Eccles's Psychons Could be Zero-Energy Tachyons

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Abstract

This paper suggests that mental units called psychons by Eccles could be tachyons defined theoretically by physicists sometime ago. 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 theories may be applicable to brain physics. Eccles proposed an association between psychons and what he called dendrons which are dendrite bundles and basic anatomical units of the neocortex for reception. We show that a zero-energy tachyon could 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. This is consistent with the view of tachyons, which treats them as strictly non-local phenomenon produced and absorbed instantaneously and non-locally by detectors acting in a coherent and cooperative way.

Key Words: exocytosis, quantum tunneling, tachyon, quantum potential, Bohmian Mechanics

1. Introduction

Unlike many other prominent neuroscientists, Sir John Eccles (1903-1997) rejected the notion of mind brain identity and developed a theory of the mind, known as dualist-interactionism. In his book, *How the Self Controls Its Brain* (1994), shows that mind-brain action can be explained without violating the conservation of energy if account is taken of quantum physics and the available knowledge concerning the microstructure of the neocortex. 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. According to Eccles, in willed actions and thought, psychons act on dendrons and momentarily increase the probability of the firing of selected neurons. Based on physicist Friedrich Beck's (Beck, 2008; Beck and Eccles, 1992; Beck, 1996) quantum mechanical analysis of bouton exocytosis, he proposes the hypothesis that mental intention (the volition) becomes neurally effective by momentarily increasing the probability of exocytosis in selected cortical areas.

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A nerve impulse propagating into a presynaptic terminal triggers a process called exocytosis that causes opening of a channel and releasing transmitter molecules into the synaptic cleft. Exocytosis is the basic activity that initiates information flow between neurons in chemical synapses. It is triggered with some small probability by an arriving nerve impulse. The detailed model proposed by Beck and Eccles (1992) is based on the quantum concept of quasiparticles, reflecting the particle aspect of a collective mode. Their proposed model refers to tunneling processes of two-state quasiparticles, resulting in state collapses. It yields a probability of exocytosis in agreement with empirical observations. The quantum treatment of exocytosis links the neocortical activity with the existence of a large number of quantum probability amplitudes (Stapp, 2007), since there are more than 100,000 boutons in a bundle of dendrites called a dendron.   Eccles's rationale 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 in the pyramidal cell.

In this paper, we suggest that the so called psychons could be tachyons defined by physicists sometime ago (Bilaniuk et al., 1962; Feinberg, 1967; Recami, 1974). Theoretically, the existence of tachyons is not contrary to the principle of Relativity. Although experiments to detect faster-than-light particles have not been successful so far, recently, there has been renewed and keen interest in tachyon theories (Recami, 1998; 2001; 2004; 2008; Recami et al., 1986; Giannetto et al., 1986) across a spectrum of research areas as diverse as particle physics to astrophysics and string theory. In this paper, we suggest that tachyon theories may be applicable to brain physics as well. We show how a zero-energy tachyon could act as a trigger for exocytosis in a whole dendron by momentarily decreasing the effective

potential (external potential plus the quantum potential also called the Bohmian potential) of a multitude of quasiparticles and thereby enhancing the tunneling process across the whole dendron.

In this paper, we consider a tachyon as a non-local object (but not a material particle), which can be associated with an imaginary mass value and with waves which are non-local in space but localized in time. The author has held the view since a long time (Hari, 2002; Vishnubhatla, 1985; 1986) that thought processes in a brain involve tachyons (faster than light objects) defined by physicists sometime ago. Some intuitive rationale for this hypothesis may be found in the stated references. Here, we adopt the point of view that treats tachyons as strictly non-local phenomena produced and absorbed by detectors in a coherent and cooperative way.   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* (Shay and Miller, 1977).

