Original Article

Mind and Tachyons: How Tachyon Changes Quantum Potential and Brain Creates Mind

Syamala D. Hari

Abstract

We propose that memory and thought in the brain involve tachyons. As a first step, in an earlier paper it was suggested that mental units called psychons by Eccles could be tachyons. Although experiments to detect faster-than-light particles have not been successful so far, recently, there has been renewed interest in tachyon theories in various branches of physics. We suggest that tachyon theory may be applicable to brain physics as well. The present paper describes how the zero-energy tachyon field has various features of mind-fields which have been postulated by some well known mind-matter researchers. We propose that the relation between the tachyon field and the change it produces in the quantum potential of the system with which the tachyon interacts is similar to the relation between an algorithm and its representation stored in a computer (digital or quantum). The quantum potential which is software-like, and the holographic memory which is database-like, both provide codes in the hardware-like physical brain, for the "real information" or the "meaning" which consists of tachyons. We show that our proposal can mathematically describe how mind acts on the physical brain as well as how the brain acts on mind. As an example of how the brain creates experience in the form of tachyons, we explain the Libet delay-and-antedating paradox using this proposal.

Key Words: quantum potential, mind field, tachyon, exocytosis, computer and brain, artificial intelligence, temporal anomalies

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1. Introduction

In an earlier paper (Hari, 2008), it was suggested that mental units called psychons by Eccles could be zero-energy tachyons. Although experiments to detect faster-than-light particles have not been successful so far, recently, there has been renewed interest in tachyon theories in various branches of physics. We suggest that tachyon theory may be applicable to brain physics as well. The present paper describes how a zero-energy tachyon (ZET) field has various features of mind-fields which have been postulated or anticipated by some well known mind-matter researchers. We propose that the relation between the tachyon field and the change it produces in the quantum potential of the system with which the tachyon interacts is the relation between an algorithm and its representation stored in a computer (digital or quantum). The quantum potential which is software-like, and the holographic memory which is database-like, both provide codes in the hardware-like brain, for the "real information" or the "meaning" which consists of tachyon fields.

Corresponding author: Syamala D. Hari
Address: 709 Margaret Court, NJ 07080 USA
Phone: + 9087563311
e-mail: murty_hari@yahoo.com
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A tachyon is essentially different from ordinary matter in the sense that a material particle cannot be accelerated to be a tachyon and conversely a tachyon cannot be decelerated to have a speed less than that of light. Tachyon mass is purely imaginary in any laboratory frame of reference[2]. All attempts to produce tachyons from matter have not been successful so far and led Feinberg to conjecture that probably tachyons cannot be produced from matter (1970). In a Scientific American article, Feinberg (1970) mentions "*One remote possibility is that tachyons do interact with matter and can exchange energy with them but cannot be produced from them.*" It is this point of view that we adopt in this article. However, in section 4 we show that new tachyons are created when tachyons interact with nonrelativistic matter (although they may not be produced from matter alone). Although in general, physicists are skeptical about tachyon existence we belong to the minority who believe that tachyons can be found if attempts are made in the right place; we believe that a living brain is a right place to look for them. Tachyons could not be found so far in lifeless matter-to-matter interactions; our hope is to find them in interactions with the brain's nonrelativistic matter.

When we associate tachyons with mind, we adopt the point of view of Shay and Miller (1977) that a tachyon is more like a field than a particle (Recami, 1986). Shay and Miller (1977) treat tachyons as strictly nonlocal phenomena produced and absorbed by detectors in a coherent and cooperative way. In this view, a tachyon cannot be created in one position to be later absorbed or measured at another position; the tachyon must be created or absorbed over a region of space, and therefore one cannot talk in terms of time of flight from one position to another. Nevertheless, a speed which is greater than the speed of light can be associated with the tachyon.[3]

In the present paper, we point out that tachyon fields have properties which have been attributed to mind fields by brain scientists such as Libet and Eccles, and physicists such as Bohm and Hiley.

Some features of the ZET field are:

- It contributes to the active information defined by Bohm and Hiley (1984), which acts on Schrödinger particles. Like the Conscious Mental Field proposed by Libet (1993; 1994; 1996), a ZET could act on certain neural activities that take place in willed actions. (Specifically, a ZET's role in exocytosis is described in Hari (2008) and summarized in this paper.)
- ZET interaction with a brain's matter obeys all known conservation laws of physics.
- When a ZET interacts with material quantum particles, it changes the probability density of finding them in a given state. It generates the back-action term in the continuity equation of the particles. Back-action is considered to be a necessary condition for describing any form of living matter using quantum theory by Sarfatti (1996).
- A ZET is associated with electromagnetic scalar and vector potentials which generate zero electric and magnetic fields. Just as electromagnetic potentials cannot be observed directly but only indirectly through their effects, it is possible that ZETs could not be directly observed by any external physical device but only indirectly by any effects they introduce on neural activities.
- ZETs may be said to be non-material because the mass of a tachyon is purely imaginary (in our laboratory frames of reference and all physically realizable frames moving with speeds less than the speed of light). However, tachyons fit well into

[2] In a Lorentz frame of reference, which moves with a speed greater than the speed of light relative to a lab frame, the tachyon mass would be seen as real but such frames are impossible to realize.

[3] A tachyon has real energy and momentum. Denoting the momentum by $\mathbf{p}$, the velocity $\mathbf{v}$ is given by $\mathbf{p} = m_0 \mathbf{v} / \sqrt{(\mathbf{v}^2/c^2-1)}$ (Feinberg 1967. p 159) and m_0 is the mass of the tachyon in the frame of reference fixed in itself and is real.

quantum theory and at least some mathematical tools exist for use in theoretical investigations.

For quite some time, the author (Hari, 2002; Vishnubhatla, 1985) has held the view that thought processes in a brain involve tachyons defined by physicists sometime ago. Some intuitive rationale for this hypothesis may be found in the stated references. It is interesting that Fred Alan Wolf (2008) recently stated some quantum field theoretical concepts associating tachyons to mind. In the past, there has been at least one theoretical physicist, Late Regis Dutheil, a quantum physicist and a consciousness researcher, who proposed a model in which mind is a field of tachyonic or superluminal matter[4].

In section 2, we present a part of the theory of the earlier paper (Hari, 2008) for convenience of reading. Using the quantum tunneling model of Beck and Eccles (1992), and Bohmian model of quantum mechanics, we describe how a ZET when absorbed collectively by the multiple boutons of a dendron, changes their quantum potential and triggers exocytosis simultaneously in all of them. In this section, we compare ZET features with those of mind fields proposed by Eccles, Libet, Bohm, and Hiley.

