



Psychophysical Interpretation and Conscious Observation in Quantum Field Theory

Rajat Kumar Pradhan

ABSTRACT

Appealing to subject-object duality, we investigate using psychophysical parallelism, the problem of Consciousness in relation to Quantum Field Theory to look for avenues for a consciousness-based unification of Quantum Theory with Special Relativity, and therefore, of all scientific knowledge of the observed physical universe. The implications of such an approach for most of the outstanding unsolved problems in Physics are briefly discussed and several possible objections to the Psychophysical interpretations are addressed.

Key Words: Transactional Interpretation, Psychophysical Interpretation, Quantum Field Theory, Arrow of Time, Time Reversal

DOI Number: 10.14704/nq.2018.16.9.1258

NeuroQuantology 2018; 16(9):34-45

Introduction

Our current scientific understanding of nature is a comprehension of the inanimate objective world of **matter-energy** in its various names and forms as interacting quantum fields, placed in a dynamic background of **space-time**, which is in general curved. Both are so coupled to each other that they mutually determine each other through the equations of general relativity and quantum field theory. As Wheeler (Wheeler, 2000) put it quite succinctly “*space tells matter how to move; Matter tells space how to curve*”. The great desire for the unification of these two facets of the objective world, namely, matter-energy of quantum field theories and curved space-time of general relativity has led us to the string theories in various dimensions and finally to M-theory.

The question that we wish to address goes one step further than the above remarkable statement of Wheeler – we ask, “*Who or what tells matter and space to tell each other like that?*” Why is it like that? Is there a more fundamental

determining or ordering principle involved in the whole show called the phenomenal universe or is it self-determined and self-contained as has been claimed (Hawking, 1988)? Can we address this issue within the ambit of modern physics? Could this principle be an all-pervading cosmic consciousness field (Baaquie & Martin, 2007) that has been proposed in the scientific literature (Pradhan, 2010)?

It has been a moot issue all along whether we are to understand consciousness, which is manifest in living beings as a “knowing mind”, with their physical bodies made up of interacting quantum fields held together by extremely complex biochemical and physiological processes, driven by the host of activities characteristic of life, and inhabiting the same spacetime as the quantum fields as an evolute of the quantum fields themselves or it is to be put in a different category altogether (Tegmark, 2014).

We have shown earlier (Pradhan, 2010) how states of consciousness can be understood

Corresponding author: Rajat Kumar Pradhan

Address: Head, Department of Physics, Bhadrak Autonomous College, Bhadrak, Odisha-756100

e-mail: rajat@iopb.res.in

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 23 February 2018; **Accepted:** 3 August 2018



using quantum mechanical formalism and also how it inevitably enters the state-assignment in quantum mechanics through subject-object duality in the psychophysical interpretation (Pradhan, 2012). It has been shown further (Pradhan, 2016) that the psychophysical interpretation even allows for influencing the probabilities of outcomes of quantum measurements as reported (Radin *et al.*, 2012, 2013, 2016) in a series of recent experiments by Radin and his collaborators. Moreover, we have also shown earlier that conscious observations are also to be taken into account in the relativistic description (Pradhan, 2014) as the subject-object duality is evidently present there as well. The only thing that we have to sacrifice is the much-avowed and prejudiced position that consciousness cannot be different from matter and that it has to be material or physical in character, in spite of the evidences to the contrary. However, it goes without saying that to believe in the existence of something nonmaterial or unphysical like consciousness or mind does not require any special acrobatics than the habitual exercises of a scientifically trained imagination which is accustomed to talking about purely mathematical concepts like probabilities and complex numbers.

On the question of granting existence to non-material or unphysical or metaphysical entities, we note that space and time are themselves metaphysical since they are never observed directly and are only inferred to exist as perceptual modes of the mind. What after all is the definition of a physical entity? *Anything that is a manifestation or form of energy can be considered to be a physical entity, since energy is the physical ultimate of all that exists.* This follows from the fact that all our knowledge of a system in our most fundamental physical theories (QFT) are contained in a Lagrangian or a Hamiltonian dealing with different forms that energy has taken up as the system and any process involving it. What we observe are the objects that affect the senses directly or indirectly. Strictly speaking, space and time were therefore not physical entities as far as physics before GTR (General Theory of Relativity) is concerned, and yet they formed the very starting point of all science and scientific description of reality. It is only in GTR that space-time becomes dynamical, and hence physical.

The duality of the physical and the metaphysical, which earlier was termed mind-matter duality, is something fundamentally

inescapable in the general scheme of science. The prevalent materialistic view that the mind is created by the brain is analogous to the proposal by Newton regarding the gravitational field as being “created” by masses, or of Coulomb and Faraday regarding the electric field as being “created” by charges. Afterwards, we came to realise through Maxwell’s electrodynamics that fields can exist independently of sources and that they can, and do, carry energy. Still later, we came to realize in QFTs that the so-called sources (e.g. charged particles) are themselves excitations of their own quantum fields, while the electromagnetic field that the charges were earlier presumed to produce, was also a field in its own right. Therefore, we can be optimistic that *the mystery will resolve itself when history will repeat itself once more*— that is, the mind will be granted as much an independent existence as the brain which is erroneously taken to be its source.

Thus, it is perfectly logical to assume a dualistic standpoint and try to understand everything from scratch once again, factoring in the mental (metaphysical) aspects alongside the physical. This is the case with the wave function of quantum mechanics or the quantum fields in QFT. They are, at least partly, nonphysical or metaphysical in character, and thus can be associated with psychic phenomena, in addition to the physical phenomena that they are routinely utilized to describe.