2. Beck-Eccles Quantum Mechanical Model of Exocytosis

In the Beck-Eccles (1992; Beck, 2008) quantum mechanical model of exocytosis, they adopt the following concept: preparation for exocytosis means bringing the presynaptic vesicular grid into a metastable state from which exocytosis can occur. The process of exocytosis is then modeled by the motion of a quasiparticle with one degree of freedom along a collective coordinate q, and over an activation barrier. The motion is characterized by a potential energy V(q), which may take on a positive value before exocytosis according to the metastable situation, then rises toward a maximum and acts as the barrier, which the quasiparticle has to tunnel through, and finally drops to zero. This quantum mechanical tunneling process consists of two states: one in which the particle has not crossed the barrier and exocytosis does not take place, and the other state in which the particle crosses the barrier and exocytosis

takes place. Eccles hypothesizes that mental intention is responsible for the action of selecting the state, where exocytosis occurs, by momentarily increasing the probability of exocytosis. The time-dependent process of exocytosis is described by Beck and Eccles (1992: p3) by a one-dimensional Schrödinger equation for the wave function $\Psi(q,t)$,

$$i\hbar\partial_t\Psi(q,t) = -\left(\frac{\hbar^2}{2M}\right)\partial_q^2\Psi(q,t)$$
$$+V(q)\Psi(q,t)$$

(2.1)

where ∂ denotes differentiation with respect to its suffix, M is the mass of the particle and $\hbar$ is the Plank's constant. In the following sections, we show that a zero-energy tachyon can trigger the crossing of the potential barrier (in other words, collapse of the quasiparticle wave-function to the state, where exocytosis occurs) by momentarily transferring momentum to the quasiparticle (somewhat like giving it a push!) without any exchange of energy. Thereby, the particle's effective potential, that is, the external potential plus the quantum potential is decreased to a value below the particle's total energy and allows the particle to tunnel through the barrier. Being a field, the tachyon pushes all the boutons in the dendron at the same time!
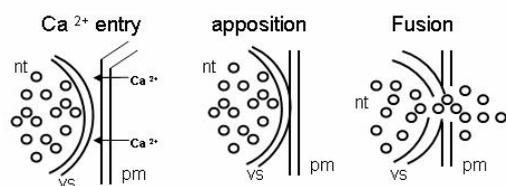

Figure 1. The stages of exocytosis (*from* Beck, 2008). Nt = neurotransmitter molecules, vs = vescicle, pm = presynnaptic membrane. Influx of Ca^{2+} after depolarization by a nerve impulse opens the calcium gated channel.

The decisive process for the release of transmitter molecules is the opening of an ion channel in the presynaptic membrane. The biophysical mechanism for this is presumably a conformation change in the electronic structure of the membrane. The dynamics of this electronic process of

conformational change is described by Beck by means of a quasiparticle with a single degree of freedom, which represents the collective degrees of freedom along this motion.

3. Zero-Energy Tachyon's Electromagnetic Field

The Klein-Gordon equation for a free tachyon having negative squared-mass $-\mu^2$ (where μ is a positive real number) is written as

$$(\frac{\partial_t^2}{c^2} - \Delta - m^2)\psi(\mathbf{x},t) = 0$$

(3.1)

where $\mathbf{x}$ is the vector (x, y, z), $\Delta = \partial_x^2 + \partial_y^2 + \partial_z^2$ and again, ∂ denotes differentiation with respect to its suffix, c is the speed of light in free space, and $m = \mu c/\hbar$. Separating the time dependence of ψ by writing $\psi(\mathbf{x},t) = \psi(\mathbf{x})\psi'(t)$, we get solutions $e^{i\omega t}\psi(\mathbf{x})$ of equation (3.1), where $\psi(\mathbf{x})$ satisfies

$$[-\Delta - k^2]\psi(\mathbf{x}) = 0 \text{ and } \omega^2/c^2 = k^2 - m^2.$$ (3.2)