Assumptions

Since the Beck-Eccles model of exocytosis uses the nonrelativistic Schrödinger equation, obviously they assumed exocytosis to be a nonrelativistic process. Hence we make the same assumption in our discussion. Eccles also assumed that for exocytosis to occur, a certain nonmaterial psychon should intervene and increase the probability of the required brain state which is a solution of the Schrödinger equation. In what follows, we will describe how a tachyon having zero energy in the laboratory frame of reference in which a bouton is observed, can do the task of the psychon; that is, interact with the bouton and increase the probability of the exocytosis state. We introduce the interaction into the same quantum tunneling model of Beck and Eccles. Since the Schrödinger equation is not invariant under Lorentz transformations, we will not require our description to be invariant under Lorentz transformations either (like e.g., usually, descriptions of electromagnetic interactions with nonrelativistic matter are not Lorentz-invariant). As Recami (1986; 9(6):36) points out, "Given a phenomenon ph, the principle of relativity requires that two different inertial observers O1, O2 find that ph is ruled by the same physical laws but it does not require O1, O2 to give the same description of ph". However, if we assume that local observers of the brain do not move relative to the observed brain with speeds comparable to the light speed c in vacuum, then tachyons whose speeds are much greater than c may be regarded as close to infinity when compared to speeds of the nonrelativistic matter in the brain. Hence, although a tachyon with infinite speed in one frame of reference may have a finite speed in another frame, the speed could still be much greater than c, if the relative speed of the two frames is much lower than c[5]. The energy of a ZET in one frame would be close to zero in the other frame also; but in all local frames tachyons will be found to exchange a finite and non-zero momentum with the brain's matter. Moreover, as already mentioned, they would not be found as particles flying around with faster-than-light speeds but they would be fields spread over regions of the brain.

Similarly, in Section 4, where we describe ZET production as the reaction of the system of nonrelativistic material particles on a ZET which acts upon the particles, again, we do not require the description to be relativistically invariant because one participant of the interaction,

[4] Dutheil, M.D. considered that the mind, though of tachyonic nature, belongs to the true fundamental universe and that our world is merely a subluminal holographic projection. He taught physics and biophysics at "Poitiers" Faculty of Medicine. He dedicated himself to research in fundamental physics from 1973 on. He was the author of "Superluminous Man" & "Superluminous Medicine". He was a joint Director in "Louis de Broglie" Physics Foundation in Paris (Evellyn Elsaesser Valarino 1997).

[5] The velocity transformation law relating velocities **v** and **v′** of a particle relative to Lorentz frames moving with relative velocity **u** gives the following relation between the speeds: $v=|\mathbf{v}|$, $v'=|\mathbf{v}'|$, $u=|\mathbf{u}|$.

$$v'^2/c^2 = 1 + [(v^2/c^2)-1][1-u^2/c^2]/[1-\mathbf{u}.\mathbf{v}/c^2]^2$$

(Feinberg, 1967; 159) so that $v'>c$ if $v>c$. If $v = \infty$ then $v'= c^2/u$; therefore $v' \gg c$ if $u \ll c$.

namely the system of particles is nonrelativistic.

We use Bohmian model of Schrödinger equation to describe the quantum tunneling process and like many mathematicians and physicists, accept Bohm's causal interpretation of nonrelativistic quantum mechanics (QM) because it agrees with experimental results (Holland, 1993; 104–107). One essential aspect of this interpretation is the ontology of quantum particle and its trajectories (Stapp 1995, Goldstein *et al.*, 1995-2009; Holland, 1993; Hiley and Pylkkanen, 2005; Figure 1) which has been used (e.g., Bittner, 2000) in quantum tunneling problems. We are aware that some physicists raised objections to Bohmian interpretation and the particle ontology and that others refuted those objections but a discussion of the validity of either side is out of scope of this article. Considering that every interpretation of QM is supported by some and not liked by others, we accept Bohm's interpretation as do many experienced mathematicians and physicists. However, like Stapp (2007), we do not agree with the part of Bohm's theory which associates consciousness with an infinite tower of quantum potentials, each one piloting the one below. Why we differ from Bohm is explained in section 3.

In section 3, we explain that a ZET field in the brain is related to Bohm-Hiley quantum potential analogously to how an algorithm in a programmer's head is related to its representation, namely a certain code, entered and stored in the computer's hardware. However, unlike in a computer, the ZET encodes itself by making changes in the quantum potential.

In section 4, we will see how our ZET proposal can mathematically describe how mind acts on matter as well as how biological matter in a brain acts on mind. We explain that the biological matter in a living brain creates meaning and experience (in the form of ZETs) although any matter outside the brain does not.

In section 5, we explain Libet's delay-and-antedating paradox using the ZET proposal.

2. A Zero-Energy Tachyon Can Trigger Exocytosis

Eccles calls some fundamental neural units of the cerebral cortex dendrons, and proposes that each of the 40 million dendrons is linked with a mental unit, or psychon, representing a unitary conscious experience. Based on physicist Friedrich Beck's (Beck and Eccles, 1992; Beck, 1996) quantum mechanical analysis of bouton exocytosis, he proposes the hypothesis that in willed actions and thought, psychons act on dendrons and become neurally effective by momentarily increasing the probability of exocytosis in selected cortical areas. Thus Eccles postulated a "mind-field" that could somehow alter quantum transition probabilities but gave no indication as to how this could happen. We repeat here the part of an earlier paper (Hari, 2008) where it was shown that a zero-energy tachyon could perform precisely the function of a psychon as described by Eccles. It will be seen that a ZET can act as a trigger for exocytosis (modeled by Friedrich Beck as a quantum tunneling process), not merely at a single presynaptic terminal but at all selected terminals in the interacting dendron by momentarily transferring momentum to vesicles, thereby decreasing the effective barrier potential and increasing the probability of exocytosis at all boutons at the same time (again, simultaneity is not Lorentz-invariant but we are not requiring Lorentz-invariance of an interaction involving nonrelativistic matter nor of descriptions of phenomena).

