Original Article

Towards a Theory of Everything Part III

Introduction of Consciousness in Loop Quantum Gravity and String Theory and Unification of Experiences with Fundamental Forces

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Abstract

Theory of everything must include consciousness. In this article, we focus on introducing the subjective experience (SE) aspect of consciousness in modern quantum physics, namely, loop quantum gravity (LQG) and string theory by using the methodology of examining invariance of these theories under the PE-SE transformations, where PEs (proto-experiences) are precursors of SEs. In our dual-aspect-dual-mode PE-SE framework, (i) each of strings, loops, elementary particles, inert matter, or neural-networks has physical (material) and mental aspects, and (ii) there are three competing hypotheses: *superposition* based $\mathbf{H_1}$, *superposition-then-integration* $\mathbf{H_2}$, and *integration* based $\mathbf{H_3}$ as discussed in Part I. In Part I and Part II of this series of 3 articles, we introduced the SE aspect of consciousness in classical and orthodox quantum physics, respectively, which are invariant under PE-SE transformations. In the **current Part III**, the critical components of LQG with Palatini action appear invariant under this transformation. In string theory, for $\mathbf{H_1}$ and $\mathbf{H_2}$, we quantitatively introduce the superposition of ***potential*** experiences (SEs/PEs) in the mental aspect of bosonic and fermionic strings using the Polyakov action. We find that experiences are independent of the time-like and space-like parameters (τ, σ). This is interpreted as a string is a dual-aspect entity and all fundamental *potential* SEs/PEs that are superposed in the mental aspect of the string remain invariant with time and space. The introduction of mental aspect in this manner suggests that the mental aspect of string could be in all dimensions: both (3+1)D real dimensions and also in the hidden dimensions that are compactified (curled up). In addition, the Neumann and Dirichlet boundary conditions were also satisfied. These led us to conclude that the physical aspect of the behavior of system in string theory remains invariant under the introduction of experiences aspect of consciousness in the mental aspect of strings. For hypothesis $\mathbf{H_3}$, the equations of string theory remain the same as they are; we simply need to acknowledge that a string has dual-aspect; its mental aspect is string-PE. Furthermore, if the introduction of SE aspect of consciousness in string theory is interpreted to imply that experiences are independent of time and space in all dimensions, it may not be true in conscious beings. This is because SEs change with subjects across space and time. This fact is revealed in the introduction of SE aspect of consciousness in general theory of relativity of classical physics: (i) For the structure of spacetime (empty space or the vacuum without matter), *potential* SEs are superposed in the mental aspect of spacetime and are embedded in spacetime geometry. (ii) For matter field, *potential* SEs/PEs are superposed in the mental aspect of each elementary particle (fermion or boson including graviton); wherever these particles move, superposed *potential* SEs/PEs must also move with them to conserve the superposed *potential* SEs/PEs. (iii) However, since our specific SE is the result of matching and selection processes that actualize/realize the relevant *potential* SE, the SE can change with space and time. For example, the neural correlate/analog of experiencing *redness* is V4/V8/VO-red-green neural-net with *redness* state. When a subject moves, the specific SE *redness* also moves with the subject's correlated neural-net. SEs also change with time as stimuli change. In other words, SEs in a subject change with spacetime. We conclude that it is possible to unify SEs/PEs aspect of consciousness with all four fundamental physical forces by the introduction of (i) *potential* SEs/PEs (as in $\mathbf{H_1}$) or PEs (as in $\mathbf{H_2}$) in latent superposed form in the mental aspect of bosonic and fermionic strings or (ii) the bosonic-string-PE and fermionic-string-PE based on *integration* principle (as in $\mathbf{H_3}$). This leads us towards the theory of everything.

Key Words: theory of everything, proto-experiences, subjective experiences aspect of consciousness, superposition, loop quantum gravity, string theory

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Abbreviations and symbols list

EM : electromagnetic
$g_{\mu\nu}$: metric tensor
GTR : general theory of relativity
H_1 : *superposition* based hypothesis
H_2: *superposition-then-integration* based hypothesis
H_3 : *integration* based hypothesis
I : stimulus intensity
Λ : the cosmological constant
LQC : loop quantum cosmology
LQG : loop quantum gravity
OR : objective reduction
Orch OR : orchestrated objective state-reduction
PE(s) : proto-experience(s)
$R_{\mu\nu}$: Ricci curvature tensor
R : Ricci scalar curvature
SE(s) : subjective experience(s)
STR : special theory of relativity
$T_{\mu\nu}$: the stress-energy tensor
TOE : Theory of everything
SAS(s) : self-aware substructure(s)
V1 : visual area 1
V4 : visual area 4
V8 : visual area 8
VO : ventral-occipital cortex

1. Introduction

As elaborated in (Vimal, 2010d), the theory of everything (TOE) must include consciousness in addition to the unification of gravitational,[2] electromagnetic, weak, and strong forces. For this purpose, our development has 3 parts: the introduction of subjective experiences (SEs) and/or proto-experiences (PEs) aspect of consciousness in classical physics (**Part I**), orthodox quantum physics (**Part II**), and modern quantum physics (loop quantum gravity (LQG) and string theory) (**Part III**).

In Part I (Vimal, 2010c) of this series of three articles, the SE aspect of consciousness was introduced in classical physics. The methodology was to examine the invariance of critical components of theories under PE-SE transformations. PEs are precursors of SEs.[3] In classical physics, the invariant entities under the PE-SE transformations are:

[2] According to (Verlinde, 2010), gravitational force is not a fundamental force; rather it is an entropic force and is a derived entity from information. See also (Vimal, 2010c).

[3] According to (Vimal, 2010b), "Under hypothesis H_1, PEs are precursors of SEs in the sense that PEs are superposed [potential] SEs in unexpressed form in the mental aspect of every entity from which a specific SE is selected [via matching and selection process in brain-environment system]. Under hypotheses H_2 and H_3, PEs are precursors of SEs in the sense that SEs somehow arise or emerge from PEs".