In particular, we know that in non-relativistic quantum mechanics the conjugate wave function $\psi^*(\mathbf{x}, t)$ which is a solution of the conjugate Schrodinger equation for the free particle:

$$(-\hbar^2/2m)\nabla^2\psi^* = (-i\hbar) d\psi^*/dt \quad (1)$$

$\psi^*(\mathbf{x}, t)$ could be interpreted as the psychic counterpart to the physical wave function $\psi(\mathbf{x}, t)$ and then many of the problems encountered in quantum theory could be addressed (Pradhan, 2012). It is our goal here to see if we can gain any new insights using such a psychophysical scheme for QFTs.

Quantum Fields in Space and time

The Schrodinger equation is hugely successful in describing many processes but its basic structure is such that it does not treat space and time on the same footing as required by relativity theory. Thus there arose the need for developing relativistically correct wave equations for quanta. These attempts



led to the Klein-Gordon and the Dirac equations which resulted in quantum field theories in which the wave functions of non-relativistic quantum mechanics become field operators capable of creating and annihilating quanta and this is referred to as second quantization. In QED (Quantum Electrodynamics), the electromagnetic field theory of Maxwell is second-quantized and thus a consistent description of interacting charged fields (electrical and otherwise) through the exchange of quanta of the corresponding interaction fields (like photons) has been achieved. Apart from the fact that the second quantized theory becomes a many particle theory involving creation and annihilation of particles, one nagging problem with all these theories has been that of the additional negative energy eigenvalues for each field, following from the relativistic energy formula:

$$E_p = \pm (\mathbf{p}^2 c^2 + m^2 c^4)^{1/2} \quad (2)$$

Historically, the Klein-Gordon equation was initially rejected precisely because of the appearance of these “unphysical” negative energy (hence negative frequency) solutions. However, when Dirac tried to linearize the above relativistic Hamiltonian with a view to getting rid of the spurious negative energy solutions, he also faced the same problem and sought to interpret them as forming an infinite unobservable negative energy sea (Dirac sea) as the background from which all our physical positive energy fermionic particles like the electrons take their birth (Sakurai, 1973).

Thus the inescapable negative energy solutions were not abandoned but were granted an existence which mirrored the positive energy solutions of the real world. The negative energy solutions had opposite charge to the corresponding positive energy solutions and thus were fit to be called antiparticles of the positive energy particles. The argument however did not work with bosons which obeyed Klein-Gordon equation or to QED which did not have to obey a Pauli exclusion principle to get a fully filled-up sea of negative energy particles. An infinite number of bosons can be accommodated in the same negative energy level and thus it poses an insurmountable difficulty for their interpretation in the Dirac sea picture.

On the other hand, the negative energy solutions could not simply be wished away because without them the positive energy solutions do not by themselves form a complete

set of eigen functions and it is necessary for any general solution to a second order wave equation to have the negative energy solutions in its expansion. On the other hand, all experimentally observed antiparticles have positive energy and they do evolve in the forward time direction, just like their particle counterparts. Finally, after about a decade of struggling with this issue of the correct interpretation of the negative energy solutions to the equations of relativistic quantum field theories, Stückelberg (Stückelberg, 1942) and Feynman (Feynman, 1949) independently provided the symmetrical interpretation which treats the particles and antiparticles on the same footing. They interpreted the negative-energy particle solutions as having backward time evolution and thus they could be taken to represent positive energy antiparticle solutions in the forward time direction. Thus, both particles and antiparticles could have positive energy in the forward time direction as is observed experimentally.

The problem of the observed asymmetry in the abundance of particles and antiparticles, the problem of renormalization and the problem of the vacuum zero-point energy still remain unsolved mysteries in QFT. The problem of unification of gravity with standard model quantum field theory of strong, weak and electromagnetic interactions, of course, has remained all the same with very little real progress in our understanding.

We note here that in general, one could have, forward time positive energy (FTPE), forward time negative energy (FTNE), backward time positive energy (BTPE) and backward time negative energy (BTNE) solutions to the second order wave equation (Cramer, 1980), out of which only the first category are experimentally observed to exist. The Stückelberg-Feynman interpretation of QFT restricts NE particle solutions to have only BT movement and thus maps the BTNE solutions to the FTPE category and they are the antiparticles to the corresponding particles. The FTPE are the ordinary particles. Only the BTPE and FTNE types are left out. They will be utilized here to give the psychophysical interpretation of QFTs.

Transactional interpretation and quantum field theory

Cramer (1980, 1986, 1988) tried to extend the notion of transactions to the regime of quantum field theories by incorporating the Stückelberg-



Feynman interpretation of antiparticles into his original emitter-absorber transaction framework for non-relativistic quantum theory. In non-relativistic quantum mechanics, the Schrodinger equation is linear and its conjugate is invoked to provide the advanced wave solutions $\psi^*(\mathbf{x}, t)$ corresponding to the retarded solution $\psi(\mathbf{x}, t)$ to form the transaction, while in case of quantum fields, the same wave equation provides us with both advanced as well as retarded solutions and thus makes transactions even more natural as the means of affecting a real objective collapse or communication.

Cramer's prescription (Cramer, 1980) for field theoretic transactions involving exchange of field quanta on the basis of what he called **generalized absorber theory** is as follows:

- 1) Emission of a particle/wave consists of the production of two half-amplitude waves with opposite time-directions, energies and charges;

$$\phi_{\text{emit}}(\mathbf{x}, t) = + [\frac{1}{2} \phi_{\text{particle}} + \frac{1}{2} \phi_{\text{anti-particle}}] \quad (3)$$

- 2) Absorption consists of the same production of a pair of half-amplitude waves, such that the retarded wave produced by the absorber is 180° out of phase with the retarded waves received from the emitter;

$$\phi_{\text{abs}}(\mathbf{x}, t) = - [\frac{1}{2} \phi_{\text{particle}} + \frac{1}{2} \phi_{\text{anti-particle}}] \quad (4)$$

- 3) The time direction of such waves can be reversed by reversing the signs of the energy and the charge of the waves since backward-time negative-energy antiparticle is indistinguishable from forward-time positive-energy particle;

- 4) Only amplitudes with the same charge, time direction and energy can interfere, subject to the above reinterpretation as per (3) above.