The Klein-Gordon equation for a free tachyon with a proper mass m_0 (mass in the frame of reference fixed in itself and a positive real number) is written as

$$\left(\partial_\nu \partial^\nu - m^2\right)\phi(\mathbf{X}) = 0 \qquad \textbf{(2.1)}$$

where vector $\mathbf{X} = (ct, -x, -y, -z) = (x_0, x_1, x_2, x_3)$ and ∂_ν stands for differentiation with respect to x_ν, $\partial^\nu = \eta^{\mu\nu}\partial_\mu$ where $\eta^{\mu\nu}$ is the Minkowski metric; $m = m_0 c/\hbar$, c is the speed of light in free space, and $\hbar$ is the Planck's constant. Writing $\mathbf{x} = (x, y, z)$ and $\phi(\mathbf{X}) = \Psi(\mathbf{x})\Psi'(t)$ we get solutions of the form $e^{i\omega t}\,\Psi(\mathbf{x})$ of equation (2.1) where $\Psi(\mathbf{x})$ satisfies

$$\left(-\Delta - m^2\right)\Psi(\mathbf{x}) = 0 \text{ and } \omega^2/c^2 = k^2 - m^2 \qquad \textbf{(2.2)}$$

Hence the frequency ω is real only for k ≥m. In the frame of reference in which the energy of a tachyon vanishes, the magnitude of the momentum is equal to m_0c and the tachyon has infinite speed. The interaction of such a tachyon with ordinary matter would be to instantaneously transfer momentum but no energy in a manner analogous to a rigid body's transferring impulses instantaneously in a collision without exchanging energy (Sudarshan, 1970). Sudarshan (1969) further describes: *"In a sense, then, tachyons reintroduce instantaneous action-at-a-distance characteristic in a relativistic theory. An event interpreted as instantaneous action-at-a-distance in one Lorentz frame will appear to be a propagated action in another frame."*

A zero-energy solution of **(2.2)** corresponds to frequency ω = 0 and $k^2 = m^2$ and satisfies the Helmholtz equation:

$$\Delta\Phi(\mathbf{x}) = -m^2\Phi(\mathbf{x}) \qquad \textbf{(2.3)}$$

Equation (2.3) has multiple linearly independent solutions $\Phi(\mathbf{x})$) corresponding to a given value of m. Each solution represents a field with zero energy and capable of exchanging momentum with a particle of matter. We take $\Phi(\mathbf{x})$ to be real. To describe the interaction of a field satisfying equation (2.3) with a particle whose motion is governed by a Schrödinger equation, we associate with $\Phi(\mathbf{x})$ the electromagnetic field defined by the four-potential:

$$\tilde{\boldsymbol{A}} = \left(\partial^{\nu}\varphi_m(\mathbf{x},t)\right) = (U,\boldsymbol{A}) \qquad \textbf{(2.4)}$$

where

$$\varphi_m(\mathbf{x},t) = e^{imct}\Phi(\mathbf{x}),$$

$$U = \partial_o\varphi_m(\mathbf{x},t) = ime^{imct}\Phi(\mathbf{x})$$

and $\boldsymbol{A} = -(\partial_1,\partial_2,\partial_3)\varphi_m(\mathbf{x},t) = -e^{imct}\nabla\Phi(\mathbf{x})$.

Note that the potentials $\boldsymbol{A}$ and U give rise to zero electric and magnetic fields. According to Eccles (1992), the interaction of psychon and dendron is momentary and hence we take $t=0$ as the time of interaction of the tachyon with the dendron. We find that at t=0, the scalar potential is purely imaginary whereas the vector potential is real and therefore, the zero-energy tachyon would only transfer momentum to a charged particle but no energy.

Beck and Eccles (1992) modeled exocytosis as a quantum tunneling process of a two-state quasiparticle governed by a one-dimensional Schrödinger equation:

$$i\hbar\partial_t\psi(q,t) = -\left(\hbar^2/2M\right)\left(\partial_q^{\,2} + V(q)\right)\psi(q,t) \qquad \textbf{(2.5)}$$

where q is the quasiparticle's degree of freedom, M is the mass of the particle, V(q) the external potential energy, and $\hbar$ is the Plank's constant. Writing the quasiparticle wave-function $\psi(q,t)$ of equation (2.5) as $\psi(q,t) = Re^{iS(q,t)/\hbar}$, where R and S are real valued functions and equating the real and imaginary parts on both sides of we obtain the following two equations:

$$\partial_t S + \left(\partial_q S\right)^2/2M + Q + V(q) = 0 \qquad \textbf{(2.6)}$$

$$\partial_t R^2 + \partial_q\left(R^2\partial_q S\right)/M = 0 \qquad \textbf{(2.7)}$$

In equation (2.6), $Q = -\hbar^2\left(\partial_q^{\,2}R\right)/2MR$ is called the quantum potential; the particle's total energy E = $-\partial_t S$, and $\partial_q S$ is the particle's momentum. Once (2.5) is solved for the wavefunction $\psi(q,t)$, the particle's trajectories can be computed classically from

$$Mdq/dt = \partial_q S \quad \text{or}$$
$$Md^2q/dt^2 = -\partial_q(Q+V) \qquad \textbf{(2.8)}$$

by prescribing initial conditions (see Holland 1993: equations 3.2.19 and 3.2.24 on pages 73 and 74 respectively). Just before tunneling begins motion is classical and E = V and Q = 0; hence in equation (2.6) the particle's kinetic energy $(\partial_q S)^2/2M = 0$ at this time. As the potential V increases and becomes > E, motion is classically forbidden. As long as the particle remains in the state of no exocytosis, it has not crossed the barrier V> E, the particle's momentum $\partial_q S$ remains zero and the quantum potential Q adjusts itself so that Q+V = E; Q+V cannot be > E because $(\partial_q S)^2$ cannot be negative. On the other hand, Q+V can be < E although V > E; if so, the second of equations (2.8) gives trajectories penetrating the barrier (Holland 1993, p 199) and equation (2.6) gives a nonzero kinetic energy.

The electromagnetic interaction with the tachyon field changes the equation (2.5) to:

$$i\hbar\,\partial_t\psi'(q,t)=\begin{Bmatrix}\left[\mathbf{I}(\hbar/i)\partial_q-(\varepsilon/c)e^{imct}\mathbf{A}(\mathbf{r})\right]^2/2M+\\ i\varepsilon m e^{imct}\Phi(\mathbf{r})+V(q)\end{Bmatrix}\psi'(q,t) \quad \textbf{(2.9)}$$

where $\mathbf{r}=\mathbf{r}(q)$ is the quasiparticle position, and $\mathbf{A}(\mathbf{r})=-\nabla\Phi(\mathbf{r})$, $\mathbf{I}$ is the unit vector along its velocity, and ε is the quasiparticle's charge. To describe the momentary interaction, we will consider equation (2.9) in a small time interval δt and take its limit as δt tends to zero. (One may wonder why e^{imct} is present in equation (2.9) but not the delta-function $\delta(t)$ if (2.9) is supposed to describe a momentary interaction. Note that from the definition of the four-potential in equation (2.4) the scalar and vector potentials are $\mathcal{A}=e^{imct}\mathbf{A}(\mathbf{r})$ and $U=ime^{imct}\Phi(\mathbf{r})$. Here, e^{imct} cannot be replaced by $\delta(t)$ nor multiplied by $\delta(t)$ because then $\mathcal{A}$ and U will not satisfy the wave equation and therefore cannot be inserted into the Schrodiger equation as electromagnetic potentials. Moreover, the $\delta(t)$ factor will make them infinitely large at t=0 whereas a ZET has only a finite momentum even at the instant of impulse transmission; the ZET gives only a gentle push to the vesicles but would not act like a thunderbolt). In the time interval δt, a non-zero solution $\psi'(q,t)$ of equation (2.9) is related to the solution $\psi(q,t)$ equation (2.5) as follows:

$$\psi'(q,t)=\psi(q,t)\exp i[-(\cos mct + i\sin mct)\varepsilon\Phi(\mathbf{r})/c\hbar]$$

