Article

Mind and Tachyons: Mind-Body Interactive Dualism

Syamala Hari*

ABSTRACT

Following on the observation in Vedanta that mind is restless and faster than matter, we propose that memory and thought in the brain involve 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. As a first step, in an earlier work, it was shown that in the quantum mechanical model of exocytosis by Beck and Eccles, a zero energy tachyon can precisely do the task of an Eccles's psychon and therefore that our proposal can mathematically model mind's action on the brain. We see below that our proposal can mathematically describe how the brain acts on the mind as well. Assuming that the brain is a non-relativistic quantum system, and representing mind-brain interaction as tachyon interaction with ordinary matter, we see that the brain creates subjective experience in the form of tachyons if the mind made up of tachyons, pays attention to the brain while it receives sensory inputs.

Key Words: Quantum Potential, Active Information Mind Field, Tachyon, Exocytosis, Computer & Brain.

1. Introduction

Following on the observation in Vedanta that mind is restless and faster than matter, the theme of this focus issue is to suggest that the mind of human and other living beings may be made up of 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. In earlier work (Hari 2008), it was proposed that memory and thought in the brain involve tachyons; it was shown that zero-energy tachyons could accomplish precisely what Eccles hypothesized that mental units (called psychons by him) would do in a basic neural process called exocytosis. This analysis used the quantum tunneling model of Beck and Eccles (1992), and Bohm's interpretation of quantum mechanics. We described how a zero-energy tachyon (ZET) field contributes to the active information defined by Bohm and Hiley and has various other features of mind-fields which have been postulated or anticipated by some well known mind-matter researchers.

One of the main criticisms of Eccles's dualistic approach is that "the term 'mind' is not well defined, and dualist-interactionism is not delimited in ways that it could generate hypotheses for empirical testing" (Watson and Williams 2003). Other critics of Eccles's dualistic approach are

*Correspondence: Syamala Hari, retired as Distinguished Member of Technical Staff from Lucent Technologies, USA.
E-mail: murty_hari@yahoo.com Website: http://mind-and-tachyons.blogspot.com

materialists who believed that a non-material mind having effect on the activity of the material brain would necessarily violate conservation of energy, an established law of science. Since Eccles hypothesis that psychons play an active role in exocytosis is an example of mind's action on the brain, our earlier work (Hari 2008) showed that our proposal models mathematically mind's action on the brain without violating energy conservation. The back action of the brain on the mind assumed to be in the form of tachyons was described in Hari (2010). In what follows, we see that the same mathematical equations show that the brain creates subjective experience in the form of tachyons if the mind made up of tachyons, pays attention to the brain while it receives sensory inputs. Thus we get the total picture depicting the mind as consisting of tachyons, the brain as a non-relativistic quantum system, and mind-brain interaction as tachyon interaction with ordinary matter, and a model that can mathematically describe the mind's action on the brain as well as the brain's action on the mind.

When we associate tachyons with mind, we adopt the point of view of Shay and Miller (1977) that treats 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.[1]

For convenience, we present the mathematical analyses of earlier work in appendices. In Appendix 1, we present a part of the theory of the earlier paper (Hari 2008). We use the quantum tunneling model of Beck and Eccles (1992), and Bohmian model of quantum mechanics to 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 Appendix 2, we describe how tachyon interaction with quantum mechanical particles in the brain allows it to generate the experience of a sensory input or a psychological input when the mind pays attention to the brain. In Section 2, we compare ZET features with those of mind fields proposed by Eccles, Bohm, and Hiley. In this section, we also 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 mapping into a computer, 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 brain's quantum potential and thereby illustrates action of the mind on the brain. In section 3, we will see that our ZET proposal can mathematically describe how the mind acts on matter as well as how the brain acts on the 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.

Tachyons are nonmaterial

A tachyon is essentially different from matter in the sense that a material particle cannot be accelerated to be a tachyon and conversely a tachyon cannot be de-accelerated to have a speed less than that of light. Tachyon mass is purely imaginary in any laboratory frame of reference[2].

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

[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.