Thus, out of the particle-antiparticle pair emitted by the emitter in (1) above, the antiparticle moving away from the point of emission, would be described by an observer, in view of reinterpretation as per (3) above, as a positive-energy particle moving towards the point of emission. The boundary condition spelt out in (2) above is such that the retarded waves cancel beyond the absorber forward in time after the moment of absorption and the advanced waves cancel beyond the emitter backward in time from the moment of emission. These have been called type-I transactions wherein the interaction

through emission and absorption of *virtual quanta* (in the form of half-amplitude advanced and retarded waves) respectively by the emitter and the absorber is such that the retarded waves interfere constructively only between the emitter and the absorber leading to a full amplitude retarded wave from emitter to absorber that we observe. Thus type-I transactions result in the so called *propagator lines* in Feynman diagrams. Emission and absorption in field theory language correspond respectively to the operation of creation and annihilation operators respectively.

The case of absorption-free emission (creation only) or emission-free absorption (annihilation only) corresponding to free-field lines in the initial and final states of Feynman diagrams require different boundary conditions (the waves sent out by the absorber have no phase change now) and have been discussed by Cramer (*ibid*) as forming the second category or type-II transactions, wherein only the waves connecting the emitter and the absorber cancel each other and full amplitude advanced waves from the emitter in backward time and from the absorber in forward time direction only remain observable. Thus in this case, an observer will see that there is creation or emission of a positive-energy particle (retarded wave solution) from the absorber in the forward time direction and annihilation or absorption of a positive-energy antiparticle (advance wave solution) in the forward time direction.

These above rules of transaction apply equally well to all kinds of quantum fields and thus provide a good ground for a unifying description of all phenomena and herein lies the power and the beauty of the transactional interpretation.

Time-symmetric quantum field theory

Davies (1970, 1971 and 1972) has quantized the wheeler-Feynman absorber theory as a time-symmetric quantum field theory and has shown that the theory can reproduce the same results as in standard quantum electrodynamics. In particular Davies replaces the Feynman propagator by the time-symmetric propagator:

$$D(x) = \frac{1}{2} [D^{\text{ret}}(x) + D^{\text{adv}}(x)] \quad (5)$$

Where, $D^{\text{ret}}(x)$ and $D^{\text{adv}}(x)$ are respectively the retarded and the advanced Green's functions.



All the standard results of QED are obtained in the Davies formulation by replacing the *local* QED interaction

$$J_{QED} = \sum_k \int dx j_{(k)}^\mu(x) A_\mu(x) \quad (6)$$

by the **non-local** current-current direct interaction between emitter and absorber four-currents $j_{(k)}^\mu(x)$ and $j_{(l)}^\mu(x)$:

$$J_{Davies} = -\frac{1}{2} \sum_k \int dx dy j_{(k)}^\mu(x) D_F(x-y) j_{(l)}^\mu(y) \quad (7)$$

where, $D_F(x-y)$ is the standard Feynman photon propagator of QED.

Psychophysical Interpretation of Quantum Fields

The psychophysical interpretation based on the mechanism of actual process of observation provides the clue to the solution of many of the major problems. It endeavors to bring the subjective and the objective aspects together within the existing framework by providing the conjugate quantities with the proper interpretation that was hitherto missing. The conjugate quantities are interpreted to represent the subjective counterparts of the corresponding objective quantities. This is achieved during conscious perception by the mental reversal of the time sense of every process that is cognized by the observer. This simple fact based on the mechanism of actual process of observation provides the clue to the solution of many of the major problems. As will be shown, it has far-reaching implications for cosmology, quantum gravity, arrow of time problem (Zeh, 2007; Carlip, 2014), matter-antimatter asymmetry, theory of perception and also for the ultimate nature of reality.

Interpretation of Field operators and Amplitudes

For a free particle wave function of the form

$$\phi(\mathbf{x}, t) = A_k \exp(i\mathbf{k}\cdot\mathbf{x} - i\omega t) \quad (8)$$

Representing forward time evolution as per the Schrödinger prescription

$$H = i\hbar d/dt \quad (9)$$

The corresponding time reversed Hamiltonian

$$H^\dagger = -i\hbar d/dt \quad (10)$$

will determine the backward time evolution of the time reversed solution

$$\phi^*(\mathbf{x}, t) = A_k^* \exp(-i\mathbf{k}\cdot\mathbf{x} - \omega t) \quad (11)$$

of the conjugate Schrödinger equation eq. (1).

It is to be noted that time reversal automatically implies momentum reversal ($\mathbf{p} \rightarrow -\mathbf{p}$) and this ensures complex conjugation of the forward-time wave function (Sakurai, 1973; Wigner, 1957). This conjugate solution is interpreted as the negative energy solution since it has negative energy eigenvalue ($-\hbar\omega$) with respect to the forward-time Hamiltonian given by eq. (9). Psychophysically, however it has positive energy ($+\hbar\omega$) backwards in time, since the energy operator is given by (10) and not by (9), and is moving backwards in time with momentum ($-\hbar\mathbf{k}$).