The effect of tachyon interaction on equations (2.6), (2.7), and (2.8) can be obtained by substituting $\psi'(q,t)=R'e^{iS'(q,t)/\hbar}$ in (2.9) and equating real parts on both sides of equation. It is seen that for $|t|\le\delta t$ and sufficiently small δt, equations (2.6), (2.7), and (2.8) change respectively to (2.10), (2.11), and (2.12) below:

$$\partial_t S' + \left(\partial_q S'-\varepsilon A/c\right)^2/2M + Q' + V(q) = 0 \quad \textbf{(2.10)}$$

$$\partial_t R'^2 + \partial_q\left(R'^2\left(\partial_q S'-\varepsilon\mathbf{A}.\mathbf{I}/c\right)\right)/M = 2\varepsilon m\Phi R'^2 \quad \textbf{(2.11)}$$

$$M dq/dt = \left|\left(\mathbf{I}\partial_q S'-\varepsilon\mathbf{A}/c\right)\right| \quad \text{and} \quad M d^2q/dt^2 = -\partial_q\left(Q'+V\right) \quad \textbf{(2.12)}$$

Where $Q'=-\hbar^2\left(\partial_q{}^2R'\right)/2MR'$ (Equations (2.12) are the same as equations 3,11.18 and 3.11.23 on p 126 of The Quantum Theory of Motion by Holland (1993).) In (2.10), the first term $\partial_t S'=-E$ is total energy of the particle and same as in (2.6) because no energy is exchanged. At t = 0, the particle's momentum changed from $\mathbf{p}$ which is zero before interaction, to $\mathbf{p}-\varepsilon\mathbf{A}/c$ after interaction. Therefore, after interaction, the particle's momentum is $\varepsilon\mathbf{A}(\mathbf{r})/c=\varepsilon\nabla\Phi(\mathbf{r})/c$; kinetic energy is the second term in (2.10) and equal to $\left(\varepsilon\,\nabla\Phi(\mathbf{r})/c\right)^2/2M$. Hence, at t=0, if $\nabla\Phi(\mathbf{r})\neq 0$ at the position $\mathbf{r}$, then from (2.10), we have

$$Q'+V = E - \left(\varepsilon\nabla\Phi(\mathbf{r})/c\right)^2/2M<E \quad \textbf{(2.13)}$$

The second of equations (2.12) may be used now to determine the particle's trajectory classically. It permits the particle to penetrate through the barrier (Holland 1993, p 199). In other words, exocytosis takes place in the bouton originally governed by the equation of motion (2.5). Moreover, if the tachyon mass *m* in is sufficiently small then $\nabla\Phi(\mathbf{r})\neq 0$ in a region covering the whole dendron (Hari 2008). Then the inequality (2.13) is valid for all the boutons in a whole dendron. Hence exocytosis takes place simultaneously in all the boutons which are ready for exocytosis.

After the momentary tachyon interaction is turned off, that is, after the sufficiently small time interval δt, the particle's wave function evolution reverts back to that described by equations (2.5) and particle motion reverts back to that described by equations (2.5) - (2.8) but with a different initial condition: the particle initial momentum is $|\varepsilon\mathbf{A}(\mathbf{r})/c|$ where $\mathbf{r}$ is the particle's position soon after δt. This is the effect of equation (2.9) which introduces a phase factor $-\varepsilon\Phi(\mathbf{r})/c\hbar$ in the wave function of equation (2.5). Once the quasiparticle crosses the barrier, that is, the quantum tunneling is completed the particle motion may even switch to classical motion.

The Field Φ Satisfies All the Criteria of Eccles's and Margenau's Mind Field.

From the analysis in the above section, it is clear that the field Φ does exactly what Eccles proposed that a psychon would do:

- Φ alters quantum transition probabilities as seen from equation (2.11) where the right hand side is not zero after interaction with the field Φ whereas the right of hand side of equation (2.7) is zero and implies conservation of probability.
- Φ increases probability of exocytosis in all boutons of the interacting dendron simultaneously. Φ gives a little push as it were, to all the boutons at the same time leading to simultaneous exocytosis in those which are ready for it. Eccles's rationale (Eccles, 1990) for the hypothesis of mental interaction includes the argument that mental intention must be neurally effective by momentarily increasing the probabilities for exocytosis in a whole dendron and coupling the large number of probability amplitudes to produce coherent action because in the absence of mental activity these probability amplitudes would act independently, causing fluctuating EPSPs (excitatory postsynaptic potentials) in the pyramidal cell.
- The interaction conserves total momentum because Φ is absorbed collectively by the boutons and the momentum of Φ is shared by them. The four-momentum of all interacting boutons together is also conserved because the mass of each bouton is reduced by spilling its contents (neurotransmitters) into a postsynaptic cleft (a body at rest can absorb a zero energy tachyon only if its rest mass decreases during the interaction [Recami, 1986] and this condition is satisfied here).

The Field Φ Contributes to Active Information

Hiley and Pylkkanen (2005) say "Let us assume that the 'mind-field' can be seen as containing active information which contributes to the quantum potential." As already seen in the previous sections, the field Φ does exactly what Hiley and Pylkkanen are hoping for a mind-field to do; it changes the quantum potential of quasiparticles to effectively reduce the height of their barriers and thereby increases the probability of exocytosis. In the footnote accompanying the above quote, Hiley and Pylkkanen say:

> "However, different doctrines in the philosophy of mind might interpret the idea of a "mind-field" in their own way (in case they would accept such an idea). E.g., a property dualist could see it as a mental property; a functionalist would focus on the functional role it plays; an eliminative materialist could see it as a new scientific (physicalist) concept of mind, replacing traditional folk-psychological categories."

From what we have presented about our tachyon field Φ so far, it meets the criteria of all the three doctrines. It performs the function of the mental property volition proposed by Eccles and plays the functional role of changing the quantum potential of a Schrödinger equation; the field Φ should satisfy a materialist as well because a branch of theoretical physics already describes it although experimental verification of the theory is not available so far.

The Field Φ Produces Back-Action in the Continuity Equation

Sarfatti (1996), another associate of Bohm calls any function $F(r(t)) \neq 0$ (not necessarily a solution of the Helmholtz equation) that depends upon the actual position $\mathbf{r}(t)$ of the particle at time t, on the right-hand side of equation (2.7), as back-action. He interprets that such an $F(\mathbf{r}(t))$ implies that the quantum wave field is directly affected by the conditions of the particles and therefore completes a feed-back control loop between the particle and its wave-function. Probability current is not locally conserved and maximal uncontrollable randomness is not possible if this term is present. He thinks that all forms of life must have back-action in the sense that if mind-like quantum potential acts on the material particle to guide it into an eigenstate then the particle should also impact the mind-like quantum wave. He thinks that back-action is a necessary condition for describing any form of living matter using quantum theory.