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electromagnetic strength tensor, electromagnetic stress-energy tensor, the electromagnetic theory (Maxwell's equations), Newtonian gravitational field, entropic force, special theory of relativity and Lorentz transformation, geodesic equation, general theory of relativity: Ricci curvature tensor $R_{\mu\nu}$, Ricci scalar curvature R, the stress-energy tensor $T_{\mu\nu}$, and the metric tensor $g_{\mu\nu}$ (generalization of the gravitational field). From this development, we concluded that: (a) for the structure of spacetime (empty space or the vacuum without matter), *potential* SEs are superposed in the mental aspect of spacetime and are embedded in spacetime geometry. (b) For matter field, *potential* SEs are superposed in the mental aspect of each elementary particle (fermion or boson including graviton); wherever these particles move, superposed *potential* SEs must also move with them to conserve SEs, i.e, to make $\mathcal{E}$ constant with space and time. (c) Our specific SE is the result of matching and selection processes and can change with space and time. For example, the neural correlates[4] of experiencing *redness* is the V4/V8/VO-red-green neural-net with redness state. When a subject moves, the specific SE *redness* also moves with the subject's correlated neural-net. These finding are consistent with the dual-aspect-dual-mode *optimal* PE-SE framework (Vimal, 2008a; Vimal, 2008b; Vimal, 2009c; Vimal, 2009d; Vimal, 2009e; Vimal, 2009g; Vimal, 2009h; Vimal, 2010a; Vimal, 2010b). It is argued that since this *optimal* framework (that has the least number of problems) is valid at all three levels (classical, quantum, and subquantum physics), the introduction of consciousness in classical, quantum, and subquantum physics is also valid.

In Part II (Vimal, 2010d), the SE aspect of consciousness was introduced in orthodox quantum physics using the same methodology as in Part I. We found that the followings are invariant under the PE-SE transformations: Schrödinger equation, current, Dirac Lagrangian, the Lagrangian for a charged self–interacting scalar field, and Standard Model (the Lagrangian for free gauge field and Lagrangian for the electromagnetic interaction of a charged scalar field (Higgs Mechanism)) using orthodox quantum physics.

In the current Part III, our goal is to introduce the SE aspect of consciousness in modern quantum physics (LQG and string theory) using the same methodology of examining invariance of theories under the PE-SE transformations as used in Part I (Vimal, 2010c) and Part II (Vimal, 2010d). This results that modern LQG and string theory are also invariant under the PE-SE transformations, which include the transformations used in Part II. We conclude that all three parts together lead us towards the theory of everything that includes consciousness.

1.1. *String theory and PE-SE framework*

String theory is a 'sub-elementary-particle' theory because elementary particles (fermions and bosons) can be derived from strings as different vibrating modes. The competitive loop quantum gravity (LQG) is based on

[4] According to (Trehub, 2005), "I have proposed a law of conscious content, which asserts that for any experience, thought, question, or solution there is an analog in the biophysical state of the brain. As a corollary to this principle, I have argued that the conventional attempts to understand consciousness simply by searching for its neural correlates [NCC] (in both theoretical and empirical investigations) are too weak to provide a good understanding of conscious content. Instead, I have proposed that we go beyond this and explore brain events that have at least some similarity to our phenomenal experiences -- namely, neuronal analogs of conscious content [NAC]. In support of this approach, I have presented a theoretical model that does more than address the sheer correlation between mental states and neuronal events in the brain. It explains how neuronal analogs of phenomenal experience [NAC] can be generated, and it details how essential human cognitive tasks can be accomplished by the particular structure and dynamics of putative neuronal mechanisms and systems in the brain."

loops.[5] Both theories can be included in 'modern quantum physics'.

Orthodox quantum mechanics was invented to introduce fuzziness by uncertainty principle to address the classical physics problem of $1/r^2$ singularity as $r \to 0$ at micro-level. However, the $1/r^2$ singularity in gravitational force was still not resolved, i.e., the problem of combining general relativity and quantum physics still remained. To address this problem, new sort of fuzziness was needed. For this, 'point particles' are replaced by 'strings' via string theory (Witten, 1998). "Quantum effects are proportional to Planck's constant $\hbar$, and stringy effects are proportional to a new [fundamental] constant α' ($\sim(10^{-32}$ cm$)^2$) that determines the size of strings" (Witten, 1998). In other words, "interactions between strings do not occur at (point-like) vertices but at finite portions of the strings"[6]. In LQG, the 'point particles' are replaced by 'loops' to address the singularity problem.

In string theory (including superstring theory, M-theory, F-theory, or theory of everything) both bosons (force carriers, such as photons) and fermions (constituents of matter, such as electrons) are simply the same string vibrating in different modes. Harmonics of strings give rise to the whole of the field of matter (Robbins, 2007); different harmonics correspond to different elementary particles; their interactions are simply 'splitting or joining' of strings. For example, "*A proton can be thought of as three vibrating strings, one for each quark*" (Vimal, 2009a); the emission of a photon from an electron is the splitting of a string into two strings, whereas the absorption of a photon by an electron is the joining of two strings into one. The "strings vibrate at different frequencies which determine mass, electric charge, color charge, and spin" (Vimal, 2009a). "These strings have certain vibrational modes which can be characterized by various quantum numbers such as mass, spin, etc. The basic idea is that each mode carries a set of quantum numbers that correspond to a distinct type of fundamental particle. [...] A consistent quantum field theory of superstrings exists only in 10 spacetime dimensions! Otherwise there are quantum effects which render the theory inconsistent or 'anomalous'. In 10 spacetime dimensions the effects can precisely cancel leaving the theory anomaly free. [...] if we start with a theory of general relativity in 5-spacetime dimensions and then curl up one of the dimensions into a circle we end up with a 4-dimensional theory of general relativity plus electromagnetism! " (Vimal, 2009a).

In 10D string theory, the six extra spatial 'hidden' dimensions are curled in infinitesimal geometric shapes at every single point in our universe. "According to string theory mathematics, the extra dimensions could adopt any of tens of thousands of possible shapes, each shape theoretically corresponding to its own universe with its own set of physical laws. [...] the six tiny dimensions had their strongest influence on the universe when it itself was a tiny speck of highly compressed matter and energy — that is, in the instant just after the Big Bang" (Vimal, 2009a). The curling up of 'hidden' dimensions into small spaces (compactification) "induces 'moduli' fields, which describe the size and shape of the compact dimensions at each point in space-time. These moduli fields generate forces with strengths comparable to gravity" (Long *et al.*, 2003). Hidden dimensions "can give rise to forces in the dimensions that we can see" (Vimal, 2009a).

Furthermore, "The various resonant vibrational modes account for the different forms matter takes in terms of mass and force charge (e.g., electrical charge, weak charge, strong charge). [...] The strings are on the order of the Planck length [$\sim 10^{-33}$ cm] in size. [...] these properties (such as mass and force charges) emerge as resonances, specific vibrational patterns [...] Greater energy means greater mass (gravitational charge) and indicates a higher vibrational mode. Similarly, electric charge, weak charge, and strong

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[5] In LQG, space (i.e. the universe) can be viewed as an extremely fine network of finite quantized loops (of excited gravitational fields) called spin networks, which evolves over time in discrete steps.