In non-relativistic quantum mechanics, $\phi^*(\mathbf{x}, t)$ itself not being a solution of the Schrödinger equation is not given any physical significance and it just enters as a mathematical conjugate of the physically significant wave function. There is no answer in Non-relativistic quantum mechanics as to why $\phi^*(\mathbf{x}, t)$, even though it is not a solution of the forward time Schrödinger equation, should enter everywhere alongside the wave function $\phi(\mathbf{x}, t)$: (a) in determining the basic occupation probabilities of states in quantum mechanics by Born rule, (b) in calculating transition probabilities and decay rates using Fermi golden rule in time-dependent perturbation theory, and, (c) in the S-matrix elements of quantum field theory. Psychophysical interpretation closes this loophole by supplying it with an interpretation on the basis of the inevitable and ubiquitous subject-object duality.

The same psychophysical considerations when applied to the field operators which are solutions of the field theoretic equations of motion like the Klein-Gordon, the Dirac equation or the quantized electromagnetic field equations lead to novel insights into, and interpretations of, quantum field theories.

Brief outline of QFT

We first of all give the following brief outline of quantum field theories:



- In QFT, as distinguished from Non-relativistic QM, the so-called negative energy solutions are valid solutions of the equations of quantum field theory and are essential for their completeness. Thus they are no longer adhoc entrants from outside as happens in non-relativistic QM.
- The wave function ψ becomes the field operator in QFT with the expansion coefficients A_k and A_k^\dagger (A_k^* of QM) elevated to the status of annihilation and creation operators respectively for quanta of momentum $\mathbf{p} = \hbar\mathbf{k}$, and they operate in the space of occupation number states.
- The conjugate field operator ψ^\dagger (ψ^* of QM) is perfectly on par with the field operator ψ and has creation and annihilation operators as coefficients multiplying the negative energy and positive energy exponentials respectively.
- For uncharged quanta, the field operator is real i.e. hermitian ($\psi = \psi^\dagger$) and for charged fields there is need for the assumption of the negative energy particle solutions as representing backward-time movement, which, following Stückelberg and Feynman can be reinterpreted to be representing the corresponding anti-particle solutions with positive energy in forward time, but with momentum and spin reversed.
- The time-reversal operator in single-particle theory as well as in QFT is always so constructed as to ensure positive eigenvalue for the forward-time Hamiltonian and thus it is permanently and inevitably accompanied by complex conjugation, since the negative energy eigenvalues are declared unphysical because they are never observed.

The generic form of the field operators is given by those corresponding to the free Dirac field:

$$\psi(\mathbf{x}, t) = \psi^+(\mathbf{x}, t) + \psi^-(\mathbf{x}, t) \quad (12)$$

and

$$\bar{\psi}(\mathbf{x}, t) = \bar{\psi}^+(\mathbf{x}, t) + \bar{\psi}^-(\mathbf{x}, t) \quad (13)$$

With

$$\psi^+(\mathbf{x}, t) = \sum_{(\mathbf{p},s)} \sqrt{\frac{mc^2}{VE}} b(\mathbf{p}, s) u(\mathbf{p}, s) \exp \frac{i}{\hbar} (\mathbf{p} \cdot \mathbf{x} - Et) \quad (14)$$

$$\psi^-(\mathbf{x}, t) = \sum_{(\mathbf{p},s)} \sqrt{\frac{mc^2}{VE}} d^\dagger(\mathbf{p}, s) v(\mathbf{p}, s) \exp \frac{i}{\hbar} (-\mathbf{p} \cdot \mathbf{x} + Et) \quad (15)$$

$$\bar{\psi}^+(\mathbf{x}, t) = \sum_{(\mathbf{p},s)} \sqrt{\frac{mc^2}{VE}} d(\mathbf{p}, s) \bar{v}(\mathbf{p}, s) \exp \frac{i}{\hbar} (\mathbf{p} \cdot \mathbf{x} - Et) \quad (16)$$

$$\bar{\psi}^-(\mathbf{x}, t) = \sum_{(\mathbf{p},s)} \sqrt{\frac{mc^2}{VE}} b^\dagger(\mathbf{p}, s) \bar{u}(\mathbf{p}, s) \exp \frac{i}{\hbar} (-\mathbf{p} \cdot \mathbf{x} + Et) \quad (17)$$

where, s is the spin index representing the up ($s=1$) and down ($s=2$) spins; V is the normalization volume; m is the mass of the field quanta and $E = |E_p| = + \sqrt{\mathbf{p}^2 c^2 + m^2 c^4}$ is the positive energy eigenvalue with respect to the forward Hamiltonian, $b(\mathbf{p},s)$ and $b^\dagger(\mathbf{p},s)$ are the particle annihilation and creation operators, while $d(\mathbf{p},s)$ and $d^\dagger(\mathbf{p},s)$ are the antiparticle annihilation and creation operators respectively. $u(\mathbf{p},s)$ and $v(\mathbf{p},s)$ are the Dirac spinors while $\bar{u}(\mathbf{p},s)$ and $\bar{v}(\mathbf{p},s)$ are the conjugate spinors obeying the respective Dirac equations for them (Bjorken and Drell, 1965).

For the complex Klein-Gordon fields representing charged scalars, the barred operators become the adjoints, the spinors are set to unity with appropriate changes in the normalization factors. The case of the real scalar field is obtained by setting $b = d$ such that the fields become self-adjoint. For the real vector field such as the electromagnetic field $b = d$, but the spinors and the creation as well as annihilation operators now get an additional vector index (μ) for the space-time components and the spin index s becomes the polarization index (α) in the polarization vector ϵ_α^μ .