Clearly, equation (2.11) is the same as equation (2.7) except for the function Φ on its right-hand side. Therefore a living brain which includes Φ satisfies Sarfatti's criterion for a quantum-theoretical description.

3. How Tachyon Field Relates to Quantum Potential

Bohm's quantum potential for a system of particles is an intrinsic property of the system. It depends only on the form of the Schrödinger wave function of the system, but not on the wave's intensity. It acts as it were, as a common pool of "active information", which provides a nonlocal connection and guides them as an "internal" force into organized movement. Bohm (1990) views the quantum potential as a *mind-like* quality of matter which reveals itself strongly at the quantum level, in the movements of the particles. He extends this notion of "mind-like" active information to processes of thought and says (Bohm, 1990);

> "There is a kind of active information that is simultaneously physical and mental in nature. Active information can thus serve as a kind of 'bridge' between these two sides of reality as a whole. These two sides are inseparable, in the sense that information contained in thought, which we feel to be on the 'mental' side, is at the same time a related neurophysiological, chemical, and physical activity (which is clearly what is meant by the 'material' side of this thought)."

Like Bohm. Hiley and Pylkkanen (2005) see the "mind-field" as a fairly subtle level of reality, which has both a physical aspect and a more subtle mental aspect. They assume that the mind-field's physical aspect, though subtle, allows it to influence other physical levels (e.g., the known neural levels) and be influenced by them. They claim that such assumptions imply avoiding dualism or idealism without falling into reductive materialism. They say "mind" acts on "matter" but not in the sense of a mechanical interaction of two separate substances. Rather, mind is to be understood as a new level containing active information, which affects the quantum potential, which in turn affects the physical processes in the brain. Hiley and Pylkkanen state that the dual role (mental and physical) of the mind-field makes a "two-way traffic" between the two levels possible. However, as Sarfatti (1996) points out, Bohm and Hiley themselves write "*the Schrödinger equation for the quantum field does not have sources, nor does it have any other way by which the field could be directly affected by the condition of the particles…*". Hence their proposal includes only the action of mind on matter but not the action of matter on mind. Sarfatti emphasizes that the existence of the "reverse traffic" is a necessary condition for matter to be living matter.

Eccles, on the other hand, proposed explicit dualist-interactionism. For him mind is a nonmaterial field carrying little or no energy, which nevertheless can trigger neural processes. He did not elaborate on the interaction in the reverse direction, that is, how the brain acts upon the mind field though. Our proposal that the mind may include zero-energy tachyon fields is compatible with Eccles's proposal in the sense that tachyons are nonmaterial and can have no energy unlike matter fields, but they can interact with material particles such as neurons. Further, our proposal has the advantage that tachyons are mathematically defined and therefore the proposal makes it possible to develop a mathematical theory of action of the brain's material on the tachyon part of the mind (see section 4).

Our proposal may not be compatible with the Bohm-Hiley proposal that mind consists of superquantum potentials of the brain at various levels in the hierarchy of quantum potentials described by them (e.g., Bohm, 1990); or at least the compatibility is not obvious and requires a mathematical proof. On the other hand, we believe that there is a relationship between the tachyon field and the quantum potential; it is similar to the relationship between an algorithm and its representation stored in a computer (digital or quantum). We will explain this relationship in the next section.

An algorithm in a computer programmer's head is not the same as its representation stored in a computer (digital or quantum)

Nowadays, computers can perform many tasks which in earlier days, were supposed to require a high level of intelligence and education. E.g., today's Artificial Intelligence (AI) programs can simulate several thought processes such as learning and problem solving. This is all possible because the human brain is in some ways, similar to a computer. Indeed, many consciousness researchers have used the computer metaphor in their scientific explanations of consciousness (e.g., Pribram, 2004). Computer users frequently use expressions like "the computer knows", "it does not understand", "it thinks", and so on. In fact, we can precisely define what we mean when we say "the computer knows the object".

Definition 1. *A computer behaves as if it knows an object (a data item or a program instruction), when a representation of that object as bytes of "0"s and "1"s in a digital computer or qubit states in a quantum computer, in other words, as a sequence of states of some hardware units (SSHU), exists in its memory.*

Once such a representation is entered into a computer's memory, it can perform any number of operations with that representation. The computer can compare the object with other objects also known to it similarly. It can add, subtract, compute functions of it, draw a picture of it, and so on. The computer can do almost anything that a person can do with that object and behave as though it "knows" the object without really knowing anything! Our use of the word representation is intended to convey that meaning is assigned to the computer's SSHUs by the programmer. The computer, whether digital or quantum, does not know the meaning of its memory contents. Even when an AI program produces a new intelligent formula, first it produces a new pattern of SSHUs at the hardware level; the new hardware pattern is then input to a machine level program which translates it into a pattern of numbers, the number pattern in its turn is input to a compiler or an interpreter and the output fed into a higher level language program, and so on, until finally after executing a few programs in succession, the formula appears in English language or in some other written-and-spoken language, which the programmer has designed the computer to output. The point to note is that both the input to and output of each computer program in this series are *not identical* with the meaning in the programmer's or user's head; they are merely representations of some meaning that exists only in a human being's head. Actually, each of the programs is an algorithm in the programmer's head and already exists in the computer memory as a representation in terms of SSHUs before the process begins. Thus the entire process of execution of these programs is a material physical process to which meaning is assigned by a human being. In other words, we have just reiterated Pribram's theme that *the medium is not the message* (Pribram, 2004). However *I do not agree* with the other theme of Pribram that *communication is mental* (Pribram, 2000) where he assumes that communication is *necessarily* mental.

We hold the view that *all communication known to us so far is physical and we are struggling to understand mental communication.* The same meaning may be conveyed by different words in different languages. Hence the meaning is different from any of the words which are used to convey the meaning. Meaning exists only in the brain but not in the words nor in the paper on which the words are written. Sometimes language is not even used to communicate information. E.g., a right signal flashing from a car is an indication to others that the car is about to make a right turn. The same piece of information can be conveyed in many ways and the means of *communication* always uses a representation. The representation may be in the form of words, sounds, electrical signals, and so on. A language is a mapping of information into words (symbols) which become sound energy when pronounced, and particles of matter when written on a paper, and become electrical energy when transmitted over a telephone line. Yet information exists only in the brain and is different from the language or signals that are used for its communication just *like water is different from its container without which it cannot be taken from place to place.* We are so accustomed to using material representations to store or *communicate* our thoughts (because we cannot help it), that we do not even recognize the fact that information and its mapping are different. Thus all communication that we use and know in the world outside the brain is physical. Mental communication exists only in the human brain and probably inside other living beings too.

