Mind and Tachyons: Quantum Interactive Dualism - Libet's Causal Anomalies

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ABSTRACT

Chalmers described 'awareness' as a functional notion intimately linked to 'subjective experience' but nevertheless different from the latter. We define 'awareness of an object (physical or mental)' in terms of the specific function of creation of physical and mental records. By using this definition of awareness and a representation of mind-brain interaction as tachyon interaction with a nonrelativistic quantum mechanical system, in earlier work, we showed that the brain creates subjective experience in the form of tachyons if the mind consisting of tachyons pays attention to the brain. In this article, we use our proposal of creation of subjective experience and Wolf's two-time observables based transaction-interpretation of quantum collapse to explain Libet's hypothesis about unconscious cerebral initiative and the role of conscious will in voluntary action.

Key Words: quantum brain, tachyons, computer and brain, subjective experience, Libet's temporal anomalies

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1. Introduction

We define 'awareness of an object (physical or mental)' in terms of the specific function of creation of physical and mental records. In earlier work (Hari 2011), we used this definition of awareness and a representation of mind-brain interaction as tachyon interaction with a nonrelativistic quantum mechanical system, to show that the brain creates subjective experience in the form of tachyons if the mind pays attention to the brain. We also showed that our theory justifies Libet's subjective antedating hypothesis. In this article, we justify Libet's hypothesis about unconscious cerebral initiative and the role of conscious will in voluntary action again using our definition of awareness and the tachyon-matter interaction model of mind-brain interaction.

There is widespread skepticism in the physicist community regarding tachyons because these objects have not been detected experimentally yet; the word 'tachyon' simply "turns off" many physicists. The skepticism is even worse when one talks about the presence of tachyons in the brain-mind system because neural transmission speeds are in msec range but not above the speed of light. We wish to point out that the proposed tachyon theory does not intend to contradict established results of neuroscience nor it is inconsistent with any established facts describing the brain. 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 p 57). Shay and Miller (1977)

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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 of the tachyon from one position to another within the brain. Rather, the tachyon interacts with many neurons at different positions simultaneously*. For example, in earlier work Hari (2008; 2011), it was shown that a zero energy tachyon (ZET) can interact with all the boutons of a whole dendron simultaneously and increase the probability of the exocytosis in all of them thus coupling a large number of quantum amplitudes to produce coherent action and the ZET can do so without violating energy conservation. In the absence of such coupling action, which was attributed to mental activity by Eccles (and called it a psychon), these probability amplitudes would act independently, causing fluctuating EPSPs in the pyramidal cell. The non-local tachyon's ability to interact with many neurons at different positions simultaneously may explain the so called 'binding problem'. It is interesting that there are at least a few modern physicists such as Fred Alan Wolf (2011) who associate 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.[2]

The main difficulty with consciousness is its definition as Chalmers (1996) stated: "consciousness is an ambiguous term, referring to many different phenomena". Chalmers (1997) sees experience as central to consciousness and conscious experience as a primitive notion which cannot be defined in terms of more primitive notions. Hence his clarification (probably not a definition) is that "An organism is conscious if there is something it is like to be that organism, and a mental state is conscious if there is something it is like to be in that state" implying that conscious experience is subjective. Conscious experience of one is not known to others and not accessible to others by any physical means. Chalmers asked: "How can we explain why there is something it is like to entertain a mental image, or to experience an emotion? It is widely agreed that experience arises from a physical basis, but we have no good explanation of why and how it so arises. Why should physical processing give rise to a rich inner life at all?" Chalmers called this problem the 'hard problem'. He then coined other term 'awareness' and distinguished it from 'consciousness' by introducing 'easy problems' as opposed to the 'hard problem'. Easy problems of consciousness are those in which the phenomenon being investigated is usually associated with consciousness but can be explained in terms of computational or neural mechanisms. So what is awareness? Chalmers says that awareness is a functional notion different from subjective experience but it is nevertheless intimately linked to subjective experience. Actually, what is explained in the 'easy problems' of a phenomenon by means of neural and computational mechanisms turns out to be its functional aspect whereas why subjective experience accompanies that/those function/s is the 'hard problem' and not solved. Since one experiences something only when one is aware of that something, in this article, we define 'awareness of an object (physical or mental)' in terms of the specific function of creation of physical and mental records of information, itself a primitive notion. We will see that this definition of awareness gives us a criterion for the occurrence of subjective experience in all monist, dual-aspect monist, and dualist theories. The definition allows us to see that the temporal causal anomalies occurring in Libet's delay (antedating and the readiness) potential experiments are consistent with our interactive dualist theory which describes mind-brain interaction as tachyon-matter interaction.

Quantum Collapse and Awareness Production

In general, quantum theorists of consciousness assume that awareness of an event is a consequence of a quantum collapse of the brain, that is, awareness of an event is created in the brain only if there is an accompanying collapse of the brain's wavefunction. The assumption

[2] Dutheil, 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" and "Superluminous Medicine". He was a joint Director in Louis de Broglie Physics Foundation in Paris (Evellyn Elsaesser Valarino, 1997).

appears reasonable when one considers Edelman's dynamic core hypothesis (Edelman, 2000). He emphasizes that occurrence of a conscious state rules out or discriminates among billions of other conscious states, each of which may lead to a different potential consequence and that this discrimination happens so fast that it is not achievable at present by a man-made artifact (Edelman, 2000; p.147). He calls this ability of the brain to actualize one state among several possible ones as differentiation. Assuming that awareness of an event occurs along with a collapse of the quantum brain's wavefunction, Wolf (1998) offered a quantum-physical explanation in support of Libet's delay-and-antedating hypothesis (Libet *et al.,* 1979) regarding the timing of the conscious sensation of a sensory stimulus. Wolf's assumption is justified by the results of Libet's experiments themselves.