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[3]." Hence it seems that tachyons are essentially different from the material of the nonrelativistic neurons although they can act upon them (for example, by contributing active information to the quantum potentials of vesicles in the cortex).

Rationale for Associating Tachyons with Mind

Although physicists (other than a few who believe in tachyons) usually tend to avoid tachyons in their work, it is interesting that Fred Alan Wolf (2011) 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, a consciousness researcher, who proposed a model in which mind is a field of tachyonic or superluminal matter[4].

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, 2014). 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 mapping of some "real information" or phenomenal information Chalmers (1996) 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 search for an appropriate course of action and the action itself depend upon some information about a future state; for example, if I want to go to New York I will take a bus to New York but not to Philadelphia. How does the brain acquire information about a possible future state of itself into its present memory[5]? If desires, motives, etc. consist of tachyons, then it would be possible for the brain to receive future state information from the mind and build a neural correlate of the desired future state in its present

[3] From the exocytosis process described here, we anticipate that tachyons most probably exchange momentum with matter but not energy. Because a tachyon's speed is always greater than c, it is almost like infinite speed in our laboratory frames of reference. Hence, in an interaction with matter observed in a laboratory frame, a tachyon could be considered as having infinite speed and zero energy. As such, the tachyon has no energy left to exchange.

[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] A future state is only possible but not necessarily actual because there is no certainty that the chosen future state will come to pass.

memory. 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. Pavšič (1981) also suggested the possibility of tachyons informing an observer about a future event and the possibility of the observer's experiencing in his future some other events, and not those about which he has been informed by means of tachyons. The tachyonic observer appears very much like our mind.

2. Action of Volition on the Brain

Eccles called 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 proposed 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. In the appendix, we presented 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 is 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.

Beck and Eccles (1992) modeled exocytosis as a quantum tunneling process of a two-state quasiparticle governed by a one-dimensional Schrödinger equation. Let us denote the total energy of the particle as E, the single degree of freedom by q, the external potential driving its motion as V, and the quantum potential in the state with wavefunction Ψ as Q. Then the potential V presents a barrier to particle motion when V increases to a value greater than E. As long as the particle has not crossed the barrier V> E, in other words, exocytosis has not occurred, the particle's momentum remains zero and the quantum potential Q adjusts itself so that Q+V = E.

The main results of the analysis given in Appendix 1 are that after momentary interaction with the zero-energy tachyon field Φ, the quasiparticle motion at t = 0 is described by the equations:

$$\left(\varepsilon\nabla\Phi(\mathbf{r})/c\right)^2/2M + Q' + V(q) = E \tag{2.1}$$

$$\partial_t R'^2 + \partial_q\left(R'^2\left(\partial_q S' - \varepsilon\nabla\Phi(\mathbf{r}).\mathbf{I}/c\right)\right)/M = 2\varepsilon m\Phi R'^2 \tag{2.2}$$

$$\mathrm{Mdq/dt} = \left|\left(\varepsilon\nabla\Phi(\mathbf{r})/\mathrm{c}\right)\right| \quad \text{and} \quad \mathrm{Md^2q/dt^2} = -\partial_{\mathrm{q}}\left(\mathrm{Q}' + \mathrm{V}\right) \tag{2.3}$$

Here M is the particle's mass, **r** is its position, ε is its charge, c is the speed of light in vacuum, and $\Psi'(\mathrm{q,t}) = \mathrm{R}'\mathrm{e}^{\mathrm{i}S'(\mathrm{q,t})/\hbar}$ is the wavefunction after interaction, and $\mathrm{Q}' = -\hbar^2\left(\partial_{\mathrm{q}}{}^2\mathrm{R}'\right)/2\mathrm{MR}'$. At the moment of interaction (t=0) with the field Φ, the quasiparticle receives a momentum equal to $|\varepsilon\nabla\Phi(\mathbf{r})/\mathrm{c}|$ and the quantum potential changes from Q to Q′. From equation (2.1) the new quantum potential Q′ satisfies

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

Because the effective potential Q′ + V is less than the total energy, the second equation in (2.3) now allows particle trajectories to penetrate the barrier and exocytosis takes place. Moreover, the above argument holds simultaneously for all particles interacting with the field Φ and therefore that exocytosis occurs from particles at all those places.