Bohm identified the mind field with superquantum potentials when he said that a quantum potential is mind-like. Bohm (1989) says:

> "I would like to suggest then that the activity, virtual or actual, in the energy and in the soma is the meaning of the information, rather than to say that the information affects an entity called the mind which in turn operates somehow on the matter of the body. So the relationship between active information and its meaning is basically similar to that between form and content, which we know is a distinction without a real difference or separation between the elements distinguished." Again in an interview with Weber (1986) Bohm expressed; "It has been commonly accepted, especially in the West, that the mental and physical are quite different but somehow are related but the theory of their relationship has never been satisfactorily developed. I suggest that they are not actually separated; that the mental and physical are two aspects, like the form and content of something which is only separable in thought, not in reality."

The last sentence shows that Bohm dismissed thought as not part of reality; when he said that both mind and matter are two aspects of one reality. *We differ from Bohm* and believe that the content is just as real as the form that contains it. We believe that the content has an identity of its own and different from all forms containing it although content is generated in the brain by means of forms and *although content cannot be communicated without being separated from the form*. This is particularly because *the same content can be communicated or stored using different forms*.

Again considering the computer analogy, if the computer is broken, we can still run the software on another computer provided we have saved a copy of the software on a storage device such as a compact disc. The point is that information contained in software exists independent of any computer hardware although the software existence and features can be recognized only when it executes on a piece of hardware by receiving some inputs and producing some outputs. It is not that materialists (those who argue that consciousness is a state of matter) think that a computer knows the meaning of its memory contents but they believe that the biological matter in a living brain somehow creates the meaning although any matter outside the brain does not. However, they have yet to explain how biological matter creates meaning.

We propose that the brain is similar to a computer in the sense that it has a physical component and some information; but unlike the computer, the brain carries some "real information" along with a representation of that information stored in its physical memory. We propose that the relation between the tachyon field and the change it produces in the quantum potential of the system with which the tachyon interacts is the relation between an algorithm and its representation stored in a computer (digital or quantum). We agree with Bohm and Hiley (1984) in the sense that quantum potential is software-like[5] because it causes change in the system dynamics. The quantum potential which is software-like, and the holographic memory which is database-like, both provide representations in the hardware-like brain for the "real information" or the "meaning" which consists of zero-energy tachyon fields.

4. The Biological Matter in a Living Brain Creates Meaning Although Any Matter outside the Brain Does Not

In the case of a lifeless computer, we know that AI (artificial intelligence) programs can learn; they can even discover new formulas and theories from the data input to them. When a computer program learns, it actually creates in its memory, some new patterns of hardware units, which were not stored in the computer prior to the program execution. The new information that the program is said to have discovered is obtained only by the programmer's assigning meaning to the

[5] The notion of active information clearly finds an analogue in the field of computer science, for example, in the fact that a program contains not only passive memory but also instructions that actively guide the computer (Bohm and Hiley, 1984).

computer's output consisting of numbers and letters (a certain language) corresponding to the newly created hardware patterns. Meanings of words in any language once again, are in the head of the programmer/user but not in the symbols of the language itself. So, the computer does not create new "real information" but it does create new patterns of hardware units to which the programmer assigns meaning according to the original rules adopted for information storage. An important point to note here is that to *create even such a hardware mapping of new information though not new information itself, a certain piece of software is required to be already present and complete execution in the computer; a machine cannot learn if it has no software or cannot execute software; in AI terms, such a machine cannot exhibit "intelligence".*

As to the living brain, it starts learning from the moment it is born. Even if it does not learn new techniques of how to respond to situations, it constantly interacts with the environment and stores the experience and thereby creates new memory both physical and mental. Like Eccles we think that the physical and mental memory structures are not the same. The physical memory may consist of Pribram's holograms; but we do not think that the "meaning" associated with a holographic structure is identical with it. What brain scientists can observe today are structures in the physical memory. Since the computer analogy suggests that new memory cannot be created from hardware alone without some code already entered in it, probably, the physical body alone cannot create mind when there is no mind already in it (no mind means no life! Interestingly, after failures of experiments to create tachyons in bubble chambers Feinberg conjectured (1970) that tachyons probably cannot be produced from matter although Feinberg never associated mind with tachyons). However, again just like in a computer, it is possible for the body and the mind to interact with each other producing more mind and creating physical memories to represent the newly created mind.

In section 2, we showed that a zero-energy tachyon emitted by a mind field, when absorbed by brain's matter can trigger exocytosis. Let us now consider what the brain's action, rather in general, material particles' action upon the tachyon-field would be without going into the physiology of the brain.

We write a Lagrangian for the free tachyon field governed by equation (2.1) as

$$L_{\text{field}} = \int £ d^3\mathbf{x} = \int d^3\mathbf{x}\left[(\partial_t\Psi/c)^2 + (\nabla\Psi)^2 + m^2\Psi^2\right]/2$$

For the *j*th nonrelativistic particle interacting with the field Ψ, the equation of motion can be derived from the Lagrangian:

$$L_{\text{particle}-j} = \int d^3x\left[M_j\mathbf{v}_j^2 - \varepsilon_j\Psi\right]\delta(\mathbf{x}-\mathbf{x}_j)$$

where M_j is the particle's mass, $\mathbf{v}_j$ is its velocity, and ε_j is a coupling constant. Then the Lagrangian for the system of particles and the field together is

$$L_{\text{field}} + \sum L_{\text{particle}-j} = \int d^3x\left\{\begin{matrix}\left[(\partial_t\Psi/c)^2 + (\nabla\Psi)^2 + m^2\Psi^2\right]/2 \\ +\left[\sum(M_j\mathbf{v}_j^2 - \varepsilon_j\Psi\right]\delta(\mathbf{x}-\mathbf{x}_j(t))\ \right]\end{matrix}\right\}$$

where the sum $\sum$ is over interacting particles at positions $\mathbf{x}_j$ j = 1,2,.... The action for the system of particles and the field together is

$$S = \int(L_{\text{field}} + \sum L_{\text{particle}-j})\, dt$$

The Euler-Lagrange equations derived by minimizing the above action S alter the field equation (2.1) to:

$$\left(\partial_t^2/c^2 - \Delta - m^2\right)\Psi(\mathbf{x},t) = \sum\varepsilon_j\delta(\mathbf{x}-\mathbf{x}_j(t)) \quad \textbf{(4.1)}$$

