisely:

$E^2_{00i} = E^2_{0i0} = E^2_{i00} = 1$ and $E_{00i}E_{00j} = iE_{00k}, E_{0i0}E_{0j0} = iE_{0k0}, E_{00i}E_{00j} = iE_{00k}$, and still we may introduce mean values $< E_{00i} >$, $< E_{0i0} >$, and $< E_{00i} >$. We have now three dichotomous sets of variables describing the net, corresponding to the progressing complexity that the actual brain net is realizing by its physiological brain dynamics.

Following this procedure, we may proceed to construct algebraic sets of dichotomous variables at any order n and thus we may arrive to account for the final macroscopic dimensions of the net. The important feature is that, following such scheme of progressive complexity, we enlarge obviously, step by step, the number of algebraic sets that each time are required in order to describe the increasing complexity of the net, but, on the other hand, we arrive also at a final picture in which the obtained final basic elements are able to synthesize all the algebraic features of the net not only at its stage of complexity but simultaneously accounting also from its initial element to its final element at any order n and including also all the links, interconnections, patterns, couplings and self-similarity that characterize the net. In this manner they delineate finally an actual final synthesis and unity of the net picturing a comprehensive synthesized articulation that delineates the quantum mechanical expression of consciousness at its highest degree of self referential structure and perception of its environment. Let us explain this result with the aid of an example. As seen, we start with the basic elements e_i, and using the self-referential operation of direct multiplication of matrices we arrive to new basic elements E_{0i} and E_{i0}.

In our picture they represent dichotomous variables, quantum like features of mind entities in evolution in the net. In order to express the consciousness arising as the result of such a net, we need to arrive at a description of the net in which, finally, only few sets of basic elements, derived from their algebra given in (20), are truly representative of all the net. In our quantum scheme this operation becomes possible. Consider for example the case of n=4, but the procedure is similar at any order of n. We see in fact that, in addition to the basic elements E_{0i} and E_{i0} that are formed as result of the self-referential mathematical operation, other sets of basic elements are formed and they in some manner synthesize the basic features corresponding to E_{0i} and E_{i0}. These new basic elements are E_{ii}, E_{ij}, E_{ji}, and this time they are given by the product of the basic elements, E_{0i} and E_{i0}. We have, for example, the basic element E_{11} that will be given by $E_{01}E_{10}$ or also E_{12} that will given by the product $E_{02}E_{10}$ or, still, E_{33} that will be given by the product $E_{03}E_{30}$. Such new basic elements will synthesize and still will couple, in general, in all the possible ways, the previous ones. In this manner we have dichotomous variables, that, regulated in a proper algebra, are missing in usual quantum mechanics, but they are of great importance in a rough quantum scheme to represent the synthetic properties of the virtual quantum net that we are realizing. In the case n=4, the basic elements representative of the synthesis of the given basic elements E_{0i} and E_{i0}, will be

$$(E_{ik}, E_{ip}, E_{0m}) \text{ or } (E_{ki}, E_{pi}, E_{m0}) \tag{29}$$

with k, p, m still basic permutation of 1,2,3 and ($ii0$) basic permutation with $i = 1$ or 2 or 3 .Note that each of the two new sets of basic elements will follow the same algebra given in (20) and in (22), and in particular they will preserve that self-referential character that we discussed previously, in addition, each basic set in (29) will synthesize simultaneously the possible couplings and thus the existing links between E_{0i} and E_{i0} in a rigorous quantum like scheme. Let us consider for example the case $i = 1$ .One of the first set in (29), for example, will be (E_{11}, E_{12}, E_{03}) and one other will be (E_{21}, E_{22}, E_{03}) and still we will have (E_{31}, E_{32}, E_{03}) where $E_{11} = E_{10}E_{01}$, $E_{12} = E_{10}E_{02}$, $E_{21} = E_{01}E_{20}$ and so on. In this manner, the first set accounts for itself of the coupling of E_{10} with E_{01} and E_{02} while the second set accounts for itself of the coupling of E_{20} with E_{01} and E_{02}, and the third accounts for E_{30} with E_{01} and E_{02}. The synthesis happens since to E_{11}, for example, may correspond the numerical value of +1 or -1 without E_{10} and E_{01} being specified in their corresponding values, but only knowing the value of their product. Still, consider that the two basic sets still operate at algebraic level in strong observance of their quantum like scheme since of their non commutativity. In the two given basic sets, for example, E_{12} and E_{21} are non commutative basic elements There is still another important feature to evaluate. Let us consider the basic element E_{ij} as a quantum like observable and thus with connected its proper quantum like state (it should be the proper wave function in the correct and usual quantum mechanical language). Such quantum like state will support itself by only in the sense that it will represent a pure information entity not linked directly to a concrete observable representative in usual physical sense. In fact to E_{0i} we will connect a quantum like state that will be representative of the observable E_{0i}.