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

It is clear that the ZET field Φ does exactly what Eccles proposed that a psychon would do:

- Φ changes the particle's quantum potential and alters quantum transition probabilities as seen from equation (2.2) where the right hand side is not zero after interaction with the field Φ whereas the right of hand side of the continuity equation (5.7) before interaction 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 energy because the interacting tachyon has no energy but only momentum. 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 each interacting bouton is also conserved because its mass 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 ZET Field Contributes to Bohm-Hiley Active Information

Hiley and Pylkkanen (2005, p21) see the mind-field as containing active information which contributes to the quantum potential. As already seen in the previous sections, the field Φ does exactly what they 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, they mention interpretations of the idea of a "mind-field" by three doctrines; 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.

From what we have presented about our tachyon field Φ so far, it meets the criteria of all the three doctrines. It is dualistic because it is not a matter field. It performs the function of the mental property volition proposed by Eccles and plays the functional role of changing the quantum potential of a Schrodinger 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.

Bohm's quantum potential for a system of particles is an intrinsic property of the system. It depends only on the form of the Schrodinger 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 (for example, the known neural levels) and be influenced by them. Hiley claims that such assumptions imply avoiding dualism or idealism without falling into reductive materialism. He says "mind" acts on "matter" but not in the sense of a mechanical interaction of two separate substances. Bohm and Hiley argue that their interpretation of mind is not as a state of biological matter in a living brain as materialists believe but that 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 Schrodinger 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 (section 3).

Is the Tachyon Proposal Experimentally Verifiable?

Since no laboratory frame of reference can be accelerated to have a speed greater than that of light, it is possible that tachyons cannot be detected in a laboratory, at a certain point of space and at a certain point of time. Like Libet's Conscious Mental Field, it is possible that tachyons could not be directly observed by any external physical device but only indirectly by any effects they produce on neural activities. By Hari (2008), a possible approach to experimental verification is suggested. This consists in estimating the tachyon mass at each of three or four vesicles simultaneously undergoing exocytosis from the vesicle's mass, energy, and external potential and verifying that the tachyon mass is the same in each case. The value of tachyon mass is not important at this time but if only a single value for tachyon mass is obtained corresponding to each of the vesicles, then the proposal that the same tachyon causes exocytosis in multiple vesicles will be validated.

Mind Field Is Not the Same as the Quantum Potential

Bohm identified the mind field with superquantum potentials. 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 (that one real entity is probably the matter in a living brain according to him). We differ from Bohm and believe that the content is just as real as the form that contains it. We believe that just like water is different from its container without which it cannot be taken from place to place, the content has an identity of its own and different from all forms containing it although content cannot be communicated without being separated from the form. This is particularly because the same content or meaning can be communicated or stored using different forms. Moreover, there is no mental aspect in any physical process in which the brain (a living being) is not involved. There is no mental aspect in any lifeless quantum system as the "content" of its quantum potential. Why should there be a mental activity inseparable from its physical activity in the brain? Why does the brain's physical activity not require somebody else to assign some meaning to it? (Hari 2012).

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. 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. We agree with Pribram's theme that the medium is not the message (Pribram 2004, p 14) but 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.
Considering that the brain-system 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" that is not identical with its neural representations, we think that the **change which a tachyon produces in the quantum potential of the interacting brain is its mapping in the physical brain. We agree with Bohm and Hiley (1984) in the sense that quantum potential is software-like[6] 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 codes in the hardware-like brain for the "real information" or the "meaning" which consists of tachyon fields.** On the other hand, we do not agree with the Bohm-Hiley-Pylkkanen proposal that mind is identical with the union of super-quantum potentials of the brain at various hierarchical levels (for example, Bohm 1990) because according to their theory, the brain cannot have action on its quantum potential which is supposed to be its mind.