Psychophysical interpretation of QFT

In the psychophysical interpretation, it is the backward-time Hamiltonian that has positive energy eigenvalue for time-reversed solutions, since a particle created at time $t = 0$ and moving forward in time with energy E_p , momentum \mathbf{p} and spin \mathbf{s} , when time-reversed mentally, would appear to be a particle moving backward in time with the same positive energy E_p , but momentum $-\mathbf{p}$ and spin $-\mathbf{s}$ and afterwards being annihilated at $t=0$. Thus the same considerations when applied to the negative energy particle solutions in backward-time (reinterpreted by Stückelberg and



Feynman as positive energy antiparticle solutions in forward-time) imply that an antiparticle of positive energy created at $t=0$ and moving forward in time with energy E_p , momentum \mathbf{p} and spin \mathbf{s} , when time-reversed mentally, would appear to be an antiparticle moving backward in time with the same positive energy E_p , but momentum $-\mathbf{p}$ and spin $-\mathbf{s}$, afterwards being annihilated at $t = 0$. Thus pair creation will appear, upon mental time-reversal by the observer during the observation, as pair annihilation and vice versa.

Note that just as in non-relativistic QM, the time-reversed physical state was the unphysical negative energy state (w.r.t. forward-time Hamiltonian), and was equivalent to taking the complex conjugate, and it was interpreted as representing its psychic counterpart; in psychophysical interpretation of quantum fields, the unphysical negative energy (forward-time) parts of the field operators are interpreted as the psychic counterparts to the corresponding physical processes of creation, annihilation and their appropriate combinations to represent psychic propagators to their physical counterparts. Thus $\psi(\mathbf{x}, t)$ and $\bar{\psi}(\mathbf{x}, t)$ are the psychophysical counterparts of each other i.e. when the positive energy component $\psi^+(\mathbf{x}, t)$ represents the annihilation of a physical electron the corresponding conjugate the negative energy component $\bar{\psi}^-(\mathbf{x}, t)$ represents the corresponding psychic creation of the electron and vice versa. Similar interpretation holds for creation and annihilation of (forward-time) positrons also.

Coming to the case of propagators, the Feynman propagator $S_F(x, x')$ for the single physical excitation of the Dirac field propagating from $x = (\mathbf{x}, t)$ to $x' = (\mathbf{x}', t')$ is given by:

$$-\frac{1}{2} S_F(x, x') = \langle 0 | T \left(\psi(x) \bar{\psi}(x') \right) | 0 \rangle \quad (18)$$

where $T(\dots)$ is the Wick time ordering operator. This will have its psychic counterpart, the conjugate propagator given by:

$$-\frac{1}{2} S_F^*(x, x') = \langle 0 | T \left(\psi(x') \bar{\psi}(x) \right) | 0 \rangle \quad (19)$$

Which will determine the time-reversed propagation of the quantum from $x' = (\mathbf{x}', t')$ to $x = (\mathbf{x}, t)$. It is to be noted that this conjugate propagator is already present in all Quantum Field theories and enters the calculations of probabilities and decay rates for processes

through the conjugate M_{fi}^* of the matrix element M_{fi} occurring in the S-matrix. The psychophysical logic employed in the derivation of Born rule – that ***the psychic and the physical are conjugates of each other*** and that ***they come together to give us reality in the form of probabilities*** – thus goes through quite nicely in quantum field theories as well.

The difference from Stückelberg-Feynman is that they impose the condition that the negative energy particle solutions are travelling backwards in time so as to have them reinterpreted as representing the positive-energy forward-time antiparticle solutions as are observed experimentally. This reinterpretation effectively rules out the forward-time realization of negative energy solutions in eq. (2) required by special relativity. But in the psychophysical scheme, the psychic counterparts have positive energy in backward time direction w.r.t backward time Hamiltonian and hence have negative energy in forward time direction w.r.t. forward time Hamiltonian. Thus when a positive energy forward-time (anti)particle is created, simultaneously its psychic counterpart with exactly the same positive energy in backward-time is also annihilated, which means the creation of a negative energy forward-time (anti)particle and thus both solutions of Einstein's mass energy relation have their relevance in the forward time direction. Only that the positive energy is physical, while the unphysical negative energy is precisely its psychic counterpart, that in the psychophysical interpretation is absolutely essential to co-exist with the physical for conscious observation to complete the measurement process.

Thus it keeps intact the Stückelberg-Feynman interpretation of antiparticles and utilizes the same in providing us with a psychophysical understanding of the structure of the matrix elements etc. of Quantum Field theories. Thus, according to the Psychophysical scheme ***all forward-time negative energy is hidden in the psychic realm and it grants existence to all forward-time positive energy objects, events and processes that are observed to exist***. This is an extremely significant conclusion on the nature of reality that we get from the psychophysical interpretation of quantum field theory.



Possible Objections

The following objections to the proposed interpretation need to be addressed before we proceed to evaluate its advantages and utility.

Objection #1: What is the need for a psychophysical interpretation?

Answer: As has been mentioned our primary position is that there has to be a psychic counterpart to everything and anything that is observed. With this basic position in mind we have proceeded to interpret Quantum mechanics, Relativity (Pradhan, 2014) and finally Quantum field theories, such that the fundamental role of the observer in any process is brought out through the inevitable subject-object duality without modifying the existing structure of any of the theories and to show that the formalisms themselves have it inbuilt in them to incorporate observer participation in all phenomena. Moreover, such an interpretation also permits us to take account of mind-matter interactions as already stated in the introduction.

Objection # 2: Why should our physical theories like quantum theory, relativity etc. which are based upon observations on physical systems describe within their framework phenomena involving the unphysical mind of the observer?

Answer: The answer to this objection lies in the fact that our physical theories are not entirely physical since they contain the psychic/mental aspects through the element of time which has admittedly a psychological arrow. There is, truly speaking, nothing physical about “physical time” that enters all our dynamical equations. Thus through time as the opening, the psychic aspects have entered physics and we have capitalized on this ubiquitous presence of time and its psychological arrow to formulate psychophysical interpretations of these theories.