The same thing will happen for E_{i0}. In analogy with a quantum mechanical physical system, the first quantum like state will be linked to the spin of one particle, in the same manner E_{i0} will be the spin corresponding to the quantum like state of the second particle while instead the quantum like state of E_{12}, for example, will be only self-representative, that is representative only of itself, since E_{12} could not be conceived as a proper quantum observable defined in proper physical terms if not indirectly in terms of E_{10} and E_{02}.In conclusion, as expected, our net arrives to conceive basic algebraic elements or quantum like observables and corresponding quantum like states that result to be expression of pure information or, say, of that pure knowledge factor, or mind like entities, that we previously discussed. No specific counterpart and reference in matter is required for their existence and dynamics.

In the same manner we will have, in the case n=8, new basic elements of the kind $E_{iii} = E_{i00}E_{0i0}E_{00i}$ and so on at any desiderated order. Finally, we will arrive to a final order n, characterizing all our virtual (quantum) net, that, as in (29), will have its synthesizing basic elements, that is to say, it will have its synthesizing dichotomous variables and, as previously explained, they will be self-referential, self representative. Consciousness will be represented from the quantum like states corresponding to such final basic elements.

Obviously, such final quantum like states, representative of consciousness, will preserve all the basic features corresponding also to the most simple basic elements that we introduced in (20). To express such quantum like states, consider again a simple case, that one of the basic element e_3 pertaining to the basic set given in (20). This algebra has idempotents and so quantum like states in this algebraic formulation will be given by such idempotents. For example, two idempotents responding to e_3 are given from

$$\psi_1 = \frac{1+e_3}{2} \quad \text{and} \quad \psi_2 = \frac{1-e_3}{2} \tag{30}$$

In both cases we have that

$$\psi_1^2 = \psi_1 \quad \text{and} \quad \psi_2^2 = \psi_2 . \tag{31}$$

We will have that

$$e_3\psi_1 = \psi_1 \tag{32}$$

and

$$e_3\psi_2 = -\psi_2 \tag{33}$$

and we may conclude that our algebra, given as in the (20), in the subalgebra signed by its idempotents ψ_1 and ψ_2 ,operates so that to attribute e_3 the value +1 in the case of the (32) and -1 in the case of the (33). In this manner, in analogy with the usual quantum mechanics, ψ_1 and ψ_2 will represent quantum like states corresponding to e_3. In the same manner and with the same algebraic structure given in (30), we will have the idempotents corresponding the final basic elements of the virtual (quantum) net with the basic differences that such quantum like states, representative of consciousness, will synthesize all the basic features, correlations, couplings and collective behavior of all the dichotomous variables engaged in the net.

5. The Quantum Model of Conscious Experience

In his excellent papers R.A. Mould [10] assumed that there is correspondence between the subjective life of the human being and the objective world. J. von Neumann [9] formulated a principle of psycho-physical parallelism. According to this principle the images of psychic experience mirror the objects in the physical environment. According to Mould, learning begins with infancy by creating a parallelism of this kind that will be practical and useful in future for the adult. In order this to happen, the conscious species must develop such psycho-physical parallelism starting with the early stage of evolution. A priori there is not a reason to believe that the subjective life of a conscious being would be rational. The appearance of rational thinking that parallels the objective world could also result greatly improbable if the psycho-physics parallelism should not exist. R.A. Mould [10] gave the following statement of the parallel principle.