[6] Adapted from http://www.stardrive.org/Jack/hyperspace1.pdf

charge are carried by a particular string vibration mode. […] Each elementary particle consists of a single string (all of which are fundamentally identical) undergoing a characteristic resonant vibration ('different notes')" (Vimal, 2009a). String has tension that is related to mass and has charge (Vimal, 2009a). Matter (fermions) and force (bosons) are simply different aspects of the same fundamental entity and are thus unified; for the same reason, all fundamental forces including gravity are also unified in string theory (Vimal, 2009a).

Since the vibrational pattern of string determines the mass and charge of the resulting fermions and bosons, the specific shape and size of the extra dimensions has a significant impact on the properties of elementary particles (Greene, 1999). "In order to include fermions in string theory, there must be a special kind of symmetry called supersymmetry, which means for every boson (particle that transmits a force) there is a corresponding fermion (particle that makes up matter). […] supersymmetry relates the particles that transmit forces to the particles that make up matter: for every boson, there is a corresponding fermion" (Vimal, 2009a).

M-theory (Witten, 1998) has 11 dimensions: 3 visible spatial xyz dimension and 1 time dimension, 6 curled up hidden spatial dimension, and 1 membrane dimension covering the 10D. This eleventh membrane dimension unifies the five string theories (Type I, Type IIA, Type IIB, heterotic HO, and heterotic HE) by examining certain identifications and dualities, where each of the five string theories becomes a special case or just different aspects of M-theory. "There are five different ways to shrink away one of the 11 dimensions of M-theory, and they lead to those five 10D superstring theories. So all five competing theories are actually part of the same Big Picture" (Vimal, 2009a).

In string theory landscape, "[a]ny scientists who study nature must live in a part of the landscape where physical parameters take values suitable for the appearance of life and its evolution into scientists" (Weinberg, 2007). This is consistent with the ultimate ensemble theory based on the anthropic principle: "all structures that exist mathematically exist also physically […] [they] contain self-aware substructures […], [which] subjectively perceive themselves as existing in a physically 'real' world" (Tegmark, 1998). According to (Tegmark, 1998), TOE is merely the ultimate ensemble theory that contains *self-aware substructures* (SASs), which can logically think and subjectively perceive time (not necessarily space!) and perceive themselves as existing in a physically *real* world. For the existence of SASs, the three necessary criteria are *complexity, predictability, and stability*. To sum up, "[i]n the discrete two-dimensional space corresponding to different numbers of space and time dimensions, all but the combination 3+1 appear to be 'dead worlds', devoid of SASs. If there were more or less than one time-dimension, the partial differential equations of nature would lack the hyperbolicity property that enables SASs to make predictions. If space has a dimensionality exceeding three, there are no atoms or other stable structures. If space has a dimensionality of less than three, it is doubtful whether the world offers sufficient *complexity* to support SASs (for instance, there is no gravitational force)" (Tegmark, 1998). If this is correct, then string theories that have dimensions higher than 3+1 D will not inhabit SASs: for example, F-theory is 10+2 D will not inhabit SASs because the time dimension is 2 and hence SASs will not be able to make *predictions*. The M-theory is 10+1 D will not inhabit SASs because the space dimension is greater than 3 and hence SASs will not be *stable*. Thus, string theories are rejected unless their properties exclude the existence of SASs. However, one could argue that it's extra hidden spatial dimensions are compactified (*curled up*). This means at the limit where the size of the compact dimension goes to zero, no fields depend on the extra dimensions, and the theory is *dimensionally reduced to simply (3+1) physics,* which represents our physical aspect.

Furthermore, “multiverse scenarios and anthropic selection are not only motivated by string theory, but lead also to a possible explanation for the fine tuning of the universe” (Hedrich, 2006). According to anthropic principle states, “the presence and even consciousness of humans in the universe may influence the laws of physics. If the laws of physics are tweaked to eliminate the evolution of life then the evolution of galaxies and stars also becomes uncertain. Experiments have demonstrated that decisions an experimenter makes appear to change the nature of matter and energy even at a time before the experimenter makes a measurement.”[7]

F-theory is the extension of M-theory and is 12 dimensional string theory with metric signature (10,2) (Vafa, 1996). It seems to have 10 spatial and 2 temporal dimensions (Eerikäinen, 2000; Kar, 1997). “Special relativity describes spacetime as a manifold whose metric tensor has a negative eigenvalue. This corresponds to the existence of a ‘time-like’ direction” (Vimal, 2009a). “Dunne's theory, elaborated from years of experiments into precognitive dreams and induced precognitive states, is that in reality all time is eternally present, that is, that past, present and future are all happening together in some way. Human consciousness, however, experiences this simultaneity in linear form. [...] The Aboriginal people of Australia, for example, believe that the Dreamtime exists simultaneously in the present, past and future, and that this is the objective truth of time, linear time being a creation of human consciousness, and therefore subjective” (Vimal, 2009a).

Interestingly, “Heim’s time is ontologically justified two-dimensional space. Its first dimension is objectifiable, physical and temporal space, and its second dimension is non-objectifiable and eternal space, nunc aeternum” (Eerikäinen, 2000). “Alex Green has developed an empirical theory of phenomenal consciousness that proposes that conscious experience can be described as a five-dimensional manifold. [...] Green considers imaginary time to be incompatible with the modern physical description of the world, and proposes that the imaginary time coordinate is a property of the observer and unobserved things (things governed by quantum mechanics), whereas the real time of general relativity is a property of observed things” (Vimal, 2009a).

Randall-Sundrum theory (warped geometry in extra dimensions) proposes a higher-dimensional mechanism for solving the hierarchy problem, and 4D Newtonian and general relativistic gravity can be reproduced even without a gap in the Kaluza-Klein spectrum (Randall and Sundrum, 1999a; Randall and Sundrum, 1999b). The hierarchy-problems are (i) why fundamental parameters (couplings or masses) of some Lagrangian are vastly different (usually larger) than the parameters measured by experiment, and (ii) why the weak force is significantly stronger than gravity;[8] they are addressed by supersymmetry theory (Vimal, 2009a). One could argue that gravity is extremely weak force in comparison to other forces, which may be because gravity might be leaking from (or into) our 4D universe into (or from) 5D universe. If this is true then one could further speculate that consciousness might be leaking out of our brains into other hidden dimension(s) or leaking in, form a membrane, into our brains (Hardcastle, 2009). However, Ockham's razor must be considered when assigning consciousness to higher dimensions: consider higher dimensions when 4D completely fails to explain consciousness. One could argue for assigning consciousness to higher dimensions because mixing consciousness with matter is a category mistake, in addition materialism fails because of the Levine’s explanatory gap (Levine, 1983) and other reasons such as pre-existence of SEs

[7] http://www.pythabacus.com/CCgame/AnthroP.htm

[8] (Relative strength, range in meter): gravitational force: (1, infinite), weak force: (10^{25}, 10^{-18} m), electromagnetic force: (10^{36}, infinite), strong force: (10^{38}, 10^{-15} m).

for *picking them out demonstratively* (Vimal, 2009a; Vimal, 2009f).