Stapp (2006) offered a quantum-physical explanation of why awareness of intention to do a volitional act in Libet's experiments (Libet *et al.,* 1983) occurs after the development of readiness potential. In Stapp's analysis, he uses a version of the von Neumann interpretation (vN/S) of quantum mechanics (QM). The vN/S theory is based on two postulates (not stated explicitly) concerning mind-brain interaction:

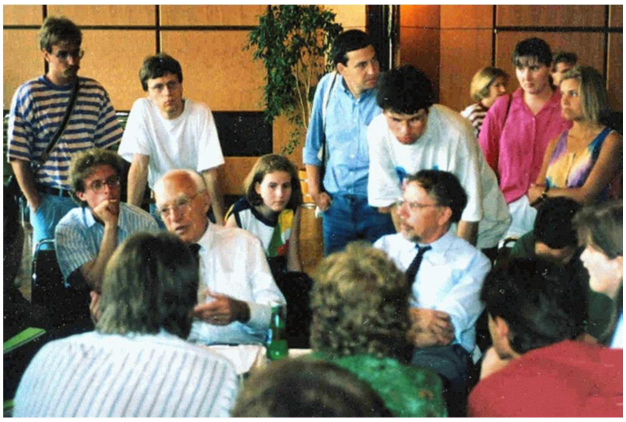
1. When an observer pays attention to a physical object (for example, the measuring device connected to a particular QM system), to receive a sensory input (for example, the reading on the device), the physical universe including the observer's brain, the brain, and the specific QM system all undergo 'quantum collapse'. Let us call this as the Observation Postulate (OP).
2. In turn, the collapse of the universe/brain creates the experience of the sensory input in the mind of the observer.Let us call this as the Awareness Production Postulate (APP).

Stapp (2014a) claims that the vN/S theory is an interactive-dualist theory but that it is different from Eccles's interactive dualism and that it is "based on a workable and empirically tested set of rules that causally connect the two realms, and each mind is tied by these causal connections to an associated brain". Since results of experiments with lifeless QM systems agree with the predictions of vN/S theory, one may consider that the mind-brain interaction embedded in the vN/S theory is verified experimentally although very indirectly. However, the OP is regarded as controversial by some other physicists because the postulate implies that the act of observation causes the measuring device's wavefunction to collapse and thereby causes the device to produce a reading! Thus the postulate seems to go against common sense. Hence other consciousness-not-required-for-collapse QM interpretations such as Bohm's causal interpretation and Cramer's transactional interpretation were proposed. These interpretations are not concerned about mind-brain interaction and derive the quantum collapse of a QM system/physical-universe by replacing the vN/S's OP with other postulates. For example, while arguing to defend Libet's delay-and-antedating hypothesis, Wolf (1998) used the transactional interpretation (TI) of QM and TTOTI model (two-time observable and TI) to determine the time interval in which the brain's wavefunction collapses in each of Libet's experimental scenarios. Since the TTOTI does not say anything about awareness, Wolf assumes that awareness accompanies wavefunction collapse, in other words, he assumes the APP of the vN/S interpretation. In each scenario of Libet's experiments, the time of occurrence of the experience does fall within the time interval of the wavefunction collapse predicted by the TTOTI model thereby justifying Wolf's assumption experimentally.

Interactive dualism, quantum mechanics, tachyons, and causal anomalies

The temporal/causal anomalies observed in Libet's experiments appeared to Libet himself as raising "serious though not insurmountable difficulties for the theory of psychoneural identity (Libet *et al.,* 1979). Sir John Eccles interpreted these anomalies as supporting his own theory of interactive-dualism. (Of course, there are reductionist interpretations of Libet's experiments also but we will not get into this debate). Unlike many other prominent neuroscientists, Eccles rejected the notion of mind brain identity and believed that mind-brain interaction can be explained without violating the conservation of energy by taking into account the QM nature of processes taking place in the microstructure of the neocortex (Eccles, 1994; Beck, 2008a; 2008b). One of the main criticisms of Eccles's dualistic approach is that "the term 'mind' was not well defined, and dualist-interactionism was not delimited in ways that it could generate hypotheses for empirical testing" (Watson and Williams, 2003). Other critics of Eccles's dualistic approach are 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. Interestingly, it happens that in the Beck and Eccles (1992) QM model of exocytosis, a zero energy tachyon can precisely do the task of an Eccles's psychon, that is, interact with boutons and increase the probability of the exocytosis in all the boutons of a whole dendron simultaneously thus coupling a large number of quantum amplitudes to produce coherent action but without violating energy conservation (Hari, 2008). This theoretical observation, led to the suggestion (Hari, 2008; 2010; 2011) that processes of thought and experience in the brain may involve tachyons. This proposal that the non-material mind may consist of tachyons provides a mathematical definition for the contents of the mind; a way of experimental verification of the proposal may be possible based on the exocytosis phenomenon. Theoretically, this proposal explains how not only mind (composed of tachyons) acts on the physical brain (for example volition facilitates exocytosis) but also how the brain produces awareness (in the form of tachyons). In particular, the proposal explains that the brain creates subjective experience in the form of tachyons if the mind consisting of tachyons pays attention to the brain (Hari, 2010; 2011). Using the description of tachyon interaction with ordinary matter and the quantum-physical description of collapse by Wolf (1998), Hari (2011) explained Libet's delay-and-antedating hypothesis. In this article, we will justify Libet's hypothesis about unconscious cerebral initiative and the role of conscious will in voluntary action using the same model and without assuming the vN/S postulates.

We emphasize that in the tachyon theory of the mind used in this article there is no soul, no homunculus, etc. In our view, the mind is similar to a computer's memory; it is an accumulation of the 'phenomenal information' of Chalmers (1996) consisting of experiences of sensory inputs as well as psychological contents such as emotions, feelings, volition, and sense of self. We assume that this phenomenal information which is not accessible to external observers by any physical means consists of tachyons defined and discussed by Bilaniuk et al. (1962), Feinberg (1967), and Recami (1986).



John Eccles (left) in the discussion round after his talk and Friedrich Beck (right). Photo, R. Beck, ©From NeuroQuantology 2008; 6(2), cover.

In this article, we will be interested in only tachyons with zero energy because we want mind brain-interactions to obey the law of conservation of energy. In section 2, we will give a definition of what it means for the brain to be aware of an object whether physical or mental. In section 3, we will summarize the earlier explanation (Hari, 2011) of the Libet's delay-and-antedating temporal anomaly using this definition and the tachyon-matter interaction model of mind-brain interaction. Here, we will not use either of the OP and the APP of the vN/S theory; we will use Wolf's TTOTI model to determine the time interval for wavefunction collapse but unlike Wolf we will not assume the vN/S postulate of awareness production. In section 4, we show that the theory of section 3 can also explain why an unconscious development of 'readiness potential' (RP) occurs prior to the awareness of the intention to act a freely voluntary act, and why on the other hand, one can consciously veto the act until actually beginning to do it even after being aware of one's own intention to act. In the appendix, we describe how tachyon interaction with quantum mechanical particles allows the brain to generate the experience of a sensory input or a psychological input when the mind pays attention to the brain.