We note in this connection that remembrance of the past is essential for the description of any process as a continuous succession of causally connected events, and it is the hallmark of the conscious mind to remember the past and to be able to have a backward-movement capability in the time axis (i.e. down the memory lane). Imagine what processes we could possibly claim to be in existence if all past up to the running present moment gets continuously erased. No process can be said to exist without the conscious observer’s cognizance of the past history of the process. If we take out the

continuous conscious recording of the past of a process, then there would be only present events without a past, and possibly there could be no “future” as well. The entire show of the phenomenal universe would immediately wind up the moment all past knowledge is erased. In fact all our knowledge is always of the past only, since there is a time-gap due to the finite time of travel of the signals carrying information from the event to the observer.

Thus the very existence of time as a parameter in the dynamical equations of all our physical theories opens up the grand avenue for their psychophysical interpretation.

Objection # 3: If observer participation is essential for reality of phenomena then did the universe exist in a superposition waiting for the first individual of an intelligent species to evolve and make its appearance on the scene so as to effect the first ever wave function collapse by rise of definite knowledge in its consciousness?

Answer: This well-known objection which is usually put forth in favour of decoherence theories and against consciousness-based interpretations loses all force once the existence of the universal, all-pervading, cosmic consciousness is taken cognizance of. In fact, without this underlying all-pervading consciousness nothing could possibly be conceived to exist at all, since all individual subjective perception of that existence is but a limited projection of the original objective existence (as perceived by the all-pervading consciousness) unto the individual psyche. The collapse of the wave-function therefore occurs in the universal consciousness as and when the objective collapse occurs because the all-pervading consciousness cognizes every happening at its one space-time location. Nothing is hidden from this all-pervading, all-observing and all-knowing consciousness. This is because a copy, so to say, of any perception (sensory, imaginary, thought, feeling or whatever) anywhere at any time by any individual mind is immediately stored in the universal mind.

There are now four routes available for attainment of knowledge by an individual observer:

- (a) The observer comes in contact with the cosmic consciousness and knows.
- (b) The observer *believes* in the reports of another who has known from such contact with the cosmic consciousness.



(c) The observer himself/herself makes the observation and brings about the collapse and thus knows.

(d) The observer *believes* in the reports of another who had brought about the collapse or had observed the collapsed state.

We remark that the details of the nature of the original objective existence and the process of extraction of a projection of it by the perception mechanism involving the senses and the mind of an individual perceiver are beyond the scope of this work and hence are kept aside for future research. However, the last two of the above four possibilities form part of our common sense and everyday approach and are well-accepted (quite naively) in all scientific investigations (Pradhan, 2011).

Universal field of consciousness

To motivate further the existence of this cosmic consciousness, we note that anything that we perceive to be part of our individuality is derived ultimately from the corresponding existence of the same substance in the cosmos. For example, one's physical body is made up of molecules and atoms that are conglomerates of mutually interacting electrons, protons and neutrons which, on their part, are derived from the corresponding quantum fields defined at all points in space-time and are thus excitations of the cosmic electron field, cosmic proton field and the cosmic neutron field interacting via the corresponding all-pervading quantum fields like the photon field of QED and the gluon field of QCD.

But our perceptions do not end with the perception of the physical body alone. We do perceive an individual mind existing within each of us, mostly linked with the brain and the nervous system that does the psychological functions of perception, feeling, willing, analysis etc. Could it be possible likewise that this individual mind is an excitation of a cosmic mind which is an all-pervading field and is the cosmic consciousness that is the primary knower of all that happens anywhere anytime by virtue of its possessing the basic characteristic of consciousness (ability to know)? This Omni-present and omniscient field (Pradhan, 2010) can then be taken as the ultimate collapse and knower of all objects, events and processes that go to make up our universe. Indeed, there have been attempts (Baaquie & Martin, 2007) to have a quantum field theoretic description of the emergence of individual centers of consciousness (individual minds) as excitations

of the quantum field of the cosmic all-pervading consciousness.

Thus the introduction, or rather, the recognition, of the existence of a universal consciousness field provides a consistent explanation of all observed phenomena and removes many obscurities and difficulties associated with the interpretations of quantum mechanics as well as of quantum field theories. In what follows we discuss some of the most important consequences of the universal consciousness field for the unified description of all phenomena.

Deeper implications

(a) Matter-Antimatter Asymmetry

The very first and the most fundamental implication of the universal consciousness as the all-knowing existence along with the psychophysical interpretation is that it allows for the creation of a perfectly zero total energy (psychic plus physical) universe, the psychic energy being the exact negative of the positive physical energy created in forward time. Similarly with all other quantum numbers which can all be perfectly zero following psychophysical interpretation. It thus solves the matter-antimatter asymmetry problem in one stroke. Any amount of matter and antimatter can be created with desired physical quantum numbers and the corresponding psychic quantum numbers perceived by the universal consciousness will exactly cancel maintaining a perfect zero-sum all the while. Any physical particle created in forward time is accompanied by the annihilation of the corresponding psychic counterpart backward in time and thus the zero-sum is maintained. In this interpretation then, the whole of creation is thus a *perfect zero-sum game!*

(b) Conservation Laws

There is however the question of the validity of the very well-tested conservation laws of physics like that of energy-momentum etc. that are found to be very accurately maintained in the physical universe. The interpretation proposed here does not go against any conservation law but it subsumes them in the broader framework of the ultimate psychophysical conservation law, the zero-sum rule, *i.e. unless there is a corresponding psychic counterpart, physical conserved quantities (such as energy-momentum or charge) cannot be created or destroyed.* As per this new conservation law for any particle, the relativistic invariant



$\sqrt{E^2 - p^2 c^2} = \pm mc^2$ is a psychophysically conserved quantity with psychic counterpart of $E_{ps} = - mc^2$ corresponding to the physical energy $E_{ph} = +mc^2$.