String theory and consciousness might be connected.[9] One could speculate that SEs might have something to do with hidden variables, 'internal' dimensions of gauge theory, and/or the compactified dimensions of string/M-theory; for example 4 spatial dimensions are needed in Kaluza-Klein theory for unifying electromagnetism and gravity, 11D in M-theory, and 12D in F-theory to unify all 4 forces (Flanagan, 2001). Thus, the total number of dimensions is (i) our visible 3 spatial and 1 temporal dimension, and (ii) 7 or 8 extra or 'hidden' dimensions. Furthermore, in the PE-SE framework (Vimal, 2008b), the superposition of all fundamental *potential* SEs/PEs was speculated to be in one or more 'hidden' dimensions of string/M-/F-theory. In F-theory, the metric signature (10, 2) indicates that two of the 12 dimensions have negative eigenvalues, i.e., one could interpret these 2 dimensions as representing two time dimensions. Alternatively, one could argue that these 2 dimensions with negative eigenvalues are for non-physical entities, one for phenomenal space and one for phenomenal time ([3+1=4] + [1+1=2]) = (4+2)-Physics. In other words, *potential* SEs/PEs might be superimposed in these two dimensions. These speculations can be tested. However, our analysis in this article suggests that the mental aspect of string could be in all dimensions: both (3+1)D real dimensions and also in the hidden dimensions that are compactified (curled up).

Furthermore, according to (Bars and Quelin, 2008), "The relation between two time physics (2T-physics) and the ordinary one time formulation of physics (1T-physics) is similar to the relation between a 3-dimensional object moving in a room and its multiple shadows moving on walls when projected from different perspectives. The multiple shadows as seen by observers stuck on the wall are analogous to the effects of the 2T-universe as experienced in ordinary 1T spacetime." Observers stuck on the wall must work hard to find relationship between shadows to make sense of them and integrate them. Problems with consciousness are somewhat similar. Problems with (3+1)-Physics (assuming that Physics needs to explain everything) are: (i) how consciousness emerges; mind and matter seem different but are related (mind-brain duality/dual-aspect in space) and (ii) phenomenal time (subjective experience of time) and physical clock time look different but are related (mind-brain duality/dual-aspect in time). String theory has addressed various duality problems, such as T-duality (small and large distance between string theories), S-duality (strong and weak coupling strengths between string theories), U-duality, Gauge-gravity duality, and so on. Can (4+2)-Physics and string theory combined address the consciousness related duality in (3+1)-Physics? One could argue that mind-brain duality/dual-aspects could be unified at higher dimensions.

Furthermore, "Corresponding to most kinds of particle, there is an associated antiparticle with the same mass and opposite charge. For example, the antiparticle of the electron is the positively charged antielectron, or positron, which is produced naturally in certain types of radioactive decay. [...] If a particle and antiparticle are in the appropriate quantum states, then they can annihilate each other and produce other particles. Reaction such as $e^- + p^+ \rightarrow \gamma + \gamma$ (the two-photon annihilation of an electron-positron pair) is an

[9] According to Ruquist, "Spin of a collection of particles or loops equal to zero [in his 26D superstring mode] is the basis of both the EPR experiments and the Conway-Kochen 'Free Will' Theorem, which may be a connection to consciousness. [...] Similar to human consciousness, Burrows divides the 12 dimensions into (i) a 4d loop for the model of the outside world, (ii) a second 4d loop for the model of the self in the world and (iii) the third 4d loop for the Self itself. It may be that all forms of consciousness require this three-fold separation for self-reflection. [...] The highest level is within the Self 4d loop and would be fixed, and perhaps similarly for the self model and the world model. The next level of entanglement down would be between the Self and either the model of the self or the world model. According to Burrow the Self can Will an increase of entanglement with specific aspects of the self model or the world model."
(http://tech.groups.yahoo.com/group/MindBrain/message/11616).

example" (Vimal, 2009a). "[M]ixing of matter and antimatter would lead to the annihilation of both in the same way that mixing of antiparticles and particles does, thus giving rise to high-energy photons (gamma rays) or other particle–antiparticle pairs. The particles resulting from matter-antimatter annihilation are endowed with energy equal to the difference between the rest mass of the products of the annihilation and the rest mass of the original matter-antimatter pair, which is often quite large" (Vimal, 2009a). In analogy to matter + anti-matter = annihilation of both but giving rise to gamma rays (high-energy photons), one could speculate that SEs (such as redness) + respective anti-SEs (such as greenness) = yellowness, which with anti-yellowness (blueness) = whiteness. Whiteness + anti-whiteness or blackness = grayness = annihilation of color and giving rise to new SE which is color-less. Creation operators can create a SE and also anti-SE in addition to matter and anti-matter by perturbation method. Moreover, string is created from relevant vacuum by creation operator. In addition, strings vibrate or move in ten dimensions; the four fundamental forces arise from these string vibrations.[10] Thus, idea of arising mind and matter from relevant vacuum is interesting and needs further investigation.

In string theory, we have assumed that the superposition of *potential* experiences in the mental aspect is in analogy to the superposition of positions in the physical aspect of entities (strings or elementary particles, bosons and fermions). The experiences are independent of 3+1 D (x, y, z, t) positions and time. This may lead to the prediction that spatial and temporal experiences are along one spatial hidden and one temporal hidden dimension of F-theory. In LQG, we assume that the superposition of *potential* experiences in the mental aspect is in analogy to the superposition of spins in the physical aspect of entities (elementary particles, i.e., fermions and bosons including gravitons). In both string theory and LQG, we assume that *potential* experiences are superposed in the mental aspect of entities including dual-aspect field. One could argue that it is also equivalent to the OR-Orch view where experiences are embedded in space-time geometry. In the dual-aspect view, *potential* SEs/PEs are eternal. This leads to Type-2 explanatory gap: "how it is possible that our [*potential*] SEs (such as happiness, sadness, painfulness, and similar SEs) were already present in primal entities, whereas there is no shred of evidence that such [*potential*] SEs were conceived at the onset of universe" (Vimal, 2009g; Vimal, 2009h); but what if universe is cyclic from quantum bounce model (Ashtekar *et al.,* 2006; Bojowald *et al.,* 2007; Corichi and Singh, 2008a) and has memory as some cosmologists suggests (Corichi and Singh, 2008a). However, one should be careful in drawing implications as discussed below.