2. Awareness of an object

The word consciousness is associated with not only subjective experience, but many other phenomena such as volition, intention, attention, executive control of action (free will), sense of self, and so on. Let us consider one particular aspect of it: to be aware of something or to know something whether physical or mental, or briefly, awareness of that object. What does to know something mean? Nowadays, while working with computers we often use expressions like "the computer knows", or "it does not know", "it remembers", "it understands", "it thinks", etc. In fact, we can precisely define what we mean when we say any of these expressions. *A computer behaves as if it knows an object (a data item or a program instruction), when a representation of that object exists in its memory 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 elements (let us call it the hardware correlate of the object).*

Once such a mapping 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 the meaning of anything it stores or it does! We talk a lot about storing information in a computer but what the computer actually stores is only a mapping of some 'real information' or 'meaning' that exists in the programmer's brain; some phenomenal information in the brain is mapped to sets of hardware elements of the computer. We cannot create meaning in a computer, nor anywhere else in the physical world outside the brain; we can only assign meaning to computer cells or even to words. A word in any language is not identical with its meaning because the same meaning may be conveyed by different words in different languages. When a word is spoken it becomes sound and becomes a sequence of electrical signals when transmitted on a telephone line; the sounds or electrical signals are not the same as their meaning which is assigned to these words, sounds, signals by us, human beings. All means of storage or communication of information whether digital, optical, electronic, electrical, etc. known to us so far all carry only a representation of some 'real information' or 'meaning' that exists in our brains. The brain creates a neural record in its memory when it receives a sensory input just as a computer creates a record of an input that comes from its key board but with the difference that the brain also creates a meaning associated with that neural record. We do not know how it creates this meaning but we know that it does (the hard problem). Hence we define the brain's awareness of an object as follows: *The mind-brain system is aware of an object (which may be a physical object, or a past event, or a sensory experience in the present, or a future goal) when a physical representation (neural correlate) of that object reportable to the outside world, and the "meaning" of the neural correlate both exist in its memory.*

The nature and structure of "meaning", that is, the mental record is not yet known. Dualists think that meaning is nonphysical and associated with its neural correlate (NCC) but exists independently from it; dual-aspect theorists think that the meaning is subtle but it is the dual aspect of the neural record, and monists think that it is a property of the neural record. But the above definition holds in all theories. In a dualist theory, this definition suggests the possibility of presence of unconscious thought in the brain. In a dualist theory, the definition also allows for the occurrence of Libet's delay-and-antedating and the readiness-potential temporal anomalies because a neural record and the associated mental record can be created at different times in the laboratory frame of reference.

The relation between the brain and its mind is in some ways, similar to that between a computer's hardware and software. In a computer (digital or quantum), to create a new record of, say a new input from its keyboard, a required program must already be present in it. In the case of the brain, the awareness/experience of, for example, seeing an object or hearing a sound cannot be created in its memory unless the owner of the brain pays attention to the object/sound. The two vN/S postulates are consistent with this requirement.

3. Libet's Delay and Antedating Paradox

As long as the brain/mind is attentive to its environment, the brain receives some sensory input or other and processes it unless the brain is damaged in some way. If the sensory input passes through the thalamus on its way to the cortex (it does so for inputs of taste, sound, touch, or vision but not smell), it generates a signal (the primary component of the evoked potential (EP)) called time-marker, in the arrival area of the somatosensory cortex (SC). This signal is neither necessary nor sufficient for eliciting a conscious sensation. The cortex continues to process the input until it achieves neuronal adequacy (NA) to register the event. However, surprisingly, the time of awareness of the sensation as reported by the subjects in Libet's experiments was close to the time of time-marker generation and therefore earlier than NA attainment. Unlike the time marker signal, NA was found to be both necessary and sufficient for conscious experience of the stimulus by applying sufficiently long stimuli directly to the cortex instead of through the sensory body. Experience of the stimulus was reported in these experiments after NA is attained (cortical signals do not produce time-markers). Hence Libet (1979) proposed the hypothesis that a subject's experience of any peripheral sensation appears to be referred backwards in time approximately to the instant of stimulation (close to when the time-marker signal occurs) while the neural processes associated with the sensation take up to about 500 msec to attain NA 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.

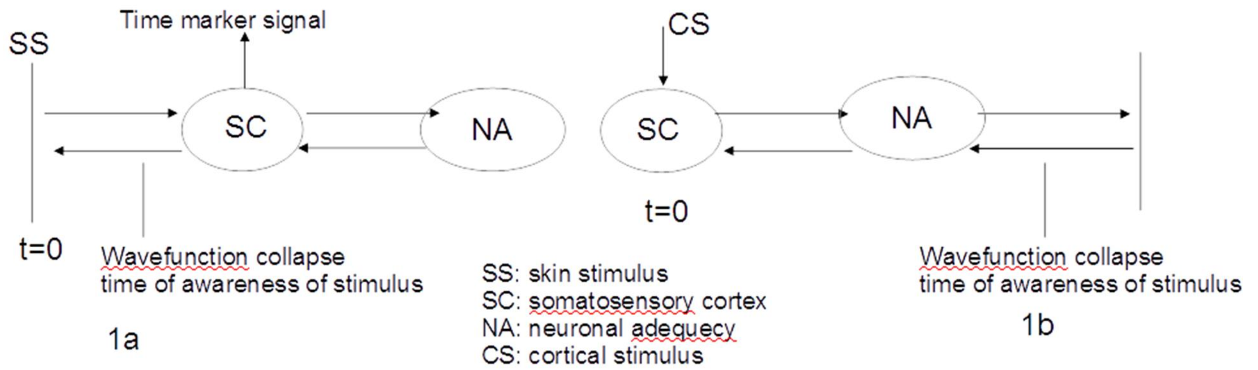


Figure 1. Two scenarios in Libet's sensation-of-sensory-stimulus experiments. The time interval for wavefunction collapse is determined by the TTOTI model of Wolf (1998). **1a.** A skin stimulus (SS) is applied leading to a time marker signal elicited on the somatosensory cortex (SC). The perception occurs within 15 msec of the stimulus, which is felt in the same place where it was applied. **1b.** A cortical stimulus (CS) is applied to SC. A phantom skin stimulus is generated and felt sometime after neuronal adequacy is attained. Neural processes take up to about 500 msec to attain NA. The sensation occurs in an area of the skin that corresponds to its map in SC.

