Article

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

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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

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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

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

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

$$\varepsilon(t) = +,-,-,-,+,....... \tag{2}$$

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

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

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 $m = 1,2,3,......$, 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

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

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, $k_1 \to k_2$. 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:

$$< S_z >= \frac{h}{2}\frac{T_+ - T_-}{T_+ + T_-} \tag{17}$$

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 $\mathrm{i, j, k} = 1,2,3$, $\mathrm{ijk} =$ 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:

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

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]