In any rate, one could safely argue that all entities *potentially* pre-exist (in analogy to a tree pre-exists in a tree-seed), though it is different matter how these entities are realized/actualized that indeed need further investigation (see footnote 11).

1.2. *Universe before Big Bang and critique on quantum bounce model*

According to (Bojowald, 2008b), "It is shown here that quantum fluctuations before the big bang are generically unrelated to those after the big bang. A reliable determination of pre-big bang quantum fluctuations would require exceedingly precise observations. [...] A solvable model of quantum cosmology … does show a bounce at small volume instead of the classical singularity present in solutions of general relativity. [...] The promotion of this specific model is not intended as a statement that its bounce would be generic for quantum gravity even within the same framework. In fact, the conclusion of the bounce in this and

[10] http://www.pythabacus.com/CCgame/Hdimen.htm

related models available so far is based on several specific properties which prevent a generic statement about this form of singularity removal. We rather take the following viewpoint: Assume there is a theoretical description of a bouncing universe; what implications can be derived for its pre-bounce state? [...] the solvable model we will be using eliminates the classical big bang singularity by quantum effects. Dynamical coherent states highlight the behavior of fluctuations of the state of the universe before and after the big bang. [...] the past is shrouded by cosmic forgetfulness".

1.3. *Universe has memory and maintains recall, and critique*

According to (Corichi and Singh, 2008a), "Loop quantum cosmology [LQC] predicts that, in simple models, the big bang is replaced by a quantum bounce. A natural question is whether the universe retains, after the bounce, its memory about the previous epoch. More precisely, does the Universe retain various properties of the state after evolving unitarily through the bounce, or does it suffer from recently suggested cosmic amnesia? We show that this issue can be answered unambiguously at least within an exactly solvable model. A semiclassical state at late times on one side of the bounce, peaked on a pair of canonically conjugate variables, strongly bounds the fluctuations on the other side, implying semiclassicality. For a model universe growing to 1 megaparsec, the change in relative fluctuation across the bounce is less than 10^{-56} (becoming smaller for larger universes). The universe maintains (an almost) total recall. [...] the relative fluctuations in the initial semi-classical state peaked in conjugate variables, strongly bound the relative fluctuations on the other side of the bounce. More precisely the relative fluctuation [in volume] of the Dirac observable $V|_\varphi$ (volume at a given instant of 'time' $\varphi = \varphi_o$) across the bounce satisfies the above inequality if the initial state was peaked in a large classical universe. In fact, for a large class of states the change in relative dispersion is zero. Since the field φ is massless, the expectation value of its momentum p_φ and corresponding fluctuations characterizing the state are trivially conserved across the bounce. Thus, above results show that a state which is semi-classical at late (early) times, preserves semi-classicality at early (late) times across the bounce. [...] the fluctuations are symmetric with respect to the time $(\varphi - x_o)$. [...] squeezed states with arbitrary squeezing, and states having a Poisson distribution belong to this class. All such states preserve the relative fluctuation across the bounce. [...] a full control on the fluctuations of the universe 'before the big bang'. [...] To summarize, we have shown that, within a simplified and completely solvable model of LQC, if the universe is semiclassical at late times, that is, if it has very small relative dispersions in both relevant canonically conjugate variables, then the universe 'before the big bang' at early times is also semiclassical."

According to (Bojowald, 2008a), "A recently derived inequality on volume fluctuations of a bouncing cosmology, valid for states which are semiclassical long after the bounce, does not restrict pre-bounce fluctuations sufficiently strongly to conclude that the pre-bounce state was semiclassical except in a very weak sense. [...] Reproducing a number up to a factor of $10^{\pm 28}$ hardly constitutes "(an almost) total recall." [...] In (Bojowald, 2008b), by contrast, dynamical coherent states provide bounds for the relative change of relative volume fluctuations, exploiting the availability of a solvable model ... Coherence here means that the uncertainty relation is aleays [always] exactly saturated. Thus, the assumption is stronger than semiclassicality, allowing more control. Still, relative changes even in such a state are bounded only by a factor of around 20. This is much smaller than the numbers controlled by (1), but still more than one as one should have it for what one could call a recall. This is the basis of cosmic forgetfulness (Bojowald, 2007): not all the fluctuations (and higher moments) of a state before the bounce can be recovered after the bounce, and values depend very sensitively on the late-time state." According to (Bojowald, 2008b), "It is shown here that quantum fluctuations before the big bang are generically unrelated to those after the big bang. A reliable determination of pre-big bang quantum fluctuations would require exceedingly precise observations."

According to (Corichi and Singh, 2008b), "A recent Comment [(Bojowald, 2008a)] on the Letter 'Quantum Bounce and Cosmic Recall' by the authors is shown to arise from an incorrect understanding of the issues at hand and of our analysis. The conclusions of Bojowald's Comment are shown to add little to our work, to be irrelevant at best, and are further shown to be in contradiction with his own claims in the literature. [...] Could a semiclassical state at late times, have evolved from an arbitrary state at early times before the bounce? For that the standard definition of a semiclassical state peaked on a classical trajectory was used, requiring (i) the expectation values for a complete set of observables are close to their classical values and (ii) the quantum fluctuations of the observables are much smaller than their mean values. Our analysis does not require coherence, a much stronger assumption. [...] Is the state before the bounce semiclassical? Yes. Is it possible that the relative fluctuations can be very different on one side and the other? Yes. Are these two statements contradictory? No. [...] The state retains semiclassicality across the bounce. [...] There is no cosmic forgetfulness."

From (Bojowald, 2008c), one could argue the followings: "Since small length scales and high curvatures are involved, quantum effects must play a role. Not only the singularity itself but also the surrounding spacetime is then modified. One particular theory is loop quantum cosmology, an application of loop quantum gravity to homogeneous systems, which removes classical singularities. Its implications can be studied at different levels. The main effects are introduced into effective classical equations, which allow one to avoid the interpretational problems of quantum theory. They give rise to new kinds of early-universe phenomenology with applications to inflation and cyclic models. To resolve classical singularities and to understand the structure of geometry around them, the quantum description is necessary. Classical evolution is then replaced by a difference equation for a wave function, which allows an extension of quantum spacetime beyond classical singularities. One main question is how these homogeneous scenarios are related to full loop quantum gravity, which can be dealt with at the level of distributional symmetric states. Finally, the new structure of spacetime arising in loop quantum gravity and its application to cosmology sheds light on more general issues, such as the nature of time."