The frequency ω is real only for $k \geq m$; plane wave solutions $e^{i(\omega t - \mathbf{k}.\mathbf{x})}$ where $k=|\mathbf{k}|$ and ω is real, are not a complete set in space because of this condition and a superposition of them cannot be localized in space (Feinberg, 1967). The phase velocity of such a wave $e^{i(\omega t - \mathbf{k}.\mathbf{x})}$ is < c and group velocity of the associated wave packet is > c. On the other hand, a superposition of solutions $e^{i(\omega t - \mathbf{k}.\mathbf{x})}$ of (3.1) with real ω can be localized in time. It happens that superposition of solutions of (3.1) corresponding to nonphysical energies (imaginary ω) and moments may be localized and propagate subluminally but we do not refer to such waves as tachyons in this paper. A tachyon's interaction with matter is non-local (Feinberg, 1967; Dhar et al., 1968; Sudarshan, 1970; Shay and Miller, 1978). A tachyon wave is a strictly non-local phenomenon in a dispersive medium produced and absorbed instantaneously and non-locally by detectors

acting in a coherent and cooperative way (Shay and Miller, 1977).

In the frame of reference in which the energy of a tachyon vanishes (and where the quasiparticle's motion is described by the Schrödinger equation (2.1)), the tachyon's momentum is equal to mc and instead of being at rest, the tachyon moves with infinite speed.[2] The interaction of such a tachyon with ordinary matter would be to transfer no energy but all its momentum instantaneously in a manner analogous to a rigid body's transferring impulses instantaneously in a collision without exchanging energy (Sudarshan, 1970). In the following sections, we will show that a zero-energy tachyon's interaction with a dendron would result in transferring momentum to various boutons in a dendron and thereby decrease the effective barrier potential and increase the probability of exocytosis in all its boutons.

A zero-energy solution of (3.1) corresponds to frequency $\omega = 0$ and $K^2 = m^2$, and satisfies the Helmholtz equation:

$$\Delta\Phi(\mathbf{x}) = -m^2\Phi(\mathbf{x}). \qquad (3.3)$$

Equation (3.3) 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 (3.3) with a particle whose motion is governed by a Schrödinger equation, we associate an electromagnetic field with a solution of (3.3) as follows. Consider the field $\varphi(\mathbf{x},t) = e^{imct}\Phi(\mathbf{x})$, and the four-vector

$$\tilde{A} = \left(-\nabla\varphi(\mathbf{x},t), \partial_\tau\varphi(\mathbf{x},t)\right)$$

where τ = ct. Writing $\bar{\mathbf{A}} = -\nabla\varphi$ and $U = \partial_\tau\varphi = im\varphi$, we find that equation (3.3) implies that $\bar{\mathbf{A}}$ and U satisfy the following Poisson equations of the vector and scalar potentials of an electromagnetic field whose

current density and charge density are both zero.

$$(\Delta - \partial_t^2/c^2)\bar{\mathbf{A}}(\mathbf{x},t) = 0, \ (\Delta - \partial_t^2/c^2)U(\mathbf{x},t) = 0$$

Moreover, $\bar{\mathbf{A}}$ and U satisfy the Lorentz gauge condition: $\nabla\cdot\bar{\mathbf{A}} + (1/c)\partial_t U = 0$. Hence $\bar{\mathbf{A}}$ and $U = im\varphi$ can be the vector and scalar potentials of an electromagnetic field. Note that the potentials $\bar{\mathbf{A}}$ and U give rise to zero fields **E** and **B** because

$$\mathbf{E} = -\nabla U - (1/c)\partial_t\bar{\mathbf{A}} = 0 \text{ and } \mathbf{B} = \text{curl}\bar{\mathbf{A}} = 0.$$

Nonetheless, we will use U and $\bar{\mathbf{A}}$ to describe the interaction of a solution of equation (3.3) with a particle of matter since these potentials may produce observable effects other than and independent of the electric and magnetic fields also produced by them (Aharonov, Bohm, 1959), in the present case the electric and magnetic fields are in fact, zero. Like Beck & Eccles (1992), we assume that the interaction of the tachyon (psychon) with the dendron is momentary and take t=0 as the time of interaction. We find that at $t = 0$ the scalar potential $im\Phi(\mathbf{x})$ is purely imaginary whereas the vector potential $-\nabla\Phi(\mathbf{x})$ is real and therefore, a zero-energy tachyon would only transfer momentum to a charged particle but no energy. This is consistent with the well known roles of scalar and vector potentials: the scalar potential is a store of field energy, and the vector potential is a momentum potential (a store of field momentum available to charge motion) (Konopinski, 1978).