3. The Brain Creates Subjective Experience by Interacting with the Mind.

We regard a living brain as being similar to a computer in the sense that it has a physical component, the numerous neurons with their connections and the biological environment and some information consisting of experiences, emotions, thoughts, etc. However, the computer whether digital or quantum, does not know the meaning of its memory contents (which are some data and some instructions to handle the data and new data entered). 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 mapped to a computer's code 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. (Yes, the biological matter does create meaning but not all by itself! It does so only when the already existing mind pays attention to it). However, they have yet to explain how biological matter creates meaning.

A living brain 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

[6] Bohm and Hiley (1984, p 260): 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.

structure is identical with it. What brain scientists can observe today are structures in the physical memory. In a computer, new memory contents cannot be created from hardware alone without some code (in other words, hardware correlates of some "real" or "phenomenal" information from a computer programmer' brain) already entered in it. Similarly and probably, the physical body alone cannot create mind when there is no mind already in it (no mind means no life!). But 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, again just like in a computer.

In our model of the brain-mind system, the effect on the brain of a ZET (a solution of (5.3)), $\Phi_m(\mathbf{x})$'s nonlocal momentary interaction (simultaneous interaction with particles at different positions in space only for a moment) is described by the following Schrodinger's equation:

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

Here the suffix j describes quantities belonging to the jth particle, ∂_j is the gradient operator containing differentiation with respect to the coordinates in $\mathbf{x}_j$ and the electromagnetic potentials U, **A** are associated by equation (5.4). Paying attention by the mind to the brain consists of a sequence of such momentary interactions imparting impulses. The potential $V(\mathbf{x}_j)$ accounts for external sensory input as well as internal neural interactions. As shown in Appendix 2, the action of neurons on $\Phi_m(\mathbf{x})$ changes it to a superposition such as

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

which is subject to the uncertainty relation:

$$(\Delta mc)(\Delta(t - t_0)) \geq 1$$

in a momentary interaction at $t = t_0$. The above inequality implies that the spread $\Delta m >> m$ and suggests creation of new ZETs, in other words, new information in the brain. Whenever the quantum brain creates a record of its input, it undergoes a collapse of the wavefunction, if so, the effect of the collapse is to create new ZETs because the mind has been paying attention and therefore sending its impulses. As shown in Appendix 2, the new ZETs contain the information about the brain's configuration at the time of interaction, that is at the time of collapse. Thus the new ZETs constitute subjective experience of the input.

4. Conclusion

We saw that a zero-energy tachyon could perform precisely the function of a psychon as described by Eccles; the tachyon 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. When the tachyon transfers momentum to quasiparticles, their quantum potentials change and thereby new active information is contributed to affect their motion. This is what exactly what Hiley and Pylkk¨anen (2005) propose that a mind-field would do.

According to Bohm and Hiley, the quantum potential is not only the container of active information but it is itself the mind field. In our view, the quantum potential is active information like a piece of computer code but it is not itself the mind field. We suggest that the tachyon, which triggers exocytosis and which is a part of mind, is like the algorithm in a computer programmer's head; the change it produces in the quantum potential of each interacting vesicle is similar to a computer code which maps the "real information", the tachyon, into the physical brain.

In our tachyon-matter interaction model, a tachyon acts upon material particles to change their motion and the back action of the particles upon the tachyon is to produce more tachyons. Since paying attention by the mind to the brain consists in a sequence of such momentary interactions, the back action of neurons on the mind produces subjective experience. Hence our model describes mind's action upon matter and matter's action upon mind as well.

We wish to point that our tachyon proposal is not inconsistent with the Spin-Mediated Consciousness theory of Hu and Wu (2004, 2006). They propose that mind has its own independent existence and resides in a pre-space-time domain. What they call mind-pixels are neural correlates of some mental units and comprised of the nuclear spins distributed in the neural membranes and proteins. In the tachyon proposal, mental units are tachyons and they are aspects of the brain's phenomenal information, in other words, software aspects. Each tachyon associates itself with a multitude of neurons whose dynamics belongs to the brain's hardware aspects and could involve nuclear spins but we simply did not deal with the hardware aspects; we concerned ourselves with only the interaction aspect of the non-material mind with the physical brain. Hu and Wu also postulate that consciousness emerges from the collapses of entangled quantum states with certain properties; this philosophically agrees with our proposition in that new tachyons are created when the collective state of the system of neurons interacting with a tachyon collapses.