Figure 1 shows two scenarios in Libet's sensation-of-sensory-stimulus experiments. In Figure 1a, a skin stimulus (SS) is applied leading to a time marker signal elicited on the somatosensory cortex (SC). The peripheral stimulus is an input to the brain (a neural computer) and the corresponding neuronal adequacy (NA) state is the one that contains a neural record of the input. According to the TTOTI model of Wolf (1998), the brain's state vector goes forward in time from the state where and when the stimulus is applied to the state where the time-marker is produced, and from there to the NA state. The echo state vector travels the entire path backward in time. Quantum collapse occurs in between the space-time state (where and when) the sensation is felt (is/observable/reportable, Wolf calls it the space-time projection of a mental state) and the brain state closest to it (in space-time), which in Figure 1a is the state where and when the time-marker is released. In Figure 1b, a stimulus is entered directly into the SC. Here, the cortical stimulus is an input to the brain (a neural computer) and the corresponding NA state contains a neural record of the input. In this scenario, the brain's state vector goes forward in time from the state of receipt of the stimulus to the NA state and from there, to the state where and when the phantom stimulus is felt.

The quantum collapse occurs in between the space-time state of experiencing the sensation and the state closest to it (in space-time), which in Figure 1b is the NA state. Thus in the laboratory frame of reference, in the scenario of Figure 1a, the collapse occurs before NA is attained whereas in the scenario of Figure 1b, the collapse occurs after NA is attained. According to the tachyon model of mind-brain interaction (see Appendix), a mental record made up of zero-energy-tachyons (ZETs) is created in the brain in either scenario, along with the brain's wavefunction collapse.

- In the first scenario, awareness of the sensory stimulus is reported to the experimenter even before the required NA is observed and that is the paradox in the laboratory frame of reference. Now, in the frame of reference of any created ZET, the birth of the ZETs and attainment of NA are simultaneous events (Recami, 1986, equation (39'), p 26) and the definition of awareness of section 2 is satisfied in this frame. So, the ZETs, 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 acts as the piece of the puzzle that ties together both the Wolf hypothesis concerning conscious experience, namely, the APP of vN/S, and Snyder's hypothesis (Snyder, 1987) concerning the difference of temporality of the experiential and neurophysiological reference frames. The ZET model resolves the apparent conflict between the Wolf and Snyder hypotheses.

- In the second scenario, awareness of the sensory stimulus is reported to the experimenter after NA is attained, at which time, both the physical record and the ZET record created by quantum collapse exist simultaneously in the laboratory frame of reference and hence the definition of awareness of section 2 is satisfied in this frame. The physical and mental records exist simultaneously in the frame of the ZETs also as in the first scenario. There is no paradox in this case.

Incidentally, the ZET model also explains why a quantum collapse of the brain creates awareness while that of any lifeless quantum never does so. The former collapse differs from the latter by creating new ZETs.

4. Voluntary Action, Conscious Will, and Readiness Potential

"Time's flow is irreversible. The singular exception is provided by the human ability to remember past happenings. When one thinks today about what one did yesterday, time's arrow is bent into a loop. The rememberer has mentally traveled back into her past and thus violated the law of the irreversibility of the flow of time. She has not accomplished the feat in physical reality, of course, but rather in the reality of the mind, which, as everyone knows, is at least as important for human beings as is the physical reality. "...An event happens, a person experiences it, memory traces are laid down representing the event, the past vanishes and is replaced by the present. The memory traces of the event continue to exist in the present, they are retrieved, and the person remembers the event. ... mental time travel involves awareness not only of what has been but also of what may come. This awareness allows auto-noetic creatures to reflect on, worry about, and make plans for their own and their progeny's future in a way that those without this capability possibly could not." So says the well-known experimental psychologist Tulving (2002).

How does the brain/mind of a person do all the above?

Tulving's passages quoted above describe two kinds of human psychological behaviors in relation to time: 1) remembering a past event and 2) planning for future. Nowadays, a computer exhibits both these behaviors to the outside world except that it does not experience a thing when it recollects a past event, and has no worry whatsoever when it makes plans for the future. Let us consider a chess playing program for example. The program plays chess very cleverly and beats most chess players. It chooses every move from a set of moves available at the time in order to beat its opponent. To choose a move, it needs to remember the positions of all king, queen, rook, etc. of both players as well as its goal and it does that. It also figures out a strategy in each step until the game ends. Hence the computer exhibits both behaviors 1) and 2) above. The required information, namely, the definition of the goal and rules specifying how to choose the moves are all already present in the computer. Somebody outside of it has already entered the required information into it and initiated the program to pass from its present state to the future goal state. When the opponent's move is entered and go-button hit, it causes execution of some stored instructions and the program generates a strategy for win. It is as though the go-hit has told the program that its goal is to win and take action accordingly and immediately. The program would not have run without the go-hit; the chess playing program makes no move by itself because it has no desire to win! It is neither happy when it wins nor sad when it loses although it can tell us how many games it played and how many times it won. In the case of the brain-mind system, the physical brain plays the role of a computer's hardware and the mind plays the double role of the software and that of the computer user/operator who initiates the program to run. Memory traces in the brain are purely material analogous to the patterns of the computer memory cells into which all the required information is encoded. They are always in the present; they have no past or future. Like a computer programmer, the mind maps its desires and purposes into its brain and once an NCC of a goal is created in the brain, thereafter, it is just another content of the purely physical brain's memory. NCCs of future goals are like things-to-do lists we write on a paper while NCCs of past events are like what we write in a diary. Whenever necessary, the mind/brain initiates the retrieval process which is then carried out to conclusion by the brain in the presence of the mind, and produces awareness of the past or anticipation of the future.

Action of the mind on the brain

Actions of human beings are often initiated by desires, purposes, needs, and goals, which are all closely associated with future states in our lives. (Activities of other living beings have purposes too). In any given situation, prior to taking an action,

1. one first thinks about what one wants (called volition, passion, desire, etc.) and then
2. how to get it (reasoning).