4. Tachyon-Dendron Interaction

In the Beck-Eccles (1992; Beck, 2008) model, the various boutons in a dendron, have probabilities of exocytosis that are independent of one another. Hence, the wave-function of all boutons together, is the product of their individual wave-functions, and the Hamiltonian of the total system is the sum of the individual Hamiltonians; in other words, each bouton has its motion described by an equation of the form (2.1) with no term of interaction with any other bouton. Therefore, to describe the effect of the electromagnetic potentials described above

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[2] Even in special relativity extended to superluminal motions, only the speed c of light in the vacuum is invariant, while the infinite speed is not invariant and it changes when changing observer.

on each bouton, we will introduce the necessary electromagnetic interaction terms into the equation (2.1) and the discussion that follows will be applicable to any bouton in the dendron.

In terms of scalar and vector potentials V and $\mathbf{a}$, the following is the Schrodinger equation in three dimensions of a particle with charge e and mass M interacting with the EM field defined by V and $\mathbf{a}$:

$$i\hbar\partial_t\Psi = (1/2M)\left[(\hbar/i)\nabla - (e/c)\mathbf{a}(\mathbf{x},t)\right]^2\Psi + \{eV+V\}\Psi$$

In the present case of a bouton, the quasiparticle's motion depends on a single degree of freedom q given in equation (2.1). The coordinate q is a collective coordinate and may not necessarily be identical with one of its Cartesian coordinates x, y, z. Still, its position vector $\mathbf{r} = \mathbf{r}(q,t) = \mathbf{r}(q)$ is a function of q; we assume that $\mathbf{r}$ does not depend explicitly on time because the external potential V of the bouton in equation (2.1) depends on q alone. Hence, the terms

$$\mathbf{a} = -e^{imct}\nabla\Phi(\mathbf{r}) \text{ and } V = e^{imct}im\Phi(\mathbf{r})$$

that enter into (2.1) have their explicit time dependence only in the factor e^{imct} because $\Phi(\mathbf{r})$ and $\nabla\Phi(\mathbf{r})$ do not depend explicitly on time. Thus, after the electromagnetic interaction with the tachyon field, the equation (2.1) of the jth bouton in the dendron changes to the equation (4.1) below, where q_j is its degree of freedom:

$$i\hbar\partial_t\Psi_j(q_j,t) = (1/2M_j)[\hat{\mathbf{l}}_j(\hbar/i)\partial_{qj} - e_j\mathbf{A}(\mathbf{r}_j)/c]^2\Psi_j(q_j,t) + [ie_jme^{imct}\Phi(\mathbf{r}_j) + V(q_j)]\Psi_j(q_j,t), j = 1, 2, \ldots, N. \quad (4.1)$$

In the above equation, e_j is the quasiparticle's charge, M_j its mass, $\hat{\mathbf{l}}_j$ is the unit vector along its velocity $\mathbf{v}_j$, $V(q_j)$ is the value of an external potential of the dendron for q = q_j, $\mathbf{A}(\mathbf{r}_j) = -\nabla\Phi(\mathbf{r})$ at $\mathbf{r} = \mathbf{r}_j$ and N is the number of boutons that are candidates for exocytosis.

We note that on the right side of (4.1), $\hat{\mathbf{l}}_j(\hbar/i)\partial_{qj}$ corresponds to the particle's canonical momentum and $M_j\mathbf{v}_j - (e_j/c)e^{imct}\mathbf{A}(\mathbf{r}_j)$ is its kinetic momentum. Hereafter, to simplify notation, we will drop the suffix j while describing the motion of a single bouton and write (4.1) as

$$i\hbar\partial_t\Psi'(q,t) = (1/2M)[\hat{\mathbf{l}}(\hbar/i)\partial_q - ee^{imct}\mathbf{A}(\mathbf{r})/c]^2\Psi'(q,t) + [ieme^{imct}\Phi(\mathbf{r}) + V(q)]\Psi'(q,t) \quad (4.2)$$