The subjective images and ideas of a conscious being are related to its physiology in such a way to allow the development of a working psycho-physical parallelism at every stage of the evolution.

The idea that mind and body evolved interactively was introduced by W. James [29] who in fact outlined that the evolution of “appropriate” subjective feelings would be incomprehensible if feelings were biologically redundant. Let us examine a model as it was proposed by Mould. An automaton operates on the basis of a simple stimulus/response sequence. As a result of a mutation, an amended sequence appears, given in the form stimulus/consciousness/response. The conscious experience in this sequence is not considered here to be the only determinant of the response in the sense that it will increase or decrease the likehood of a response or another. If the response favored by the newly introduced consciousness is wrong, then the species will not survive but if the favored response is right, then the species will survive. It follows that in the end a successful species will have a specific conscious experience that is associated with a successful stimulus response sequence. This is a psycho-physical parallelism [10].The basic idea in [10] is that when the emerging subjective states of a neurological quantum superposition are different from one another, they will generally exert an influence on their relative probability amplitudes. Let us consider that a painful subjective state emerges in superposition with a pleasurable subjective state, then the probability amplitude of the painful state will be decreased relative to the probability amplitude of the pleasurable state. Let us imagine a primitive organism makes contact with an electric probe. Its nervous system splits into a superposition consisting of a withdrawn behavior W that is accompanied by no-pain, and a continued contact behavior C that instead is accompanied by pain. We may assume that the probability of survival of each component in this model should be 0.5 initially. However, because of the admitted influence of subjective pain (conscious experience) on probability amplitudes, only the withdrawn state may be considered that will survive in the reduction. We may represent the process in the following manner [7]:

W(withdrawal –no-pain)(p=0.5) → W(no-pain)(p=1.0)

Stimulus S →

C(continue contact-pain)(p=0.5) → C(pain)(p=0.0) (34)

If a conscious experience appears in association with a response to a stimulus, it will enhance the response by increasing probability relative to other responses. From the viewpoint of an evolving mechanism of conscious experience if the strategy W(no-pain) C(pain) will result a good survival strategy then such association will serve the species well, whereas the association with disavantage as W (pain) C (no-pain) will be dismissed. Here the variable panic is considered only because it is usually considered in psychology to represent one of the most important variables in psychological dynamics of being species. Obviously, also other basic variables pertaining to conscious experience could be considered.

In conclusion, it is evident that on the problem of conscious evolution any researcher may have his favorable or unfavorable position. What is important in the present our approach is that we intend to consider here a basic scheme as it follows: generally speaking, given a stimulus S, we may have as answer two possible results, R_1 and R_2. Let us indicate the subjective experience by E and its absence or its first stage uninfluence by nE. According to Mould and his scheme, the effect of subjective experience E is to increase the probability of the response to which it is associated. The basic Mould scheme is as it follows

$$StimulsS \rightarrow \frac{R_1(E) \rightarrow R_1(E) \rightarrow SURVIVE}{R_2(nE) \rightarrow REPRESSED} \quad (35)$$

On this basis we intend to introduce a quantum model of conscious experience. To this purpose we would recall the quantum mechanical notion of awareness that we considered in the previous section by the self referential notion that we introduced in (27).

In the case of our quantum like mechanical model of conscious experience we may introduce also an autoreferential definition and in this case we indicate by ψ_{CE} the quantum like state (wave function in quantum mechanics) pertaining to conscious experience and by ψ_S that one pertaining instead to the contents of the experience. We introduced self-referential framework on the basis of the considered algebraic structure given in (20). According to the (23), we had

$$E_i = F(e_i, x)$$

where it is intended that $E_i \equiv e_i$ in the algebraic properties of such considered elements while x represents the corresponding empirical contents or the contexts to which the awareness is performed.