Furthermore, it is hard to believe that the mental aspect of every boson and every fermion and/or related fields of all galaxies (including all stars, back holes, neutron stars, white dwarfs, and the rest) of our universe will have superposed *potential* SEs. Why Nature will do that via such an inefficient process but is this really true? The superposition of *potential* SEs in their mental aspect does not seem to cost anything; one could view them as possibilities, i.e., if neural-networks are formed anywhere in the universe and the necessary ingredients of consciousness are satisfied, a specific SE can be selected by matching process and the network will experience it. It is not clear that it would be more efficient and economical that SEs somehow *emerged* when neural-nets were formed and the necessary ingredients of consciousness are satisfied during evolution. One could argue that SEs *emerged* from PEs (precursor of SEs) or from matter (Vimal, 2009h). Perhaps, nature designed a more efficient and intelligent mechanism for the emergence.[11]

Alternatively, one could argue that 'SEs appear irreducible' gives false impression of reality,[12] i.e., SEs may not be irreducible. For example, some *Vedic* scholars hypothesize that SEs can be derived from a PE and 3 *gunas* (qualities) (Vimal, 2009b).

For Levine's explanatory gap (Levine, 1983) (how experiences can *emerge from* or be *identical with* non-experiential brain), one could argue for the dual-aspect view with *potential* SEs superposed in the mental aspect of fermions and bosons (elementary particles).

We should consider various predictions of both materialism and dual-aspect views and see which one can reject which view. All views predict that neural-nets are necessary for SEs. Materialism rejects inverted qualia (and also 'inverted earth') whereas dual-aspect view is silent or does not reject. Dual-aspect view rejects zombie whereas materialism is silent on this. We need to search for predictions that are clear cut different for various views. If the hypothesis H_1 or H_2 of the dual-aspect PE-SE framework is valid, then only the main proposal of this article (i.e., the invariance of physics under the PE-SE transformations) is valid.

2. Introducing Consciousness in Modern Physics

In this article, we focus on introducing the subjective experience (SE) aspect of consciousness in modern quantum physics, such as, loop quantum gravity (LQG) and string theory.

2.1. *The relevant PE-SE transformations*

As elaborated in (Vimal, 2010c), psychophysically SE has logarithmic relationship with stimulus intensity (I): brightness or luminance is proportional to log(I), i.e. I is proportional to the exponential of (brightness or luminance). According to hypothesis $\mathbf{H_1}$ (or $\mathbf{H_2}$), the *potential* subjective

[11] Let us consider the emergence of water from the interaction of hydrogen and oxygen: In the dual-aspect view, some of the properties related to the physical aspect of water may be somewhat explained using the reductionistic view and some using holistic mysterious emergence (Corning, 2010), but what about its mental aspect. Its liquidness and its appearance are the subjective experiences (SEs) constructed by mind (constructivism). Emergentists would argue that emergence could explain SEs, but how it could explain is still the mystery.

Furthermore, one could argue that mysterious emergence might be unpacked by assuming (i) all irreducible higher-level entities (and their properties) *potentially* pre-exist and (ii) their irreducible physical and mental properties are superposed in the respective physical and mental aspects of all fundamental entities.

In other words, water (with its properties we know of) *potentially* pre-exists; when hydrogen and oxygen are reacted in certain proportion under certain conditions some entity needs to be assigned to the resultant H_2O. By trial-and-error method (rather trial-and-success process), evolution, selection, and adaptation assigned water (with the properties we know of) to H_2O because water fitted the best. This unpacking principle of emergence is based on (i) the *potential* pre-existence of irreducible entities, (ii) matching of latent properties superposed in physical and mental aspects of constituting entities, and then (iii) selecting the best-fitted properties. For example, hydrogen is inflammable and oxygen is life force for animals (including humans). One could argue that some of the possible properties of H_2O can be: (A) fire extinguishing (opposite to inflammable) and essential life supporting non-toxic properties for animals and other properties, which belong to water, (B) inflammable and toxic for animals, (C) inflammable, (D) life supporting non-toxic but not fire-extinguishing, and so on. Evolution might have tried all but the water-property (A) fitted the best and hence selected and was assigned to H_2O.

"Chlorine and sodium are both toxic to humans by themselves, but when they are combined they produce a totally new substance that is positively beneficial (in moderate amounts)—ordinary table salt. […] A water molecule is also an emergent phenomenon, [as is salt]" (Corning, 2010).

Similarly all emerged entities including structure, functional and experiential (SEs) aspects of consciousness. This implies that the same unpacking principle for emergence holds for all, namely, structure, function, experiences, and all physical entities including human artifacts. Thus, the mystery of emergence could be unraveled in this manner. In other words, mysterious emergence can be unpacked into pre-existence of potential-properties, matching, and selection mechanisms. This proposal is being developed in (Vimal, 2011).

[12] For instance, the projection of 3D object on 2D that gives false impression of reality to 2D-creatures that 3D-objects do not exist.

experiences (or proto-experiences for **H₂**) are superposed in the mental aspects of strings or elementary particles. This is represented by

$\mathcal{E}(\sigma,\tau)=[\sum_k \beta_k f(\varepsilon_k(\sigma,\tau))]$, where ε_k is k[th] *potential* SE for hypothesis H_1: superposition is necessary. **(1a)**

$\mathcal{E}(\sigma,\tau)=[\sum_k \beta_k f(\varepsilon_k(\sigma,\tau))]$, where ε_k is k[th] *potential* PE (not SE) for $\mathbf{H_2}$: superposition is necessary. **(1b)**

$\mathcal{E}(\sigma,\tau)=\beta f(\varepsilon(\sigma,\tau))$, where ε is *potential* PE (not SE) for hypothesis $\mathbf{H_3}$: no superposition **(1c)**

where $\mathcal{E}(\sigma,\tau)$ represents the superposition of *potential* SEs/PEs $\varepsilon_k(\sigma,\tau)$ in the mental aspect of an entity (such as boson, fermion, string, field, potential, etc) in (1a) and (1b); τ is time-like parameter for the entity, such as time t; σ is space-like parameter for the entity, such as x, y, z. $f(\varepsilon_k(\sigma,\tau))$ is a function of *potential* SE/PE ε_k, which could simply be equal to $\varepsilon_k(\sigma,\tau)$. β_k is the superposition-coefficient, where the subscript k represents k[th] *potential* experience; k=1 to N_{SE}; N_{SE} is the maximum number of *potential* experiences, which is very large; therefore, specificity is zero. The square of the coefficient $[\beta_k]^2$ for the mental aspect is the probability (index of possibility) of the k[th] experience. For hypothesis $\mathbf{H_3}$, k=1, i.e., there is one PE in the mental aspect of each entity; there is no superposition, rather a micro or macro entity has its PE in its mental aspect; hypothesis $\mathbf{H_3}$ is the dual-aspect quantum panpsychism. The parameters (σ,τ) are precisely the same for both inseparable physical and mental aspects, which are like two sides of the same coin in the dual-aspect view; in other words, $\mathcal{E}(\sigma,\tau)$ or $\varepsilon_k(\sigma,\tau)$ are attached to corresponding entity and hence they are exactly the same as that of the entity; if entity moves, then $\mathcal{E}(\sigma,\tau)$ or $\varepsilon_k(\sigma,\tau)$ moves with it and is never separated from each other.