The search for an appropriate course of action and the action itself depend upon some information pertaining to 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. Therefore, action at present depends upon information regarding a future state[3]. The example in Figure 2 pictorially shows that action at present, with a purpose in mind depends on information pertaining to the chosen future state. Note that the goal in my *present imagination* is not the same as the future physical state of my body because I am not in NY yet. The imagined goal is a mapping of the future physical state (different from the present physical state, otherwise no action happens), into my present memory. So, *the present memory content does depend on a not yet realized physical state*. At this time we do not know *how the brain creates in its present memory, a mapping of a future physical state of itself*. Thus the goal achieving behavior in living systems seems to constitute a breakdown of the causal closure principle. Although the chess program mentioned above makes each move so that its future state is a win state, there is no causality violation by the computer because the future state and the instruction to reach the future state are already entered into the computer by an external agent.

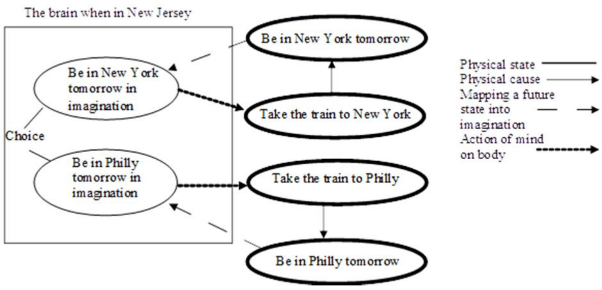


Figure 2. Action at present, with a purpose in mind depends on the chosen future state information.

Stapp (2014c) discusses retro-causation in the context of extrasensory experiences (Radin, 1997), psi phenomena (Bem, 2011), and presentiment experienced in binocular rivalry experiments. He explains that quantum mechanics permits such effects if one accepts the hypothesis of Eccles (1987) that the mental content of a quantum event can bias the quantum mechanical statistical weighting factor associated with its occurrence. In all these experiments, the observer's experience precedes the observation of the event. Stapp says that in these experiments, the mental content of the

[3]Stapp (2014b): "Intentions are formulated in terms of a *projected* (into the future) body-world schema: they are expressed in terms of an image of how the body in its environment is intended to be at a slightly future time. (Thus, for example, the tennis player imagines how he will strike the ball, or where the ball he is about to hit will land in his opponent's court)."

observer at the time of observation influences the outcome of the observation and therefore seems to justify the Eccles hypothesis. From the NY example mentioned above, it appears that one does not have to go to extrasensory experiences to detect the occurrence of retro-causality but that retro-causality may be present in our daily thinking and actions much more often than we recognize it. To understand the mind-brain interaction involved in the process of achieving a goal, let us take another look at the implementation of a goal-achieving process in a computer described above.

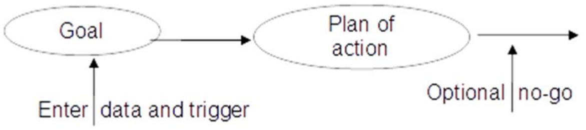


Figure 3. Simulation of a goal achieving process (future state realization) in a computer.

Figure 3 shows the major steps that occur when a goal achieving process is implemented in a computer. First, someone outside the computer (whether it is a human being, or another program, or a physical device), has to enter into it what future state is to be achieved. Then the computer figures out a strategy to achieve the future state assuming that it already has the required data and programs; if not, whatever data are required need to be entered at the very beginning. Then the computer builds records of the future state information and an action plan. Further, the computer needs from outside the instruction to go ahead and achieve the future state. This trigger to activate the action plan can be entered at the very beginning along with the future state information (let us call it the goal); this is like saying - here is your goal figure out how to realize it and then realize it. Alternatively, the trigger can be entered if and when the computer allows the user to choose between 'yes' and 'no' to carry out the plan of action after figuring out the plan. For example, before deleting a selected file, the computer often asks us "are you sure you want to delete the file?" On the other hand, in simple tasks like for example, printing a file, once the user selects the file to print and presses the print button (the trigger), the program not only figures out how to space letters and lines but also prints the file. In the case of the brain-mind system, since the physical brain is the hardware part of a neural computer, the brain creates the NCC of the phenomenal information pertaining to the future state when it receives the information. The goal is required by the brain to take action, whether it is just lifting a finger as in Libet's experiments related to volition, or studying to become an engineer. The will or a desire or a purpose which enters the goal into the brain initiates the future state realization process in the brain. Once it receives the goal, the brain also creates a plan of action and would execute the plan only if it gets a trigger from the same will or desire or purpose. In real life, we do change our minds about the tasks we want to accomplish and the goals we want to pursue. In the example of Figure 2, one may discard the plan of going to say, New York, even after deciding to take a bus or train. Hence the mind is able to give the brain the go or no-go instructions at suitable times.

Conscious Intention and the Readiness Potential

Libet and colleagues performed various experiments investigating brain activity in voluntary action and found that voluntary acts are preceded by electrophysiological "readiness potentials" (RPs). They found that (Libet, 1985) the main negative RP shift began at about 550 msec before movement actually took place, for spontaneous acts involving no preplanning. The time of conscious intention to act was obtained from the subject's recall of the spatial clock position of a revolving spot at the time of his initial awareness of intending or wanting to move (W). W occurred at about 200 msec before the action (Libet *et al.,* 1983). Subjects distinguished awareness of wanting to move from awareness of actually moving (M). Libet associated M to the awareness of initiation of motor command and initiation of efferent cerebral output for the movement. In Libet et al.'s experiments, W times were consistently and substantially in advance of mean times reported for M. Not only did Libet et al. find that a spontaneous voluntary act is initiated unconsciously by the brain but they also found that the decision to act could be consciously controlled during the remaining 150 msec or so after the awareness of intention to act appears. Subjects could in fact "veto" motor performance during a 100-200-msec period before a prearranged time to act. Hence Libet proposed that conscious control can be exerted to select or control volitional outcome before the final motor outflow. The preparatory cerebral processes associated with an RP can and do develop even when an already intended motor action is vetoed at approximately at the time that W normally occurs. The important events in the experiments of Libet *et al.* (1983) investigating brain activity in voluntary action are shown in Figure 4.

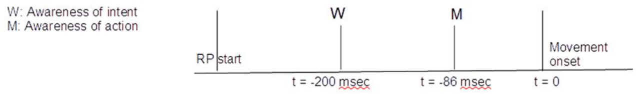


Figure 4. Sequence of events leading to a self-initiated voluntary act.