Using quantum like states, we will write the autoreferential definition of quantum conscious experience in the following manner

$$\psi_{CE} = F(\psi_{CE}, \psi_S) \qquad (36)$$

where this time the symbol F characterizes the functional dependence existing in the given autoreferential definition (27) as one deduces easily using the idempotents given in (30). The problem now remains to represent ψ_{CE} in explicit case relating conscious experience. First of all, we must consider that ψ_{CE} must represent a quantum like state with a peculiar attitude: it must be able to create for itself some alternatives respect to the given ψ_S. In addition, at the first stages of the conscious experience such subjective experience must not depend on whether the factual statements represented by ψ_S are true or false, while instead, as well as subjective conscious experience increases, it must account for such possible differences. We have the possibility to characterize such two basic features of ψ_{CE}, and it is to consider that it no more is represented in quantum mechanical terms by a simple superposition of states as just it happens when we characterize quantum states of physical reality but to admit, in addition, that each state is given by a possible statistical distribution.

Let us consider, for example, the case of the scheme introduced in (35). In this case we have a stimulus – response variable, R_i, that, as previously discussed, may assume two possible values, i = 1 or 2 .It obviously commutes with the observables discussed in the previous section and characterized by the virtual (quantum net). Therefore it will be represented from the same quantum like states. If we indicate by φ_1 and φ_2 two possible quantum like states, in quantum mechanics we should be accustomed to express quantum mechanical superposition by

$$\psi_R = c_1\varphi_1 + c_2\varphi_2 \qquad (37)$$

where

$$|c_1|^2 + |c_2|^2 = 1 \qquad (38)$$

Given the physical system characterized by some specific physical conditions, we usually admit one and only one value for the probability $|c_1|^2$ regarding the state φ_1 and, similarly one probability value $|c_2|^2$ for state φ_2. Owing to the basic motivations, previously introduced, the situation changes radically in writing ψ_{CE} of a conscious experience. Let us consider, for example, the simple and trivial case of vectors with real components in a plane. ψ_{CE} will be then a unit vector in a plane and there will be two functions in (37), namely, $c_1 = \cos\alpha$ and $c_2 = sen\alpha$ where now the profound difference respect to the standard case of quantum mechanics is that any value of $\alpha(0 \le \alpha < 2\pi)$ is possible. Consequently, we have to consider the probability that an angle in the range $(\alpha, \alpha + d\alpha)$ is admitted and thus we have to introduce a proper statistical distribution $f(\alpha)d\alpha$. Consequently, what becomes of importance in quantum mechanical approach to conscious experience is now the average values of probabilities $<|c_i|^2>$ with $i = 1,2$. Obviously all this changes the traditional framework of quantum mechanical elaborations connecting a classical statistical approach to its basic approach.

A quantum mechanical formulation of conscious experience becomes therefore a profound link between classical and quantum treatments. Note that, admitting statistical distributions for the c_i $(i = 1,2)$ in (37), the required autoreferential characterization of conscious experience is fully realized. Let us examine the case of two components as in (37) when the conscious experience operates at the first stage of its evolution. A proper statistical distribution could be the strictly uniform distribution that will lead to

$$<|c_1|^2> = <|c_2|^2> = \frac{1}{2} \tag{39}$$

without possible enhancement of one state respect to the other. Also the case of a weakly uniform distribution will lead obviously the same result given in (39). With reference to the Mould's scheme given in (35), it results that the conscious experience is at a so still low stage that it will not be able to enhance the probability of one response respect to the other one.

Generally speaking, let us consider now the case of a more articulated scheme of conscious experience in which a number of possible responses are involved in answer to a given stimulus. Let us fix by n such a number. As a generalization of (37) and (38) we will have that the probability of such state will be

$$P_n(t) = \sum_{i=1}^{n} |c_{n,t}|^2 \tag{40}$$

with connected average value

$$< P_n(t) > = \sum_{i=1}^{n} < |c_{n,t}|^2 > \tag{41}$$

For a strictly uniform distribution (absence or initial stage of determinant conscious experience) it will be that

$$<\left|c_{n,t}\right|^2>=\lambda \qquad (42)$$

independent from n and it will be $n\lambda=1$, that is to say $\lambda=1/n$.