(c) Creation

The universe's appearance as a quantum fluctuation of the vacuum that got amplified and then evolved according to physical laws up to its present status can then be easily accommodated in this broader psychophysical scheme as having a corresponding psychic backward-time movement towards the dissolution at the moment of creation (Big-bang). The universal consciousness would have knowledge of everything, charted out in complete details from end to end i.e. from big-crunch to big-bang psychically, which merely unfolds physically before us as our familiar universe in forward time from big-bang to big-crunch. This is the operational meaning of omniscience on the part of the cosmic consciousness. Naturally then, nothing could be unknown to this omniscience and thus no hidden variables can be there for it. This cosmic consciousness can be identified as the omniscient God of the philosophers - both eastern and western alike. The limitations of locality and causality apply only to the observations by local individual centers of consciousness like us and not to this omniscience. Hence the possibility of hidden variables cannot be ruled out for scientists making quantum measurements who are limited individual observers.

The initial state of the universe in a particular cycle would be a super-dense holographic volume with all DOF's perfectly frozen, such that the number of such fundamental DOFs obeys the Bekenstein-Hawking entropy formula: $S = k (A/4\ell_p^2)$, where, A = surface area, k = Boltzmann constant and $\ell_p = \sqrt{G\hbar/c^3}$ is the Planck length. Creation of a local island as a "universe" can be assumed to have started with the beginning of the era of accelerated inflation. Preceding that, in the trans-Planckian regime, these fundamental frozen holographic DOFs could be those of M-theory. In this state, all our ordinary notions of particles, matter and energy etc. break down and it would best be described as an *undifferentiated* stationary state of matter-energy-vibration with perfectly interpenetrating vibrating stationary wave modes, a wholeness beyond imagination, which we can call the *primordial nature*. As already pointed out, the psychic counterpart of this *undifferentiated* initial physical state would

then have pervaded everything and known everything simultaneously at the instant of creation.

(d) Dissolution

The big-crunch at the end of the particular cycle would not be a singularity, but a finite volume densely packed with the frozen Planckian DOF. The tremendous gravitational collapse is arrested, and ultimately brought to a halt, by the "degeneracy pressure" arising from the space-time uncertainty relation when the DOFs reach a density such that the average separation between to Planckian DOFs on the surface becomes of the order of Planck length (ℓ_p), i.e. each DOF corresponds to an average area $\sim \ell_p^2$ on the surface. This quiescent state of the *primordial nature* continues till the next cycle begins with an inflationary Big-bang. It is of course not clear after the universe enters the big-crunch and settles itself in the *primordial nature*, whether it is the cosmic consciousness that gives the impetus for the beginning of a new universe through a Big-bang, and if yes, why and how. This would be a big question for future research.

(e) Arrow of Time

The nature of the cosmic consciousness seems to be of the nature of a uniform fiber-bundle on space-time and is thus independent of, and hence, beyond space-time but is defined at all points in space-time and thus fills all space-time. It exists everywhere in space-time just as we say space exists at all times and time exists everywhere in space. The backward time arrow (Barbour *et al.*, 2014) is utilized by the universal consciousness only for purposes of generation of knowledge, while the phenomenal universe rolls out as a forward-time process. Thus both forward and backward arrows of time exist simultaneously with the forward giving physical processes corresponding to the psychic processes in backward time. Thus the time-symmetry in our fundamental theories like QFT and Relativity no longer remains a headache since they provide us with a unified psychophysical description of phenomena, given the proper interpretation. The arrows of time become a problem only when we cling only to the "physical half" of the complete psychophysical process that any phenomenon is.

(f) Absolute frame

The moment of creation by something like a Big bang corresponds to that instant when all the DOF



were frozen and all quanta making up the universe at that moment were simultaneously at absolute rest with respect to each other. Each of the frozen quanta would, at that moment have had perfectly precise momentum value ($\Delta p = 0$) and by the uncertainty principle their positions would have been perfectly uncertain and hence each of them would have uniformly pervaded the entire available volume. Any massless quanta (like photons and gravitons) would have had perfect monochromaticity, that is, exactly measurable energy $\epsilon_n = nh\nu$ with infinite lifetime which would have formed standing wave patterns in the volume. In other words, in such a situation *everything existed everywhere in a perfectly interpenetrating manner!* Since there was no movement, or rather, no scope for any kind of movement, of energy from one Planckian volume to the other, this would then, for all purposes, define a frame at "absolute rest" for our universe.

Thus, even though it is usually claimed following the Relativity theory that *there can be no absolute frame of reference* and that *all processes are relative*, the proposal of a universal all-knowing consciousness pervading all space at the moment of creation can serve as an absolute observer in an absolute reference frame. It can continue to remain as an absolute frame throughout the entire subsequent evolution of the universe, provided it remains unaffected by changes in the physical world of space-time-fields.

(f) Mind and Matter

Our approach based on subject-object duality gives a clear independence to both, mind and matter, as far as their origins are concerned. They are quite separate entities, existing side by side, from the beginning to the end and the duality between them seems to be absolute, apart from the interaction between them leading to measurement and perception. Neither has originated from the other. Whether this duality can be truly absolute or whether one can be derived from the other remains an open question for future researches. It remains to be seen whether parallel to the evolution of the physical universe from the one wholeness of primordial nature to the multiplicity of the universe of objects between the big-bang and the big-crunch, there is a similar evolution from one whole cosmic consciousness to the multiplicity of varieties of individual conscious minds in the subjective front as well. If yes, can we proceed in a manner as in QFTs starting from a universal consciousness field

to the myriad interacting individual centers of consciousness (Martin and Carminati, 2008)?