The brain being made up of matter, a new process such as the RP should have a cause to start it. This fact is seen in Figure 3 which depicts the main events in the simulation of a goal achieving process in a computer. Figure 3 shows that at the very start, the goal (the required information regarding the future state) has to be entered into the brain, the neural computer by an external agent. It shows that the trigger to implement the action plan also needs to be entered by the agent and that the trigger can be entered at the start for tasks of short durations which do not need a later confirmation by the agent. Hence we propose that the directly unobservable mental intention (volition) causes the RP to start and develop and that the developed RP contains records of the goal and action plan as well as the trigger to activate the plan once it is completed. Proposals about action of the mind on its brain in the volition phenomenon were made earlier. For example, Eccles (Beck and Eccles, 1992) proposed the hypothesis that mental intention (volition) becomes neurally effective by momentarily increasing the probability of exocytosis in selected cortical areas. This hypothesis was supported by Hari (2008) by the proposal that Eccles's psychons could be zero-energy tachyons. According to Stapp (2006), the appearance of the RP before the occurrence of W (awareness of intention) is consistent with the vN/S theory; according to him, the action plan development represented by the RP is the action of the mind on the brain through a series of Process 1 probes. The vN/S theory postulates that the mind's action on the brain (the Process 1) is a projection operator on the Hilbert space of the states of the quantum brain. Hence this theory is less abstract than Eccles's theory of the mind's action on the brain in the sense that the vN/s theory provides some tools to express this action in mathematical terms. However, the creation of subjective experience, that is, action of the brain on its mind is assumed in the vN/S theory as a postulate, the APP. On the other hand, in the theory of representation of the mind by tachyons Hari (2008; 2010; 2011), the mind-brain interaction is more explicit than in the vN/S theory because the mind's action on the brain can be directly entered into the Schrodinger equation of the brain as electromagnetic interaction; furthermore, creation of subjective experience is seen to explicitly consist of ZETs and as the back-action of the brain on the mind in response to the mind's paying attention to the brain. For convenience, action of the mind on the brain and that of the brain on the mind are both described in terms of tachyon-matter interactions in the Appendix.

Figure 5 explains the events W, M, and veto using the TTOTI model. We notice the resemblance of the RP process to the cortical stimulus scenario shown in Figure 1b related to Libet's delay-and-antedating experiments.

In Figure 5a, according to the TTOTI model, the RP-start state vector containing the goal information (entered as cortical input by the mind) goes forward in time to the final state where and when the movement starts; the final state clearly contains an observable/reportable record of the goal. The echo state vector travels the entire path backward in time. Quantum collapse occurs in between the space-time state (where and when) the movement starts (which is/observable/reportable) and the state closest to it (in space-time), which is a state that contains the completed goal record (compare with Figure 1b; here, NA is the state containing the completed record of the cortical input). The collapse indicates the creation/actualization of the neural record (as RP) of the cortical input. The corresponding mental record, the 'meaning' of the RP is also created by the collapse according to the tachyon-matter interaction theory (see Appendix). Hence the definition of awareness in section 2 is satisfied and awareness of the goal occurs at the time of quantum collapse. Awareness of the goal is the same as awareness of intention; in other words, the event W occurs after the RP progresses enough to complete creation of the goal record (neuronal adequacy). Thus the RP is started by unconscious will and awareness of the will occurs in the state W.

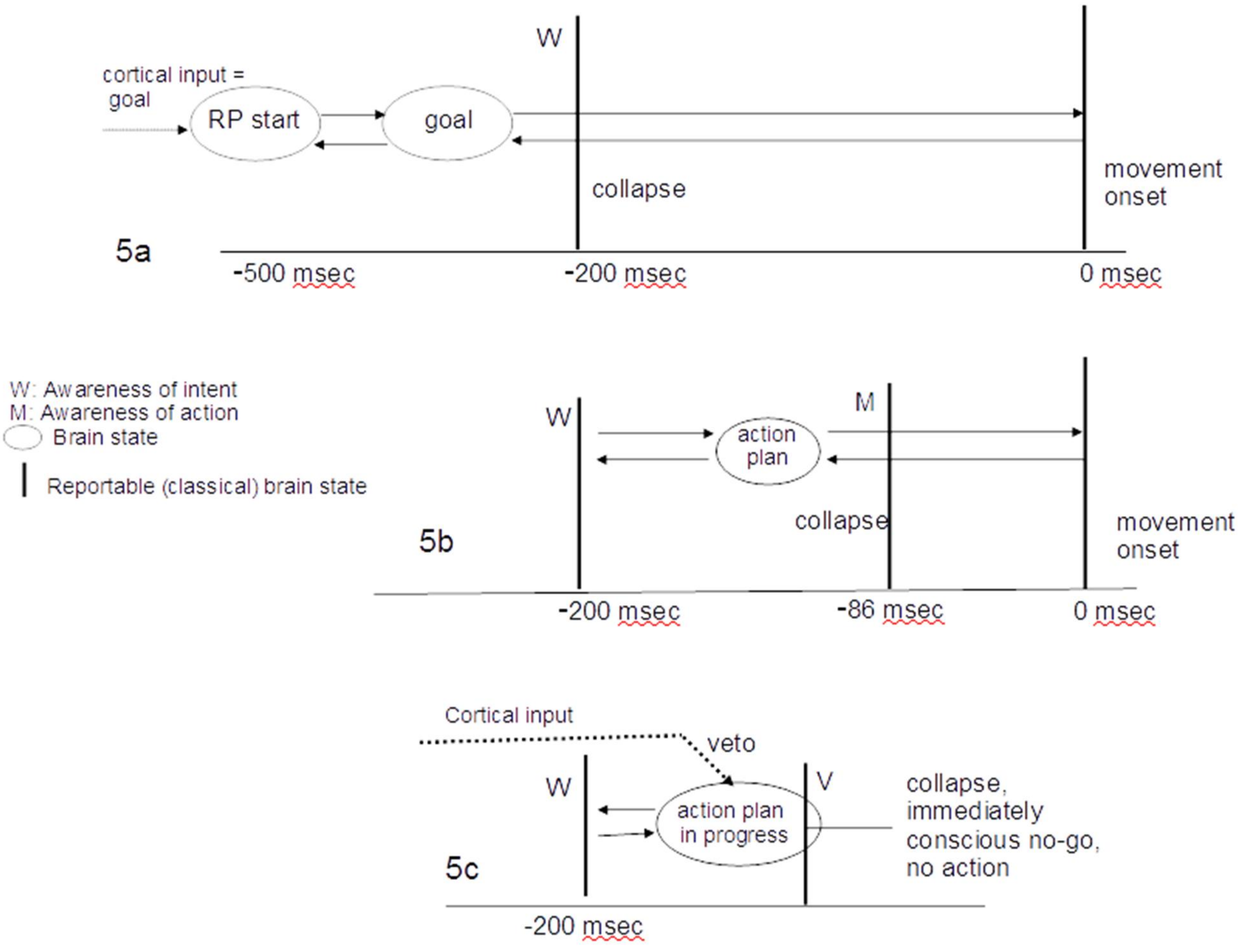


Figure 5. Occurrence of awareness of intention (W), awareness of actually moving (M), and conscious veto due to quantum collapses of the brain.