If conscious experience intervenes with its determinant contribution (see scheme (35) in the case of two possible responses), the case of a strictly or weakly uniform distribution will no more hold, and we will have the basic fundamental equation

$$(n-1)\lambda+\omega=1 \qquad (43)$$

where, among the n states just one, characterized here by ω, is discriminated respect to the other ones for the presence of its conscious determinant experience. By the (41, 42, and 43) our initial purpose that the effect of the subjective experience E (see the (35)) is to increase the probability of the response to which it is associated, is here fully realized.

As a general case we will admit that ω differs from λ by a factor α that we will call "conscious experience factor", and so we will have that

$$(n-1)\lambda+\alpha\lambda=1 \quad (\alpha\neq 1) \qquad (44)$$

that is to say

$$\lambda=\frac{1}{n+\alpha-1} \qquad (45)$$

The presence of increasing values of α in the (44) will enhance the probability with survival of some states and dismission of other ones as required in the (35) in the simple case of two possible responses.

Note that, in the case of a non determinant conscious experience and thus of a uniform distribution, we may write that

$<\left|c_{i,t}\right|^2>=\lambda$ (independent from i) ; $<\left|c_{i,t}\right|^4>=\mu$ (independent of i) ; $<\left|c_{i,t}c_{j,t}\right|^2>=\theta$ (independent of i and j) (46)

and, in conclusion,

$$n\lambda=n\mu+n(n-1)\vartheta=1 \qquad (47)$$

If instead some state has determinant conscious experience it will result that

$$(n+\alpha-1)\lambda=(n+\beta-1)\mu+(n-1)(n-2+2\gamma)\vartheta=1 \qquad (48)$$

where $\beta\neq 1$ and $\gamma\neq 1$ have similar meaning of α and they account for the presence of determinant conscious experience also in the other algebraic terms in (48).
From the equation (46) we may calculate λ and ϑ as function of μ. One obtains in fact that

$$\lambda=\frac{1}{n+\alpha-1} \quad \text{and} \quad \vartheta=\frac{1-(n+\beta-1)\mu}{(n-1)(n+2\gamma-2)} \qquad (49).$$

Therefore, having fixed the general features of our model of conscious experience, we may proceed in detail in the evaluation of the possible surviving or depressed states as indicated in the simple example previously given in (35). To approach this problem we may pose the following problem: given the wave function representing our conscious experience in the manner that we have formulated here by using the equations from (37) to (49), as seen it has been expressed in the dimension space given generally by n. We ask now if such wave function, lying in the n-dimension space, and regulated by the (46) and (47), is able to self organize itself in a manner to admit itself in an m-dimension space with $m<n$. If this may happen, it will result that some states, and precisely (n-m), will result to have been repressed just as it was previously represented in the simple scheme of two cases ($R_i(i=1,2)$) that we considered in (35). In formal terms this is to say that, in addition to the starting wave function representing conscious experience at the initial stage of its experience, we must estimate if a new wave function may be considered relating this time new probabilities $P_1(t)$ and $<P_1(t)>$, given respectively in the following manner:

$$P_1(t)=\sum_{i=1}^{m}\left|c_{i,t}\right|^2 \qquad (50) \qquad \text{and} \qquad <P_1(t)>=\sum_{i=1}^{m}<\left|c_{i,t}\right|^2> \qquad (51)$$

as alternative to (40) and (41). Note that the basic key is represented in the dimension space m in (50) and (51). It is considered to be m< n in (50) and (51) respect to other ones given in (40) and (41). This is equivalent to consider if the wave function of conscious experience is able to self–rearrange itself, passing from the configuration of probability given in (40 and 41) to the new configuration given in (50 and 51) where, owing to m<n, some states have been actually repressed or dismissed.