To describe the tunneling process in the language of Bohmian mechanics (Bohm, 1959; Holland, 1996), we will write the wave-function $\Psi(q,t)$ in equation (2.1) as

$$\Psi(q,t) = R(q,t)e^{iS(q,t)/\hbar}$$

where R and S are real valued functions. Equating the real and imaginary parts on both sides of (2.1), we obtain the following two equations:

$$\partial_t S + (\partial_q S)^2/2M + Q + V(q) = 0 \quad (4.3)$$
$$\partial_t R^2 + \partial_q(R^2\partial_q S)/M = 0, \quad (4.4)$$

where $Q = -\hbar^2(\partial_q^2 R)/2MR$ is called the quantum potential. Equation (4.3) is similar to the Hamilton-Jacobi equation of classical mechanics; therefore, $-\partial_t S = E$, the total energy of the particle, and $\partial_q S =$ the particle's momentum. (4.4) is the equation of continuity relating the probability density R^2 that the particle is at the position q at time t, to the probability current $R^2(\partial_q S)/M$. Once (2.1) is solved for the wave-function $\Psi(q,t)$, the particle's trajectories can be computed classically from

$$Mdq/dt = \partial_q S \quad (4.5)$$

or

$$Md^2q/dt^2 = -\partial_q(Q+V) \quad (4.6)$$

by prescribing initial conditions. In (4.6) we wrote V(q) as V for brevity and will do so hereafter. At the first classical turning point where the tunneling process begins, E=V and

Q=0; hence from equation (4.3), the particle's kinetic energy $\left(\partial_q S\right)^2 / 2M = 0$ at this point. When the potential V increases and becomes >E, motion is classically forbidden. As long as the particle remains in the state of no exocytosis, in other words, 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. Note that Q+V cannot be >E because $\left(\partial_q S\right)^2$ cannot be negative. On the other hand, Q+V can be <E although V>E; if so, equation (4.6) gives trajectories penetrating the barrier and equation (4.3) gives a nonzero kinetic energy $\left(\partial_q S\right)^2 / 2M$. Therefore, V>E and Q+V<E together correspond to the state where exocytosis has taken place.
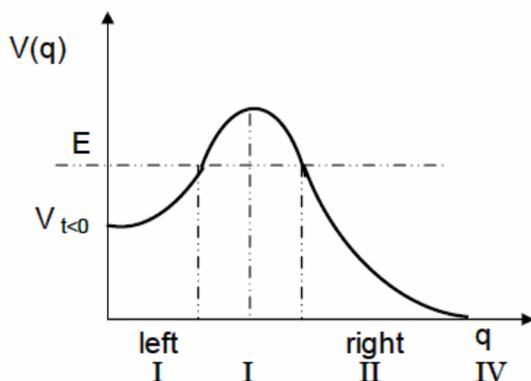

Figure 2. Quantum tunneling of the quasiparticle.

Figure 2 above is the same as Figure 4 from (Beck and Eccles, 1992) except that the time of interaction is taken as t=0 in our discussion. The dashed curve sketches tunneling state through the barrier. At the beginning (t <0), the wave packet is in the left area. After time t the amplitude has a part left of the barrier and a part right of the barrier. $\partial_q S = 0$ within the barrier. If the tachyon interaction takes place when the particle is at or within the barrier V > E, its effect on equations (4.3) , (4.4), (4.5) and (4.6) can be obtained by substituting

$$\Psi'(q,t) = R'(q,t)e^{iS'/\hbar}$$

in (4.2), and equating real and imaginary parts on both sides of equation and noting that $\partial_q \hat{I} = 0$. Thus it is seen that at the interaction time t=0, equations (4.3) and (4.4) change respectively to (4.7) and (4.8) below.