We use experience related transformations (called PE-SE transformations) in scalar and vector potentials, wavefunctions, operators, fields, coordinates, and LQG parameters for introducing SEs/PEs in modern quantum physics.

As elaborated in Part II (Vimal, 2010d), the relevant PE-SE transformations for this article are as follows:

Scalar potential in quantum physics can be transformed as:

$$\phi \to \phi' = (\phi - \hbar\partial_t \mathcal{E}) \quad \textbf{(2a)}$$

where $\hbar$ is reduced Planck constant.

Vector potential:

$$A \to A' = A + \nabla\mathcal{E} \quad \textbf{(2b)}$$

Vector potential can also be written as:

$$A_\mu \to A'_\mu = A_\mu - (1/e)\partial_\mu \mathcal{E} \quad \textbf{(2c)}$$

where e is a charge and μ = 0, 1, 2, 3.

The PE-SE transformation for a wavefunction ψ associated with the mental aspect of matter field related to a particle in an electromagnetic field is as follows:

Wavefunction:

$$\psi \to \psi' = e^{jq\mathcal{E}}\psi \quad \text{for (2a)-(2b)} \quad \textbf{(2d)}$$

where j represents the mental aspect and q is a charge.

Wavefunction can also be transformed as,

$$\psi \to \psi' = e^{j\mathcal{E}}\psi \quad \text{for (2c, 2f-2h)} \quad \textbf{(2e)}$$

Differential operator:

$$\mathrm{W}^i_\mu \to \mathrm{W}'^i_\mu = \mathrm{W}^i_\mu - (1/g)\partial_\mu \mathcal{E} + \epsilon^{ijk}\mathcal{E}^j \mathrm{W}^k_\mu \quad \textbf{(2f)}$$

Bosonic field:

$$B_\mu \to B'_\mu = B_\mu - (1/g)\partial_\mu \mathcal{E} \quad \textbf{(2g)}$$

where g is a gauge coupling constant.

W-bosonic field:

$$W^i_\mu \to W'^i_\mu = W^i_\mu - (1/g)\partial_\mu \mathcal{E} + \epsilon^{ijk}\mathcal{E}^j W^k_\mu \quad \textbf{(2h)}$$

where ϵ^{ijk} are the structure constants of SU(2).

Electromagnetic (EM) potential:

$$\begin{aligned}\varphi_\rho \to \varphi'_\rho &= [A', \phi']_\rho \\ &= [(A+\nabla\mathcal{E}), (\phi - \partial_t \mathcal{E})]_\rho \\ &= \phi_\rho + (\partial\mathcal{E}/\partial x_\rho)\end{aligned} \quad \textbf{(2i)}$$

The **gauge transformation** (Carroll, 1997) in electromagnetic, weak, and strong interaction forces is:

$$A_\mu \to A'_\mu = A_\mu + \partial_\mu \lambda \quad \textbf{(2j)}$$

where A is the four-vector potential, such as that of electromagnetic field, λ is related to the potential and $\partial_\mu \lambda$ is related change in the potential.[13]

The **co-ordinate transformation** (or diffeomorphism = active co-ordinate transformation) in the general theory of relativity (GTR) (Carroll, 1997).p124 is:

$$x^\mu \to x'^\mu = x^\mu + \delta^\mu \quad \text{and} \quad \Box\delta^\mu = 0 \quad \textbf{(2k)}$$

where $\Box = \nabla^\mu \nabla_\mu$ is the covariant D'Alembertian, x^μ is spacetime coordinates ($\mu = 0,1,2,3,...$: $x^0 = t$, $x^1 = x$, $x^2 = y$, $x^3 = z$, ...) and δ^μ is a change in co-ordinate x^μ during co-ordinate transformation.

[13] One could argue that A is a gauge field (such as field related to the four-vector potential of electromagnetic field: e.g., electric field $E = -\nabla\phi - \partial_t A$ as in Eq. (6) of (Vimal, 2010d)) and λ is related to gauge potential.

In analogy to (2j) and (2k), the **dualistic PE-SE transformations** are:

$\varphi_\mu \to \varphi'_\mu = \phi_\mu + j\partial_\mu \mathcal{E}^\mu$, where $\varphi = [\phi, A]$ (for EM, weak, and strong interaction) **(2*l*)**

$x^\mu \to x'^\mu = x^\mu + j\mathcal{E}^\mu$ and $\mathcal{E}^\mu = 0$ (for STR, GTR, and LQG) **(2m)**

where $\mu = 0,1,2,3$ and $\mathcal{E}^\mu = \mathcal{E}$. One could argue that (2*l*) and (2m) are for dualism because mental entities ($\partial_\mu \mathcal{E}^\mu$ and $\mathcal{E}^\mu$) are orthogonal and independent of physical entities (φ_μ and x^μ).

For the **dual-aspect PE-SE transformations** (Vimal, 2010a) are:

$\varphi_\mu \to \varphi'_\mu = \phi_\mu e^{j\partial_\mu \mathcal{E}^\mu}$ where $\varphi = [\phi, A]$ (for EM, weak, and strong interaction) **(2n)**

$x^\mu \to x'^\mu = x^\mu e^{j\mathcal{E}^\mu}$ and $\Box\mathcal{E}^\mu = \nabla^\mu \nabla_\mu \mathcal{E}^\mu = 0$ (for STR, GTR, and LQG) **(2o)**

LQG should be both relativistically invariant and gauge invariant. This implies that action $S_{(P)}$ is invariant under diffeomorphisms of $\mathcal{M}$ as well as local $SO(\eta)$ transformations (Ashtekar and Lewandowski, 2004).p10:

$$(e, \omega) \to (e', \omega') = (b^{-1}e,\ b^{-1}\omega b + b^{-1}db) \quad \textbf{(2p)}$$

where $SO(\overline{\eta})$ is η-by-η special orthogonal group, e is the edge of spin network, b is a transformation map, d is exterior derivative, and ω is dual-vector.