In order to estimate such attitude of conscious experience to rearrange itself on new states with repression of some other ones, we must introduce a new but well known statistical index Z_1 that will be able to account for the spread of the individual values of $P_1(t)$, given in (50), respect to the mean value $<P_1(t)>$, given in (51). It will be

$$Z_1\equiv\frac{<\left[P_1(t)-<P_1(t)>\right]^2}{\left[<P_1(t)>\right]^2}> \qquad (52)$$

Note that, owing to the relevant value of m, as the number of states involved in conscious experience, $<P_1(t)>$ will considered generally to assume a very small value and consequently a value of $Z_1 << 1$ will be considered to give an unfavorable value of $P_1(t)$ to give a new state for conscious experience arranged in a new dimension space m<n . In conclusion, for conscious experience to be self rearranged on new states with repressed other states, we may consider, for example, to be $Z_1 \approx 2$. Let us consider such value for Z_1 and let us assume also that with certainty conscious experience rearranges itself in the new state at dimension m. This is to say that $P_1(t)$ =1. Considering that the value $Z_1 = 2$ is required, we have from the (52) that

$$Z_1 = 1 + \frac{1}{<P_1>^2} - \frac{2}{<P_1>} \tag{53}$$

and it will result that

$$<P_1> \approx 0.41 \tag{54}$$

Owing to (49) we will have $\alpha \approx 1.439$ with $\lambda = 0.41$ and $\omega = \alpha\lambda = 0.59$ in the case of n=2 and m=1. We may conclude that in this case, probability enhanced of about 18%. Finally, the (47-53) enable us to estimate the (52) in all the cases of interest.

We have now completed our exposition of the quantum model of conscious experience. In accord with the scheme given in (35), we have seen that this quantum model show autoreferential attitude as well as capacity of self rearrangement of its probability field in order to enhance those probabilities leading to survival of conscious experienced states.

To conclude we would add some considerations in order to explicit in detail the reasons because we adopted a statistical model for quantum like states pertaining to our conscious experience. Let us admit that to a subject is posed the question A that admits several possible answers like a, b, c, d, e, …… . Subject's possible answers must be considered to be context dependent as it was outlined in our previous studies and, in particular, as also it was analyzed by D. A Aerts et al. [30] that discussed in detail this problem and also recently performed actual experiments on this matter. It is such notion of context that must be intended in detail in the framework of our model. The context certainly involves for example the nature of the posed question A, and the background in which it is offered to the subject. However, the context involves also the mental and emotional state of the subject at the moment in which the question A is posed to him, and, finally, it is given also from his recognition, memory and story, that is to say from the conscious experience of the subject as well as it may be recalled from the subject at the moment in which the question A is represented. From his story, the subject, recalling in his memory the context α , will be induced to potentially attribute to answer a the probability p_a , to answer b, the probability p_b , and so on. In quantum like formalism we will have that

$$\psi_A = c_a\varphi_a + c_b\varphi_b + \dots\dots\dots\dots\dots + c_n\varphi_n \tag{55}$$

with $|c_a|^2$ giving the probability p_a, $|c_b|^2$ giving p_b, and so on. At the same time, however, the subject, stimulated from a different context relating his story, his memory storage or is emotional or conceptual state in the present or in the past his story, will be induced to potentially admit an alternative to the previous quantum like superposition, considering instead

$$\psi_A = c_a^1\varphi_a + c_b^1\varphi_b + ... + c_n^1\varphi_n \tag{56}$$

and still

.

.

.

$$\psi_A = c_a^m\varphi_a + c_b^m\varphi_b + ... + c_n^m\varphi_n \tag{57}$$

with m corresponding to the final, large number of contexts that the subject will be able to recall on the basis of his story, memory, recognition and so on. In correspondence of each superposition we will have new probability amplitudes and thus new possible probabilities. Owing to the highest complexity that we may conceive in brain activity and in the corresponding virtual (quantum) net, we will have for ψ_A a quantum like superposition of quantum states in which the probability amplitudes will be statistically distributed according to a statistical framework as previously discussed in this section. It is this statistical structure that will vary in function of the conscious experience of the subject and than of the several and different contexts that he will able to recall.

In a phenomenological and formal view point this framework may be intended in the following manner. It is commonly believed that in quantum systems chaotic structures cannot arise. However, the question arises if it may be possible to have in quantum systems a situation analogous to classical chaotic structures. In other words, it is posed the problem if it may be possible for two slightly different boundary conditions or some physical parameter, as it may be as example a coupling constant, that to them correspond to two qualitatively different wave functions. Such dependence on physical conditions in quantum systems may be analogous to classical chaotic dynamics. Recently, other examples were given by us in the picture of biological observables violating Lipschitz condition at singularities [31].