To find how the momentary interaction with the particles at time t = t_o changes the zero-energy tachyon field, we may minimize *S* subject to the conditions: t = t_o and $\partial_t\Psi$ = 0. Substituting these conditions in (4.1), we find that after the interaction, the ZET field equation (2.3) changes to:

$$\left(\Delta + m^2\right)\Psi(\mathbf{x}) = \sum\varepsilon_j\delta(\mathbf{x}-\mathbf{x}_j(t_o)) \quad \textbf{(4.2)}$$

Now, recall that the effect of the ZET, $\Phi_m(\mathbf{x}) = \Phi(\mathbf{x})$ which satisfies equation (2.3), on the Schrödinger equation of quantum particles was introduced via the four-potential $\{\partial^\nu\varphi_m(\mathbf{x},t)\}$, where $\varphi_m(\mathbf{x},t) = e^{imct}\Phi_m(\mathbf{x})$. To find the effect vice versa of the particles on $\varphi_m(\mathbf{x},t)$, we may apply similar analysis to the massless scalar wave equation:

$$\partial_\nu \partial^\nu \varphi(\mathbf{x}, t) = 0 \quad \mathbf{(4.3)}$$

for which $\varphi_m(\mathbf{x},t)$ is a solution. In this case, we find that the field φ continues to satisfy equation (4.3) even after interaction. Since $\Phi_m(\mathbf{x})$ does change after interaction as seen from equation (4.2), it follows that after interaction, the field $\varphi_m(\mathbf{x},t)$ with a definite value for m changes to a general linear superposition:

$$\phi(\mathbf{x}, t) = \sum_k e^{im_k ct} \Phi_{m_k}(\mathbf{x}) dm_k \quad \mathbf{(4.4)}$$

If one defines the mass operator as $-(i/c)\partial_t$ then the wavefunction $\varphi_m(\mathbf{x},t)$ is the eigenfunction of this operator with the eigenvalue m, the mass of the ZET (strictly speaking $m_0 = m\hbar / c$ is the ZET proper mass). For different values of m these eigenfunctions represent free non-interacting ZETs with definite masses. A linear superposition such as (4.4) is associated with a tachyon with non-definite mass. Fourier analysis of (4.4) leads to the uncertainty relation between the spread of ZET mass and spread of time given below:

$$(\Delta mc)(\Delta t) \geq 1 \quad \mathbf{(4.5)}$$

In a momentary interaction the inequality (4.5) implies that the spread $\Delta m >> m$ and suggests creation of new ZETs.

Clearly, a superposition of green's functions: $\sum \varepsilon_j G(\mathbf{x} - \mathbf{x}_j(t_o))$ is a solution of equation (4.2) when $G(\mathbf{x} - \mathbf{x}_j(t_o))$ is a green's function of the Helmholtz equation and satisfies;

$$(\Delta + m^2)\Psi(\mathbf{x}) = \varepsilon_j \delta(\mathbf{x} - \mathbf{x}_j(t_o))$$

along with specified boundary conditions. Expressing $G(\mathbf{x} - \mathbf{x}_j(t_o))$ for each j, as a superposition of functions $\Phi_{m_k}(\mathbf{x})$ associated with eigenvalues m_k, a solution of equation would look like

$$\Phi'(\mathbf{x}) = \sum_j \varepsilon_j \sum_{m_k} \Phi_{m_k}(\mathbf{x}) \Phi_{m_k}(\mathbf{x}_j) / (m^2 - m_k^2)$$

where $\mathbf{x}_j = \mathbf{x}_j(t_o)$. The field $\Phi'(\mathbf{x})$ is thus a superposition of ZETs of masses m_k which are in general, different from m, the mass of the interacting field $\Phi_m(\mathbf{x})$. Thus, because of interaction with material particles new zero-energy tachyons may have been created.

5. Libet's Delay-and-Antedating Paradox

Considering the explanation of a computer's knowing an object stated in Definition 1 in section 3, a similar definition applies to a human brain with the following difference**:**

Definition 2. *A brain knows an object if and only if a representation of that object together with the "real information" in the form of ZETs regarding the object already exists in its memory. Hence we anticipate that awareness of an object (which may be an experience) occurs when and only when a physical record of that object and its associated mental record consisting of ZETs, are created in the brain.*

We will see that this definition of occurrence of consciousness in the brain (as involving both a neural record and mental record consisting of ZETs), is consistent with the quantum-physical explanation of Libet's delay-and-antedating hypothesis, by Wolf (1998) and adds further clarity to his explanation.

Libet's work on stimulus and sensation and the theory of "human mind antedating stimulus sensation" have been subject to much debate. Libet (1979) proposed the well-known hypothesis that a subject's experience of any peripheral sensation appears to be referred backwards in time approximately to the instant of stimulation although the neural processes associated with the sensation take some finite period of time to attain "neuronal adequacy" which is required for awareness of the sensation. Because no neural process was found (actually not found as yet) that would account for such backwards in time subjective referrals, Libet concluded that subjective referrals and corrections take place at the mental level but not in the activities at neural levels. Dualist John Eccles interpreted Libet's work as implying that a non-physical mind is the one responsible for the backward step in time.

In support of Libet's hypothesis, Wolf (1998) offered a quantum-physical explanation based on the so called two-time observable (TTO) quantum theory (Aharonov, 1990) and the transactional interpretation (TI) (Cramer, 1983) of quantum mechanics. He proposed a model based on TTO and TI wherein *two* neural events lead to backwards-through-time wave function collapse in the intervening space-time interval. Wolf (1998) states:

> "A conscious experience occurs if and only if two events occur. If one assumes that consciousness arises with a single event, paradoxes like the ones indicated by Libet's experiments occur. Neuronal adequacy and subjective experience are not one and the same events. Neither are peripheral stimulation and subjective experience one and the same even though they seem to be. The truth actually lies somewhere in-between. Both the stimulation and neuronal adequacy (two events) are needed for the apparent conscious (one event) experience…"

The last observation is not at all surprising when one considers the computer-like behavior of the brain. A peripheral stimulation is an input to the brain (a neural computer) and the corresponding neuronal adequacy state is the one that contains a neural record of the input. The computer cannot know an input (in the sense described in section 3) unless it receives the input to begin with, and then creates a record of the input in its memory. But something else also happens in the brain besides what happens in a lifeless mechanical computer. In addition to receiving the input and creating a physical (neural) record, the brain creates a mental record which we call conscious experience and which does not seem to exist in any lifeless computer, at least not yet. Wolf (1998) states "*quantum mechanical descriptions are relevant to neural behavior*. Consequently the brain and nervous system can be treated as a quantum system. This shows that mental events do correspond with neural events through the action of the collapse of the probability field of the quantum wavefunction." *But does collapse of the wavefunction of a quantum system necessarily imply that some mental event occurs in the system along with the collapse?* Of course not. There are no mental events in many lifeless quantum systems that we currently know, e.g., no consciousness occurs in the Wheeler's delayed choice machine, which is the model for Wolf's analysis. Hence this concept of "correspondence" in the case of the brain as a quantum system is still an assumption but not an already proven scientific fact.