$$\partial_t S' + \left(\partial_q S' - e\mathbf{A}/c\right)^2 / 2M + Q' + V = 0 \qquad (4.7)$$

$$\partial_t R'^2 + \partial_q[R'^2 \partial_q(S - e\mathbf{A}.\hat{I}/c)]/M = em\Phi R' \quad (4.8)$$

where $\quad Q' = -\hbar^2 \left(\partial_q^2 R'\right)/2MR'$. At t=0, equations (4.5) and (4.6) change respectively to

$$Mdq/dt = \partial_q S' \qquad (4.9)$$

and

$$Md^2 q/dt^2 = -\partial_q(Q' + V) \qquad (4.10)$$

In (4.7), the first term $\partial_t S' = -E$ is total energy of the particle and same as in (4.3) because the interaction does not involve exchange of energy. The second term in (4.7) $\left(\partial_q S' - e\mathbf{A}/c\right)^2 / 2M$ is the particle's kinetic energy. At t=0, $\partial_q S' = \partial_q S = 0$. Hence, using $\mathbf{A}(\mathbf{r}) = -\nabla\Phi(\mathbf{r})$ we find that at t=0, the kinetic energy is $((e/c)\nabla\Phi(\mathbf{r}))^2 / 2M$ and momentum is $|e\nabla\Phi(\mathbf{r})/c|$ which is acquired by the particle as a result of the interaction. Therefore, if $\nabla\Phi(\mathbf{r}) \neq 0$ at the position $\mathbf{r}$, then from (4.7), we have

$$Q' + V = E - ((e/c)\nabla\Phi(\mathbf{r}))^2 / 2M < E.$$

Equation (4.10) may be used now to determine the particle's trajectory classically and permits trajectories to penetrate through the barrier. Thus, except at those points where $\nabla\Phi$ vanishes, the quantum potential acts to lower the barrier momentarily to permit trajectories to pass through the barrier. Indeed, it turns out that for sufficiently small m, the whole dendron will be within a region where $\nabla\Phi$ does not vanish. This can be seen as follows. Assuming that $\nabla\Phi$ does not vanish at the origin (if not we can change the origin to a point where grad Φ does not vanish by a translation of the origin of co-ordinates), consider the coordinates $\mathbf{x}'=m\mathbf{x}$. Equation (3.3) when expressed in terms of $\mathbf{x}'$ becomes

$$\Delta'\Phi'(\mathbf{x}') = -\Phi'(\mathbf{x}').$$

Since $\nabla\Phi(\mathbf{x}) = m\nabla'\Phi'(\mathbf{x}')$, $\nabla'\Phi'(\mathbf{x}')$ does not vanish at $\mathbf{x}'=0$. Hence there is an r such that $\nabla'\Phi'(\mathbf{x}') \neq 0$ in the region $|\mathbf{x}'|<r$. This implies that $\nabla\Phi(\mathbf{x}) \neq 0$ when $|m\mathbf{x}| < r$; hence r/m would include the entire dendron if m is sufficiently small.

The solution $\Phi(\mathbf{x})$ may be assumed to have been normalized to satisfy the condition that the total momentum acquired by all the boutons in the interacting dendron equals mc, the momentum of the tachyon because the solution $\Phi_N(\mathbf{x})$ is given by

$$\Phi_N(\mathbf{x}) = m\Phi(\mathbf{x}) / (\sum_{j=1}^{N} |\nabla\Phi(\mathbf{r}_j)|)$$

does satisfy the condition:

$$\sum_{j=1}^{N} |\nabla\Phi_N(\mathbf{r}_j)| = m.$$

5. How Is This Theory Verified Experimentally?

So far, in the above sections, we have been describing only the theoretical possibility of a tachyon's interaction with a dendron resulting in exocytosis at its multiple boutons to produce a strong enough EPSP (*excitatory postsynaptic potential*) by a pyramidal cell. Clearly, unless there is a way to verify the theory by making measurements on the brain, the theory will be no more than a speculation or hypothesis. Leaving a detailed analysis of such verification to a future paper, here, we suggest a possible approach to such verification.