References

[1] Conte E., Pierri GP., Federici A., Mendolicchio L., Zbilut J. P. (2006). A model of biological neuron with terminal chaos and quantum-like features, *Chaos, Solitons and Fractals*, 30, 774-780, 2006
Conte E., Todarello O., Federici A., Vitello F., Lopane M., Khrennikon A, Zbilut J.P. (2007). Some remarks on an experiment suggesting quantum-like behavior of cognitive entities and formulation of an abstract quantum mechanical formalism to describe cognitive entity and its dynamic,. *Chaos, Solitons and Fractals*, 31 (5), 1076-1088.

[2] Zak M. (1991). Terminal chaos for information processing in neurodynamics, *Biol. Cybern*., 64, 343-351 and references therein;
Zak M. (1997). Dynamical simulation of probabilities. *Chaos, Solitons and Fractals*, 8, 793-804;
Zak M. (1992). The problem of irreversibility in Newtonian dynamics. *Int. J. Theoretical Physics*, 31, 333-342.
Zbilut J.P. (2004). *Unstable singularities and randomness: their importance in the complexity of physics and social sciences*, Elsevier.
Zbilut J.P., Zak M., Meyers R.E.(1996). A terminal dynamics model of the heartbeat. *Biol. Cybern*., 75, 277-280.
Dixon D.D. (1995). Iecewise deterministic dynamics from the application of noise to singular equations of motion. *Journal of Physics*, 28, 5539-5545.

[3] Walker E.H. (1977). Quantum mechanical tunnelling in synaptic and emptatic transmission. *Int. J. Quantum Chem*., 11, 103-123.
Walker E. H. (1970). The nature of consciousness. *Math. Biosciences*, 3, 131-178.

[4] Beck F.(1996). Can quantum process control synaptic emission? *Int. J. Neural systems*, 7 (4), 343-353.
Beck F., Eccles J.C. (1989). Quantum aspects of brain activity and the role of consciousness. *Proc. Natl. Acad. Sci*. 11357-11361.

[5] Dan Ventura, Martinez T. (*April 1997*) An artificial neuron with quantum mechanical properties, Proceedings of the International Conference on Artificial Neural Networks and Genetic Algorithms, pp. 482-485,.

[6] Stockmann H-J. (1999). *Quantum chaos: an introduction*, Cambridge university press.

[7] Wojcik W., Bialynicki-Birula I., Zyczkowski K. (2000). Time evolution of quantum fractals. *Phys. Rev*., 20, 1-4.

[8] Weirstrass F. (1815). *Mathematische werke II*, Muller, Berlin.

[9] von Neumann J. (1955). *Mathematical foundations of quantum mechanics*, Princeton Univ.Press.

[10] Mould R., The parallel principle, quant-ph /0111096,2001;quantum consciousness, quant-ph/0908077, quant-ph/0106103; Consciousness and quantum mechanics, Found. Phys., 1998, 28, 11, 1703-1713, Quantum brain states, N.Y. 11794-3800, http://nuclear.physics sunsyb.edu/Mould;

[11] Snyder F.W. (1986). Light as an expression of mental activity. *J of Mind and Behaviour*, 7, 567-583; (1983). The inclusion in modern physical theory of a link between cognitive –interpretative activity and the structure and course of the physical world. *J. of Mind and Behaviour*, 10, 153-171; (1995). On the quantum wave function as a link between cognition and the physical world: a role for psychology, *J. of Mind and Behaviour*, 16, 151-179;
Snyder F.W., Pronko N.H. (1957). Vision with spatial inversion. *Psychological Research*, 7, 21-30 and (1952) Univ. of Witchita Press.

[12] Epsteim P. (1945). The reality problem in quantum mechanics. *American J. Physics*, 13 (3), 127-136

[13] Nakhamanson R., Mind body interpretation in quantum mechanics, http:77Lanl.gov/pdf/physics/005042;

[14] Nakhamanson R., Mind body interpretation in quantum mechanics, http:77Lanl.gov/pdf/physics/0004047;

[15] Shepherd GM (1990). *The synaptic organization of the brain*. New York: Oxford UP.
Jacobson M (1991). *Developmental neurobiology*, 3rd Ed. New York: Plenum.