In Figure 5b, the brain continues to develop the action plan in the form of further RP starting from the observable/reportable state W because the action plan development requires the use of the selected and completed goal record. It is possible that the mind may contribute some cortical input to this process or the brain may be able to do it without assistance from the mind (for example in voluntary acts that become somewhat 'automatic'). In this scenario, the brain's state vector goes forward in time from W to the state of completion of the action plan record (again in the form of RP) and from there to the final state of movement onset while the echo state traces the entire path backward in time. The quantum collapse occurs in between the state with completed neural record of the action plan and final state of movement onset. Since the action plan completion and its activation are supposed to be simultaneous, this collapse creates the mental record of the activated action plan. Thus the state M contains awareness of the initiation of the motor command and comes after W and before the state of movement onset.

Figure 5c shows "vetoing" of motor performance during a 100-200-msec period before movement starts. Here, the brain's quantum state V, where the veto (a cortical input by the mind) enters the brain is supposed to proceed forward in time to the observable state W which does not have the completed action plan record but only the intention to act. However, W occurs earlier than the state V. This means that the brain's wave function collapses immediately and awareness of veto action occurs immediately, hence the conscious veto stops the movement process.

Conclusion

Conscious experience of one is not known to others and not accessible to others by any physical means. Why and how it arises from the physical basis of the brain but never in any lifeless material system is a 'hard problem'. Our proposal that memory and thought in the brain involve tachyons is an interactive dualist theory containing a mathematical definition for the mind and it is free from ill-defined entities such as soul and homunculus. The proposal allows us to describe both action of the mind on the brain and that of the brain on the mind, as action of tachyons on ordinary matter and back-action of matter on tachyons respectively, and in particular, shows how subjective experience is created as a consequence of the quantum collapse of the brain. Using this model of mind-brain interaction, we are able to justify Libet's delay-and-antedating hypothesis and the hypothesis of unconscious initiation and conscious control of voluntary acts. The major challenge to the theory is to provide experimental verification particularly because tachyons have not been detected experimentally so far. However, similar to EM potentials which are not directly observable but their existence can be detected by observing their effects even in regions where the EM fields vanish, it is possible that tachyons can be detected by their action on neural systems in the brain. In particular, the exocytosis phenomena may be a suitable area of investigation for their detection.

Appendix
Creation of Subjective Experience by the Brain

Paying attention by the mind to the brain

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

$$\left(\partial_t^2/c^2 - \nabla^2 - m^2\right)\psi(\mathbf{x}, t) = 0, \qquad (1)$$

where $\mathbf{x}$ is the vector (x, y, z), $\nabla^2 = \partial_x^2 + \partial_y^2 + \partial_z^2$, ∂ denotes differentiation with respect to its suffix, c is the speed of light in free space, and $m = \mu c/\hbar$, $\hbar$ is the Planck's constant. 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 (1), where $\psi(\mathbf{x})$ satisfies:

$$\left[-\nabla^2 - k^2\right]\psi(\mathbf{x}) = 0, \quad \text{and} \quad \omega^2/c^2 = k^2 - m^2 \qquad (2)$$

The frequency ω is real only for $k \geq m$; plane wave solutions $e^{i(\omega t - \mathbf{k}.\mathbf{x})}$ 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 of (1) can be localized in time because solutions $e^{\pm i\omega t}\psi(\mathbf{x}, t)$ exist for all real ω. We assume that local observers of the brain do not move relative to the observed brain with speeds comparable to c, hence tachyon speeds which are much greater than c may be regarded as close to infinity when compared to speeds of the nonrelativistic particles in the brain. 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. In the frame of reference in which the energy of a tachyon vanishes, the magnitude of its momentum = mc; rather than being at rest, such a tachyon has infinite speed! (but it does not move from one point of space to another!) 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).

A zero-energy solution of (1) corresponds to frequency $\omega = 0$ and $k^2 = m^2$ and satisfies the Helmholtz equation:

$$\nabla^2\Phi_m(\mathbf{x}) = -m^2\Phi_m(\mathbf{x}) \qquad (3)$$

Equation (3) has multiple linearly independent solutions $\Phi_m(\mathbf{x})$ corresponding to a given value of m. Each solution is a field with zero energy and capable of exchanging momentum with particles of matter. We take $\Phi_m(\mathbf{x})$ to be real. To describe the interaction of a field satisfying equation (3) with a particle whose motion is governed by a Schrödinger equation, we associate electromagnetic potentials with a solution of (3) as follows. Consider the field

$$\varphi_m(\mathbf{x}, t) = e^{imc(t-t_0)}\Phi_m(\mathbf{x}),$$

where t_0 is a fixed point of time, and the following four-vector in terms of φ: $\tilde{A} = \left(-\nabla\varphi_m(\mathbf{x}, t), \partial_\tau\varphi_m(\mathbf{x}, t)\right)$, where $\tau = ct$. Writing

$$\mathbf{A} = -\nabla\varphi_m \quad \text{and} \quad U = \partial_\tau\varphi_m = im\varphi_m \qquad (4)$$

we find that equation (3) implies that $\mathbf{A}$ and U satisfy the following Poisson equations of the vector and scalar potentials of an electromagnetic (EM) field whose current density and charge density are both zero. **A** and U satisfy the Lorentz gauge condition also.

$$(\nabla^2 - \partial_t^2/c^2)\mathbf{A}(\mathbf{x}, t) = 0,$$
$$(\nabla^2 - \partial_t^2/c^2)U(\mathbf{x}, t) = 0,$$
$$div\mathbf{A} + (1/c)\partial_t U = 0$$

Hence **A** and *U* can be the vector and scalar potentials of an EM field. Note that the potentials **A** and U give rise to zero fields **E** (electric field) and **B** (magnetic field). Nonetheless, we will use *U* and **A** to describe the interaction of a solution of equation (3) with a particle of matter since EM potentials may produce observable effects other than and independent of the electric and magnetic fields produced by them (Aharonov and Bohm, 1959). We assume that the interaction of a tachyon with ordinary matter is momentary because a tachyon with zero energy and hence with infinite speed looks extended in space but like a point in time to non-relativistic observers/particles. Interestingly, Eccles believed that primitive units of the mind called psychons by him interact only momentarily with the brain (Beck & Eccles, 1992).