5. Appendix 1

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

$$\left(\partial_\nu \partial^\nu - m^2\right)\Psi\left(\mathbf{x},\ \mathrm{t}\right) = \mathbf{0} \tag{5.1}$$

where $\mathbf{x}$ is the vector $\left(\mathrm{ct}, -\mathrm{x}, -\mathrm{y}, -\mathrm{z}\right) = \left(\mathrm{x}_0, \mathrm{x}_1, \mathrm{x}_2, \mathrm{x}_3\right)$; ∂_ν stands for differentiation with respect to x_ν, $\partial^\nu = \eta^{\mu\nu}\partial_\mu$ where $\eta^{\mu\nu}$ is the Minkowski metric; c is the speed of light in free space, and $m = m_0 c/\hbar$. Writing $\Psi\left(\mathbf{x}, \mathrm{t}\right) = \Psi\left(\mathbf{x}\right)\Psi'\left(\mathrm{t}\right)$ we get solutions of the form $e^{i\omega t}\ \Psi(\mathbf{x})$ of equation (5.1) where $\Psi(\mathbf{x})$ satisfies

$$\left(-\Delta - m^2\right)\Psi(\mathbf{x}) = 0 \quad \text{and} \quad \omega^2 / c^2 = k^2 - m^2 \tag{5.2}$$

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).
A zero-energy solution of (5.2) corresponds to frequency ω = 0 and $k^2 = m^2$ and satisfies the Helmholtz equation:

$$\Delta\Phi\left(\mathbf{x}\right) = -m^2\Phi\left(\mathbf{x}\right) \tag{5.3}$$

Equation (5.3) has multiple linearly independent solutions Φ(**x**) corresponding to a given value of *m*. Each solution represents a field with zero energy and capable of exchanging momentum with particles of matter. We take Φ(**x**) to be real. To describe the interaction of a field satisfying equation (5.3) with a particle whose motion is governed by a Schrödinger equation, we associate with Φ the electromagnetic field defined by the four-potential:

$$\tilde{\boldsymbol{A}} = \left(\partial^\nu \varphi_m\left(\mathbf{x}, t\right)\right) = \left(U, \mathbf{A}\right) \tag{5.4}$$

where $\varphi_m\left(\mathbf{x}, t\right) = e^{imct}\Phi\left(\mathbf{x}\right), U = \partial_0\varphi_m\left(\mathbf{x}, t\right) = im\varphi$ and $\mathbf{A} = -(\partial_1, \partial_2, \partial_3)\varphi_m\left(\mathbf{x}, t\right)$.
Note that the potentials **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, a 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:

$$i\hbar\partial_t\psi\ (q, t) = -\left(\hbar^2 / 2M\right)\left(\partial_q{}^2 + V(q)\right)\ \psi\left(q, t\right) \tag{5.5}$$

where q is the quasiparticle's degree of freedom, M is the mass of the particle, V(q) the external potential energy, and ħ is the Plank's constant. Writing the quasiparticle wave-function $\psi\left(q, t\right)$ of equation (5.5) as $\psi\left(q, t\right) = Re^{iS(q,t)/\hbar}$, where R and S are real valued functions and equating the real and imaginary parts on both sides of (5.5), we obtain the following two equations:

$$\partial_t S + \left(\partial_q S\right)^2 / 2M + Q + V\left(q\right) = 0 \tag{5.6}$$

$$\partial_t R^2 + \partial_q\left(R^2\partial_q S\right) / M = 0 \tag{5.7}$$

In equation (5.6), $Q = -\hbar^2 \left(\partial_q{}^2 R\right)/2MR$ is called the quantum potential; the particle's total energy E = $-\partial_t S$, and $\partial_q S$ is the particle's momentum. Once (5.5) is solved for the wavefunction $\psi(q,t)$, the particle's trajectories can be computed classically from

$$Mdq/dt = \partial_q S \quad \text{or} \quad Md^2q/dt^2 = -\partial_q\left(Q+V\right) \tag{5.8}$$

by prescribing initial conditions. Just before tunneling begins motion is classical and E = V and Q = 0; hence in equation (5.6) 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 does not undergo 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 (5.8) gives trajectories penetrating the barrier and equation (5.6) gives a nonzero kinetic energy.