[16] Agnati L.F., Fuxe K., Zoli M., Zini I., Toffano G., Ferraguti, F. (1986). A correlation analysis of the regional distribution of central enkephalin and endorphin immunoreactive terminals and of opiate receptors in adult and old male rats. Evidence for the existence of two main types of communication in the central nervous system: the volume transmission and the wiring transmission. *Acta Physiol. Scand*. 128, 201-207.
Agnati L.F., Fuxe K. (2000). Volume transmission as a key feature of information handling in the central nervous system possible new interpretative value of the Turing's B-type machine. *Prog. Brain Res*. 125, 3-19.

[17] Perus M. (2001). Multilevel synergetic computation in brain. *Non Linear Phenomena in Complex Systems*, 4 (2), 157-193; see also Consciousness: network dynamical information and phenomenal aspects and Visual conscious experience, http://bion.si/mitja.htm

Perus M., Bischof H., Quantum wave pattern recognition: from simulations toward implementation,quant-ph /0303092v2-2003

For the use of Pauli master equation see:

Dugic M., Rakovic D. (2000). Quantum tunnelling in associative neural networks. *Europ. J. of Phys. B*, 13, 781-790, see also: Procedings & Int. Conf. Inf. Soc. IS 2003, Kononenko I., Jerman J. Editions, Lubljana, Slovenia;

[18] Hebb DO (1949). *The Organization of Behavior*. New York: Wiley.

[19] Huping Hu, Maoxin Wu (2004). Spin as primordial self-referential process driving quantum mechanics, spacetime dynamics and consciousness. *Neuroquantology*, 1, 41-49 and 2004, 2 (4), 309-317, and references therein;

[20] Suezaki Y., Tatara T., Kaminoh Y., Kamaya H and Ueda I. (1990). A solid-solution theory of anesthetic interaction with lipid membranes: temperature span of the main phase transition. *Biochimica et Biophysica Acta*. 1029, 143-148

[21] Matthews, R (1992). A low-fat theory of anesthesia. *Science*, 255 (5041), 156-157

[22, 23] Babich F.R., Jacobson A.L., Bubash S., and Jacobson A.L. (1965). Transfer of a Response to Naive Rats by Injection of Ribonucleic Acid Extracted from Trained Rats. *Science*, 149, 656-657.

[24] Davydov A.S., Ermakov V.N. (1987). Linear and non linear electron tunnelling through a system of potential barriers. *Physica D*, 28, 168-180.

[25] Alekseev K., Berman G.P., Campbell D.K. (1998). Strange attractors in resonant tunnelling, *Phys. Rev. B*, 58 (7), 3954-3962.

[26] Conte E. (2011). An investigation on the basic conceptual foundations of quantum mechanics by using Clifford algebra. *Advanced Studies in Theoretical Physics*, 5 (11), 485-544.

[27] Lefebvre V.A. (2002). The Law of Self-Reflexion: A Possible Unified Explanation for the Three Different Psychological Phenomena. http://cogprints.org/2927/1/The_Law_of_Self%2DReflexion.pdf

[28] Khromov A.G. (2001). Logical self-reference as a model for conscious experience. *J. Math. Psychology*, 45, 720-731.

[29] James W. (1981). *The Principles of Psychology*, Harward University Press.

[30] Aerts D., Gabora L. (2004). A theory of concepts and their combinations I: the structure of set of contexts and properties. quant-ph/0402207v1-2004 and references therein;

[31]Conte E., Federici A., Zbilut J.P. (2004). On a simple case of possible non deterministic chaotic behaviour in compartment theory of biological observables. *Chaos, Solitons and Fractals*, 22, 277-284.

[32] For a recent review of our results see

Conte E. (June 2012). *Advances in Application of Quantum Mechanics in Neuroscience and Psychology*, Nova Science Publishers, (ISBN 978-1-61470-325-9). This book also contains all the references on our recent contributions published elsewhere. For a detailed indication of such papers visit as example the site www.saistmp.com.