The effect on the brain of a ZET's nonlocal momentary interaction (simultaneous interaction with particles at different positions in space) can be described in terms of the ZET's associated field $\Phi_m(\mathbf{x})$ by means of the Schrodinger equation (SE) of a many-body system in three dimensions. Denoting the charge of the jth neuron by e_j, its mass by M_j, and its position by $\mathbf{x}_j$, the SE governing the motion of a system of nonrelativistic neurons interacting with the EM scalar and vector potentials *U* and **A** at t = t_o is:

$$i\hbar\partial_t\Psi = \Sigma_j\left\{\begin{array}{l}(1/2M_j)\left[(\hbar/i)\nabla_j - \varepsilon_j\mathbf{A}(\mathbf{x}_j,t)/c\right]^2 \\ +\varepsilon_j U(\mathbf{x}_j,t) + V(\mathbf{x}_j)\end{array}\right\}\Psi$$

(SE)

where the summation Σ is through j = 1, 2, ...N, N being the number of neurons in the system, ∇_j is the gradient operator containing differentiation with respect to the coordinates in $\mathbf{x}_j$. The potential V($\mathbf{x}_j$) accounts for external sensory input as well as internal neural interactions. The jth particle's momentum $\mathbf{p}_j$ before interaction changes to $\mathbf{p}_j - \mathbf{A}(\mathbf{x}_j)/c = \mathbf{p}_j - \nabla\Phi_m(\mathbf{x}_j)/c$ after interaction. Since the interaction is momentary, when t > t_o or t < t_o, the SE of the system is

$$i\hbar\partial_t\Psi = \Sigma_j\left\{(1/2M_j)(\hbar/i)\nabla_j^2 + V(\mathbf{x}_j)\right\}\Psi$$

Paying attention by the mind to the brain consists of a sequence of such momentary interactions imparting impulses. We believe that the unconscious will enters the future state information into the brain in the case of voluntary acts, also by means of impulses.

Response of the Brain to the Mind's Action

Consider the Lagrangian for the free tachyon field governed by the KG equation (1):

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

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

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

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

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

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

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

The Euler-Lagrange equations derived by minimizing the above action S alter the field equation (1) to

$$\left(\partial_t^2/c^2 - \nabla^2 - m^2\right)\Psi(\mathbf{x}, t) = \Sigma\varepsilon_j\delta(\mathbf{x} - \mathbf{x}_j(t)) \quad (5)$$

To find how the momentary interaction with the particles at time t = t_o changes the ZET field, we minimize S subject to the conditions: t = t_o and $\partial_t\Psi = 0$. Substituting these conditions in (5), we find that after the interaction, the ZET field equation (3) changes to:

$$\left(\nabla^2 + m^2\right)\Psi(\mathbf{x}) = \Sigma\varepsilon_j\delta(\mathbf{x} - \mathbf{x}_j(t_0)) \quad (6)$$

Now, the interaction of the ZET, $\Phi_m(\mathbf{x})$ governed by the equation (3), with quantum particles governed by the Schrodinger equation was introduced via the four-potential in equation (4). To find the back-action of the particles on $\varphi_m(\mathbf{x}, t)$, we may apply similar analysis to the massless scalar wave equation:

$$(\partial_t^2 / c^2 - \nabla^2)\, \varphi = 0 \qquad (7)$$

for which $\varphi_m(\mathbf{x}, t)$ is a solution. In this case, we find that the field φ continues to satisfy equation (7) even after interaction. Since $\Phi_{\mathbf{m}}(\mathbf{x})$ does change after interaction as seen from equation (6), it follows that after interaction, the field $\varphi_m(\mathbf{x}, t)$ with a definite value for m changes to a general linear superposition:

$$\phi = \sum_k e^{im(k)c(t-t0)} \Phi_{m(k)}(\mathbf{x}) \qquad (8)$$

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 $\mu = m\hbar / c$ 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 (8) is associated with a tachyon with non-definite mass. Fourier analysis of (8) leads to the uncertainty relation between the spread of ZET mass and spread of time given below:

$$(\Delta mc)(\Delta(t - t_0)) \geq 1 \qquad (9)$$

In a momentary interaction at $t = t_o$, the inequality (9) implies that the spread $\Delta m >> m$ and suggests creation of new ZETs. If t_o is the time when the brain's wavefunction collapses assuming instantaneous collapse as in the Copenhagen interpretation, the inequality implies creation of new ZETs at $t = t_o$. In Bohm's interpretation, there is no collapse but an effective collapse is arrived at by the system in a continuous manner. In this case, the inequality (9) 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 (9) holds if the energy μc^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 in (SE) is to create new ZETs. Since 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 represent all that information.

According to our definition (D) of section 2, for the mind to be aware of an input to the brain, the latter needs to create a reportable (to the outside world) neural record of the input. Ability to report means choosing (by the brain) where and when to exhibit the record, that is, which path the record should take for presentation. This decision implies a collapse of the wave-function of the quantum brain. Note that the so called neuronal adequacy, that is, neural readiness to complete creation of a neural record of the input may be achieved before or after the collapse depending upon the boundary conditions, leading to the well-known delay-and-antedating paradox discussed in section 3. In either case, in the frame of reference of the ZETs created at the moment of the brain's quantum collapse, the neural record of the brain's input and its corresponding mental record made up of ZETs exist simultaneously (Hari, 2011). Hence awareness and subjective experience (because it follows awareness) of the input either from the outside world or from within, for example, volition, occur along with the collapse of the wave-function of the quantum brain.

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