After the electromagnetic interaction with the tachyon field, the equation (5.5) changes to:

$$i\hbar\,\partial_t\psi'\left(q,t\right) = \left\{\left[\mathbf{I}\left(\hbar/i\right)\partial_q - \left(\varepsilon/c\right)e^{imct}\mathbf{A}\left(\mathbf{r}\right)\right]^2/2M + i\varepsilon m e^{imct}\Phi\left(\mathbf{r}\right) + V\left(q\right)\right\}\psi'\left(q,t\right), \tag{5.9}$$

where $\mathbf{r} = \mathbf{r}(q)$ is the quasiparticle position, and $\mathbf{A}\left(\mathbf{r}\right) = -\nabla\Phi\left(\mathbf{r}\right)$, **I** is the unit vector along its velocity, and ε is the quasiparticle's charge. The effect of tachyon interaction on equations (5.6), (5.7), and (5.8) can be obtained by substituting $\psi'\left(q,t\right) = R' e^{iS'(q,t)/\hbar}$ in (5.9) and equating real parts on both sides of equation. It is seen that at the interaction time t=0, equations (5.6), (5.7), and (5.8) change respectively to (5.10), (5.11), and (5.12) below:

$$\partial_t S' + \left(\partial_q S' - \varepsilon A/c\right)^2/2M + Q' + V\left(q\right) = 0 \tag{5.10}$$

$$\partial_t R'^2 + \partial_q\left(R'^2\left(\partial_q S' - \varepsilon\mathbf{A}.\mathbf{I}/c\right)\right)/M = 2\varepsilon m\Phi R'^2 \tag{5.11}$$

$$Mdq/dt = \left|\left(\mathbf{I}\partial_q S' - \varepsilon\mathbf{A}/c\right)\right| \quad \text{and} \quad Md^2q/dt^2 = -\partial_q\left(Q'+V\right), \tag{5.12}$$

where $Q' = -\hbar^2\left(\partial_q{}^2 R'\right)/2MR'$. In (5.10), the first term $\partial_t S' = -E$ is the total energy of the particle and same as in (5.6) because no energy is exchanged. At t = 0, the particle's momentum changed from **p** which is zero before interaction, to **p** − ε**A**/c after interaction. Therefore, after interaction, the particle's momentum is $\varepsilon\mathbf{A}\left(\mathbf{r}\right)/c = \varepsilon\nabla\Phi\left(\mathbf{r}\right)/c$; kinetic energy is the second term in (5.10) and equal to $(\varepsilon \,\mathrm{grad}\, \Phi(\mathbf{r})/c)^2/2M$. Hence, at t=0, if $\nabla\Phi\left(\mathbf{r}\right) \neq 0$ at the position **r**, equation (5.10) implies:

$$Q' + V = [E - \left(\varepsilon\nabla\Phi\left(\mathbf{r}\right)/c\right)^2/2M] < E \tag{5.13}$$

The second of equations (5.12) may be used now to determine the particle's trajectory classically. It permits trajectories to penetrate through the barrier. In other words, exocytosis takes place in the bouton originally governed by the equation of motion (5.5). Moreover, if the tachyon mass m is sufficiently small then $\nabla\Phi(\mathbf{r}) \neq 0$ in a region covering the whole dendron (Hari 2008). Then the inequality (5.13) is valid for all the boutons in a whole dendron. Hence exocytosis takes place simultaneously in all the boutons which are ready for exocytosis.