Wolf (1998) talks about two situations involving this correspondence between mental and neural events. One is exocytosis regarding which Eccles (Beck and Eccles, 1992) postulated that a mental event, namely volition, causes the collapse of the wavefunctions of vesicles; Wolf seems to agree. The other is awareness of the peripheral sensation. In this case, Wolf assumes that awareness occurs along with the collapse of brain's quantum wavefunction. As regards exocytosis, we showed in section 2 (Hari, 2008) that a zero-energy tachyon can precisely play the role of volition. In the case of awareness of the peripheral sensation, we will see below that besides a neural record whose creation is reflected by neuronal adequacy, a mental record consisting of ZETs and associated with the new neural record is also created in the brain thus satisfying Definition 2.

Wolf's model explains temporal anomalies in Libet's experiments dealing with sensory experiences generated by real sensory stimuli as well as imagined sensory experiences generated by cortical stimuli. New predictions of Wolf about the timings of occurrence of the experience have some experimental evidence. In each of the scenarios which he discussed, the TTOTI model determines the time interval in which the quantum wavefunction collapses. TTOTI does not say that consciousness occurs along with the collapse. That is Wolf's assumption. However, in each scenario, the time of occurrence of the experience in the Libet's experiment does fall within the time interval of the wavefunction collapse predicted by the TTOTI model thus justifying Wolf's hypothesis.

In our ZET model, the brain is a system consisting of some neurons and ZETs. In previous sections, we have obtained the equations governing the action of a ZET on neurons as well as the action of neurons on a ZET. The former action is described by the Schrödinger equation:

$$i\hbar\partial_t\Psi=\Sigma_j\left\{\begin{matrix}(1/2M_j)\left[(\hbar/i)\,\partial_j-\varepsilon_j\boldsymbol{A}(x_j,t)/c\right]^2\\+\varepsilon_j U(\mathbf{x}_j,t)+V(\mathbf{x}_j)\end{matrix}\right\}\Psi \quad \mathbf{(5.1)}$$

where the suffix j describes quantities belonging to the jth particle and the electromagnetic potentials U, $\mathcal{A}$ are given by equation (2.4). Conversely, the action of neurons on the ZET is described by equation (4.4) and governed by the inequality:

$$(\Delta mc)(\Delta t) \geq 1$$

If the wavefunction collapse is assumed to be instantaneous as in the Copenhagen interpretation, the above inequality implies that $\Delta m >> m$ and hence creation of new ZETs. In Bohm's interpretation, there is no collapse but an effective collapse is arrived at by the system in a continuous manner. The above Heisenberg inequality holds for arbitrarily small intervals around the time of the effective collapse. On the other hand, the TI used by Wolf determines the timing of collapse up to an interval. In this case, the inequality $\Delta m >> m$ holds if the energy m_0c^2 of the tachyon, which is its energy in the frame of reference fixed in it, is sufficiently small. If so, the effect of collapse of the wavefunction Ψ in (5.1) is to create new ZETs. Since in TI, the collapse depends upon the information pertaining to the initial and final states before and after the collapse, and the information pertaining to the stimulus that caused the collapse, the ZETs created by the collapse also depend upon all that information. Thus experience of the peripheral sensation occurs because the relevant ZETs are created.

Recalling the role of a ZET in exocytosis, where the proper mass of the ZET is required to be sufficiently small (Hari, 2008) for the ZET to have a non-zero gradient across the whole dendron, it appears that tachyons (and therefore mind) need only very small energies to work with the brain.

In the laboratory frame of reference, awareness of the sensory stimulus is reported to the experimenter even before the required neuronal adequacy is observed and that is the paradox. Wolf's resolution is that in this frame, the brain's wavefunction collapse indeed occurs earlier than neuronal adequacy. What we showed above is that ZETs which carry the collapse information are also created when the collapse occurs. Now, in the frame of reference of any created ZET, the birth of the ZETs and attainment of neuronal adequacy are simultaneous events and definition 2 is satisfied in this frame. So, the ZETs, which are the mental contents of the person experiencing the sensation, report the time of experience as the time of the birth of the ZETs. So, the ZET hypothesis agrees with both the Wolf hypothesis concerning the timing of conscious experience and Snyder's hypothesis (Snyder, 1987) concerning the difference in temporality of the experiential and neurophysiological reference frames; the ZET hypothesis does not see a conflict between the Wolf and Snyder hypotheses.

6. Why Tachyons and Further Work

The proposal that memory and thought in the brain involve tachyons is based mainly on some observed fundamental differences in the behaviors of living beings and lifeless systems (Hari, 2002). These behavioral differences include the following:

The first observation is well-known and discussed by Searle (1980) and may be briefly stated as "*Information in a living brain is different from any of its representations used for its storage or communication*". Whenever we refer to "information" in physical sciences, it consist some form of matter or material energy and is merely a representation of some "real information" stored in a living brain. The meaning exists only in the brain and not in any representation of it outside the brain. It is possible that the meaning which is known to be carried nonlocally by systems of neurons may consist of tachyons which have imaginary masses and nonlocal and thus different from the ordinary matter and energy obtained from matter.

Another observation is that our actions almost always have a desire, urge, purpose, motive, etc. as their basis. We act in the present not only because what we are at present or what we were in the past but also because what or where we want to be in the future. So, our reasoning is inductive as well as deductive. The causality associated with inductive reasoning is called circular causality. If desires, motives, etc consist of tachyons, then it would be possible for an action in the present to have a future state as a cause. Among the several papers written on causality of or its violation by tachyons, the paper "*Causality and Tachyons in Relativity*" written by Caldirola and Recami (1980) is particularly interesting in the present context. In the section with title '*Can a Tachyonic Observer Inform Us about Our Future?*' of this paper, the authors conclude that a tachyonic observer can convey to an ordinary observer the effects on a future event E of the anti-signals (negative energy signals) sent by himself to E so as to physically influence E. To me, this seems to be how we think when we try to achieve a goal whatever it may be; we first think about the effects on the future event of present actions and then act. To me, the tachyonic observer seems to be our mind.

Clearly, the scope of further work is vast. A theory of tachyon interaction with matter needs to be developed in the context of the neuron environment of the brain. One possible method of experimental detection of tachyons in a brain would be to verify the existence of a dispersion relation of the form $\omega^2/c^2 = k^2 - m^2$ for electromagnetic fields of the brain. Since at present, EEG is the primary means by which electromagnetic activities in the brain are measured and their features inferred, the well known alpha, beta, theta and delta rhythms offer suitable area of investigation. An explanation of the occurrence of readiness potential before the occurrence of awareness of volition, using the tachyon theory would also be a worthwhile attempt in the study of consciousness.

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