After the momentary tachyon interaction is turned off, the particle's motion reverts back to that described by equations and (4.3) and (4.4) but with a different initial condition: at time t+δt the particle's momentum is $|\partial_q S| = |e\mathbf{A}/c|$ where $\mathbf{A} = \mathbf{A}(\mathbf{r})$, $\mathbf{r}$ being the particle position at time t+δt. Therefore, after time t+δt, the equation (4.6) becomes

$$Md^2q/dt^2 = -\partial_q(Q + V - (\partial_q S)^2) \leq 0. \qquad (5.1)$$

Assuming that the interaction provides kinetic energy which is very small relative to E, and therefore neglecting $(\partial_q S)^2$ on the right hand side of (5.1), we obtain a constant momentum $|e\mathbf{A}/c|$ for the particle for its journey through the barrier. Equating this to the momentum obtained by the WKB solution of Schrodinger equation in the barrier region, we have

$$|e\mathbf{A}|/c = \sqrt{(2M(V-E))}. \qquad (5.2)$$

Taking the effective barrier height V−E in the range 0.05 to 0.1 eV and the effective mass M of the quasiparticle between 2 and 10 electron masses, $|e\mathbf{A}/c|$ is found to be in the range 10^{-13} to 10^{-12}eV, from which an estimate of m can be obtained for the quasiparticle at position $\mathbf{r}$. Estimation of m is not important at this time but existence of a single value of m which satisfies equation (5.2) at multiple positions $\mathbf{r}$ (positions of multiple boutons) is what validates the proposed hypothesis of tachyon interaction with the brain. Note that both sides of (5.2) are functions of $\mathbf{r}(q)$ while $\mathbf{A}(\mathbf{r})$ depends also on the tachyon mass m because it is the gradient of a solution of the Helmholtz equation (3.3) corresponding to m. Hence given a function V−E, existence of a value of m and an associated solution of (3.3) that also satisfies (5.2) implies that exocytosis is triggered by the same tachyon field simultaneously in all boutons of the dendron. It turns out that the theory of partial differential equations (Dautray and Lions, 1990; Hazewinkel, 1989; Sumbatyan and Scalia, 2004) assures existence of values for m and a unique solution of (3.3) that also satisfies (5.2) corresponding to each such value of m. By considering a closed region enclosing the whole dendron with all boutons of the dendron lying on its boundary such that the quasiparticles' motions are along the normals to the boundary at the corresponding points, that is, where the ion channels open, it is seen that equation (5.2) can be looked upon as a von Neumann boundary condition for the Helmholtz equation (3.3). Hence a solution satisfying both (3.3) and (5.2) does exist.

6. Why Tachyons and Further Work

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

1. The first observation is now 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 non-locally by systems of neurons may consist of tachyons which have imaginary masses and non-local and thus different from the ordinary matter and energy obtained from matter.

2. It seems that self-awareness in a brain may involve an infinite loop of writing information into memory (Vishnubhatla, 1985), which involves faster-than-light signal propagation and which even quantum computers cannot do. Although at present, it is not established in brain science that faster-than-light signal transmission takes place, in this author's view, presence of tachyons in the brain and their interaction with neurons would allow the brain to complete such an infinite loop of writing information into its memory.

Actually, since Jibu and Yasue (1997) published their theory of the dynamically ordered region of water realizing a boson condensation of evanescent photons inside and outside biological cells, there is ongoing discussion (Georgiev, 2006) of tunneling (evanescent) photons propagation within the tunneling region with infinite speed. However, it has to be noted that these tunneling photons are associated with non-vanishing real mass and different from the tachyons discussed above.

3. 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 but because we want to be something or somewhere in the future (Georgiev, 2002). So, our reasoning is inductive as well as deductive. The causality associated with inductive reasoning is called circular causality (Freeman, 2000) but it is not the same as the circular causality that is usually associated with feedback circuits and self-organization. The difference is that a motive that triggers a feedback loop is outside the loop in lifeless systems whereas

in the case of the brain, the trigger is somehow created from within the brain. Again, 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 (for example, Sudarshan, 1970; Feinberg, 1967; Recami, 1986; 1987), "*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.

Clearly, the scope of further work is vast. A theory of tachyon interaction with matter needs to be developed and more so in the context of the neuron environment of the brain.

One possible method of experimental detection of tachyon waves in a brain would be to verify the existence of the dispersion relation of the form in equation (3.2) for electromagnetic fields of the brain. Since at present, EEG is the primary means by which electric and 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.

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