6. Appendix 2

We write a Lagrangian for the free tachyon field governed by equation (5.1) 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 jth nonrelativistic particle interacting with the field Ψ, the equation of motion can be derived from the Lagrangian:

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

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

$$L_{\text{field}} + \Sigma\, L_{\text{particle-j}} = \int d^3\mathbf{x} \left\{ \begin{array}{l} \left[(\partial_t \Psi / c)^2 - (\nabla\Psi)^2 + m^2\Psi^2 \right] / 2 \\ + \Sigma \left[M_j v_j^2 / 2 - \varepsilon_j \Psi - V(\mathbf{x}_j) \right] \delta(\mathbf{x} - \mathbf{x}_j) \end{array} \right\},$$

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 (5.1) to:

$$\left(\partial_t^2 / c^2 - \Delta - m^2 \right) \Psi(\mathbf{x}, t) = \sum \varepsilon_j \delta(\mathbf{x} - \mathbf{x}_j(t)) \tag{6.1}$$

To find how the momentary interaction with the particles at time $t = t_0$ changes the zero-energy tachyon field, we may minimize S subject to the conditions: $t = t_0$ and $\partial_t\Psi = 0$. Substituting these conditions in (6.1), we find that after the interaction, the ZET field equation (5.3) changes to:

$$\left(\Delta + m^2 \right) \Psi(\mathbf{x}) = \sum \varepsilon_j \delta(\mathbf{x} - \mathbf{x}_j(t_0)) \tag{6.2}$$

Now, recall that the effect of $\Phi_m(x)$, which is a ZET and a solution of equation (5.3), on the Schrodinger equation of quantum particles was introduced via the four-potential $\{\partial^{\nu}\varphi_m(x,t)\}$, where $\varphi_m(\mathbf{x},t) = e^{imct}\Phi_m(\mathbf{x})$. To find the effect of the particles on $\varphi_m(x,t)$ vice versa, we may apply similar analysis to the massless scalar wave equation:

$$\partial_{\nu}\partial^{\nu}\varphi(x,\ t)\ =\ 0, \tag{6.3}$$

for which $\varphi_m(x,t)$ is clearly a solution. In this case, we find that the field φ continues to satisfy equation (6.3) even after interaction. Since $\Phi_m(x)$ does change after interaction as seen from equation (6.2), it follows that after interaction, the field $\varphi_m(\mathbf{x},t)$ with a definite value for *m* changes to a general linear superposition:

$$\phi(x,\ t)\ = \sum_k e^{im_k ct}\Phi_{m_k}(x)\,dm_k \tag{6.4}$$

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 (6.4) is associated with a tachyon with non-definite mass. Fourier analysis of (6.4) leads to the uncertainty relation between the spread of ZET mass and spread of time given below:

$$(\Delta mc)(\Delta(t - t_0))\ \geq\ 1 \tag{6.5}$$

In a momentary interaction the inequality (6.5) implies that the spread $\Delta m >> m$ and suggests creation of new ZETs.

Clearly, a superposition of green's functions: $\sum\varepsilon_j G(\mathbf{x}-\mathbf{x}_j(t_0))$ is a solution of equation (6.2) if $G(\mathbf{x}-\mathbf{x}_j(t_0))$ is a green's function of the Helmholtz equation and satisfies;

$$(\Delta\ +\ m^2)\ \Psi(\mathbf{x})\ = \varepsilon_j\delta(\mathbf{x}-\mathbf{x}_j(t_0)),$$

along with specified boundary conditions. Expressing $G(\mathbf{x}-\mathbf{x}_j(t_0))$ for each j, as a superposition of functions $\Phi_{m_k}(\mathbf{x})$ associated with eigenvalues m_k, a solution of equation (6.2) 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 $\mathbf{x}_j = \mathbf{x}_j(t_0)$. 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. The above equation shows that these new tachyons depend upon the positions of the particles at $t = t_0$, which in turn depend upon the potential V(**x**), the sensory input. This means that the mind monitors its brain every moment by means of momentary impulses and in return, the brain records its wavefunction-collapsed configurations in the mind and that is subjective experience.

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