Finally, we point out that in a perfectly physical objective sense, the quiescence of the big crunch could continue forever without any impetus from some outside agency for a fresh Big-bang. It is everyday experience that a conscious will (we may call it the sixth fundamental force after the proposed anti-gravity as the fifth) can operate on matter-energy and bring about changes in them in a purposeful manner. Since individual centers of consciousness (Martin, Carminati and Carminati, 2010) are endowed with this ability of willful action, it goes without saying that the cosmic consciousness would likewise possess a will of cosmic dimensions, a cosmic will force, the sum total of all individual wills, and may operate on all the physical DOF in the universe in a purposeful manner, such as to effect a fresh creation from the big-crunch by a big-bang. The cosmic will as the totality of all wills will be in the cosmic consciousness/mind and hence it will have to be added as the third important substratum apart from space and time. What space is to matter, time is to energy, same is mind to information/knowledge. With these as basic ingredients of a new theory we will have a true unification.

Conclusion

We have provided a psychophysical interpretation of the quantum field theories and have also briefly outlined how the unification of all phenomena on such a basis would lead to resolution of many long-standing issues in cosmology. The psychophysical interpretation extends the Stückelberg-Feynman interpretation by incorporating subject-object duality precisely in the same way as done in for Quantum theory. The Field operators, the propagators and the matrix elements for different processes, all get their psychophysical counterparts in the form of their corresponding conjugates from within the theory itself. Possible objections to this new interpretation are taken up and its deeper cosmological implications are discussed.

References

- Baaquie BE, Martin F. Quantum psyche: Quantum field theory of the human psyche. *NeuroQuantology* 2007;3(1): 7-42.
- Barbour J, Koslowski T, Mercati F. Identification of a gravitational arrow of time. *Physical Review Letters* 2014;113(18):181101.
- Bjorken JD, Drell SS. *Relativistic Quantum Fields*, 1st edition, New York: McGraw Hill, 1965: 59.



- Carlip S. Arrow of time emerges in a gravitational system. *Physics* 2014;7:111.
- Carminati GG, Martin F. Quantum mechanics and the psyche. *Physics of Particles and Nuclei* 2008;39(4):560-77.
- Cramer JG. An overview of the transactional interpretation of quantum mechanics. *International Journal of Theoretical Physics* 1988;27(2):227-36.
- Cramer JG. Generalized absorber theory and the Einstein-Podolsky-Rosen paradox. *Physical Review D* 1980;22(2):362-76.
- Cramer JG. The transactional interpretation of quantum mechanics. *Reviews of Modern Physics* 1986;58(3):647.
- Davies PC. A quantum theory of Wheeler-Feynman electrodynamics. In *Mathematical Proceedings of the Cambridge Philosophical Society* 1970; 68 (3): 751-64.
- Davies PC. Extension of Wheeler-Feynman quantum theory to the relativistic domain. I. Scattering processes. *Journal of Physics A: General Physics* 1971;4(6):836.
- Davies PC. Extension of Wheeler-Feynman quantum theory to the relativistic domain. II. Emission processes. *Journal of Physics A: General Physics* 1972;5(7):1025-36.
- Feynman RP. Space-time approach to quantum electrodynamics. *Physical Review* 1949;76(6):769.
- Hawking S. *A Brief History of Time: From the Big Bang to Black Holes*. Bantam books, 1988.
- Martin F, Carminati F, Carminati GG. Quantum information, oscillations and the psyche. *Physics of Particles and Nuclei* 2010;41(3):425-51.
- Pradhan RK. An expansion of psychophysical interactions in the quantum double slit experiment. *Physics Essays* 2016; 28(3): 324-30.
- Pradhan RK. Are quantum states subjective? *OJP*, 2011 18(2): 158-62. arXiv: 1202.4886[quant-ph].
- Pradhan RK. Psychophysical interpretation of quantum theory. *NeuroQuantology* 2012; 10(4):629-45.
- Pradhan RK. Subject-object duality and the states of consciousness: A quantum approach. *NeuroQuantology* 2010; 8(3):262-78.
- Radin D, Michel L, Delorme A. Psychophysical modulation of fringe visibility in a distant double-slit optical system. *Physics Essays* 2016;29(1):14-22.
- Radin D, Michel L, Galdamez K, Wendland P, Rickenbach R, Delorme A. Consciousness and the double-slit interference pattern: Six experiments. *Physics Essays* 2012;25(2): 157-71.
- Radin D, Michel L, Johnston J, Delorme A. Psychophysical interactions with a double-slit interference pattern. *Physics Essays* 2013;26(4):553-66.
- Sakurai JJ. *Advanced Quantum Mechanics*. 4th edn. Reading Mass: Addison-Wesley, 1973.
- Stückelberg ECG. *Helvetica Physica Acta* 1942; 15:23-37.
- Tegmark M. Consciousness as a state of matter. *Chaos, Solitons & Fractals* 2015;76:238-70.
- Wheeler JA, Feynman RP. Classical electrodynamics in terms of direct interparticle action. *Reviews of Modern Physics* 1949;21(3):425-33.
- Wheeler JA, Feynman RP. Interaction with the absorber as the mechanism of radiation. *Reviews of Modern Physics* 1945;17(2-3):157- 81.
- Wheeler JA, Ford K. Geons, black holes and quantum foam: A life in physics, *American Journal of Physics* 2000; 68(6): 584(Reviewed by John S. Rigden).
- Wigner EP. Group theory and its applications to the quantum theory of atomic spectra. (1931), 326, (Translation) New York: Academic press, 1959.
- Zeh HD. *The physical basis of the direction of time*. Berlin: Springer, 2007.