The PE-SE transformation can be obtained by replacing b with $e^{j\mathcal{E}^\mu}$ in (2p):

$$\begin{aligned}&[e,\omega] \to [e', \omega'] \\ &= [(e^{j\mathcal{E}^\mu})^{-1} e,\ (e^{j\mathcal{E}^\mu})^{-1}\omega e^{j\mathcal{E}^\mu} + (e^{j\mathcal{E}^\mu})^{-1} d e^{j\mathcal{E}^\mu}] \quad \textbf{(2q)} \\ &= [e^{-j\mathcal{E}^\mu} e,\ e^{-j\mathcal{E}^\mu}\omega e^{j\mathcal{E}^\mu} + e^{-j\mathcal{E}^\mu} j e^{j\mathcal{E}^\mu} d\mathcal{E}^\mu] \quad \textbf{(2r)} \\ &= [e^{-j\mathcal{E}^\mu} e,\ \omega + jd\mathcal{E}^\mu] \quad \textbf{(2s)}\end{aligned}$$

A **gauge transformation** g_α in $\mathcal{G}_\alpha$ is a map g_α :
$x_\alpha \rightarrow$ G from all points x_α on α. Thus, g_α can be thought of as the restriction to α of a G-valued function defined on $\mathcal{M}$. Under g_α, connections A_α transform as (replace ω with A_α and b with g_α in (9)):

$$A_\alpha \rightarrow A'_\alpha = g_\alpha^{-1} A_\alpha g_\alpha + g_\alpha^{-1} d_\alpha g_\alpha \quad \textbf{(2t)}$$

where d_α is the exterior derivative along the edges of α.

The PE-SE transformations for string theory is:

$$\Phi^\mu \rightarrow \Phi'^\mu = e^{j\mathcal{E}^\mu}\, \Phi^\mu \quad \textbf{(2u)}$$

where Φ = χ, ψ, and φ for bosonic string, fermionic string with leftward motion, and fermionic string with rightward motion, respectively.

2.2. *Loop Quantum Gravity*

The Standard Model (Vimal, 2010d) is unable to renormalize gravitation in contrast to the electroweak and strong interactions. This implies that the Standard Model has infinitely many free parameters and lacks predictions related to gravitation.

General theory of relativity (Einstein, 1916) is useful in unfolding gravitational interaction and the structure of space and time on large scales (Will, 2006); however, it is not useful for describing small-scale behavior; for which quantum gravity is needed (Bojowald, 2008c; Nicolai *et al.,* 2005; Rovelli, 2008).

According to (Ashtekar and Lewandowski, 2004), "In this approach, one takes the central lesson of general relativity seriously: gravity is geometry whence, in a fundamental theory, there should be no background metric. In quantum gravity, geometry and matter should both be 'born quantum mechanically'. Thus, in contrast to approaches developed by particle physicists, one does not begin with quantum matter on a background geometry and use perturbation theory to incorporate quantum effects of gravity. There is a manifold but no metric, or indeed any other fields, in the background. [...] General relativity is usually presented as a theory of metrics. However, it can also be recast as a dynamical theory of connections. [...] Such a reformulation brings general relativity closer to gauge theories which describe the other three fundamental forces of Nature in the sense that, in the Hamiltonian framework, all theories now share the same kinematics. The difference, of course, lies in dynamics. In particular, while dynamics of gauge theories of other interactions requires a background geometry, that of general relativity does not. Nonetheless, by a suitable modification, one can adapt quantization techniques used in gauge theories to general relativity."

Loop quantum gravity (LQG) is a quantum theory of spacetime, which tries to reconcile the theories of quantum mechanics and general relativity (Vimal, 2009a). LQG is developed from general relativity using Ashtekar variables (which represent geometric gravity using mathematical analogues of electric and magnetic fields). In LQG, space (i.e. the universe) can be viewed as an extremely fine network of finite quantized loops (of excited gravitational fields) called spin networks, which evolves over time in discrete steps (Bojowald, 2008c; Rovelli, 2008). LQG incorporates general relativity and does not require higher dimensions. It preserves many of the important features of general relativity, while at the same time employing quantization of both space and time at the Planck scale (Bojowald, 2008c; Rovelli, 2008).

The LQG theory is a background independent (non-perturbative) theory similar to Einstein's general theory of relativity, and includes both matter and forces, but the theory does not address the problem of the unification of all physical forces (Bojowald, 2008c; Rovelli, 2008). The string theory (Section 2.3) unifies all forces but it is background dependent (perturbative) theory.

In the Palatini framework, the basic gravitational variables constitute a pair $(e_\mu{}^I, \omega_\mu{}^I{}_J)$ of 1-form fields on manifold $\mathcal{M}$ taking values, respectively, in V (vector space) and in the Lie algebra $so(\bar{\eta})$ of the group $SO(\bar{\eta})$ of the linear transformations of V. This preserves the metric $\bar{\eta}_{IJ}$. **(3)**

Because of our topological assumptions, the co-frame fields (co-tetrad) e_μ^I are defined globally; they provide an isomorphism between $T_x\mathcal{M}$ and V at each $x \in \mathcal{M}$. The action is given by (Ashtekar and Lewandowski, 2004).p10.

$$S_{(P)}(e,\omega) = \frac{1}{4k}\int_{\mathcal{M}} \epsilon_{IJKL}(e^I \wedge e^J \wedge \Omega^{KL}) \qquad \textbf{(4)}$$

where $\wedge$ is exterior product or wedge product (Vimal, 2009a), ϵ_{IJKL} is an antisymmetric/alternating tensor (a tensor is antisymmetric on two indices I and J if it flips sign when the two indices are interchanged: $\epsilon_{IJKL} = -\epsilon_{IJKL}$) on V compatible with ϵ_{IJ} such that the orientation of

$$\epsilon_{\alpha\beta\gamma\delta} = \epsilon_{IJKL}\, e_\alpha^I\, e_\beta^J\, e_\gamma^K\, e_\delta^L \qquad \textbf{(5)}$$

agrees with the one we fixed on $\mathcal{M}$ and

$$\Omega := d\omega + \omega \wedge \omega \qquad \textbf{(6)}$$

where Ω is the curvature of the connection 1-form $\omega_\mu{}^I{}_J$, d is exterior derivative, and ω is dual-vector. The co-frame $e_\mu{}^I$ determines a space-time metric $g_{\mu\nu}$ with signature (–,+,+,+)

$$g_{\mu\nu} = \eta_{IJ}\, e_\mu^I\, e_\nu^J \qquad \textbf{(7)}$$

However, the equation of motion obtained by varying the action with respect to the connection implies that ω_μ^{IJ} is in fact completely determined by the co-frame:

$$de + \omega \wedge e = 0 \qquad \textbf{(8)}$$

LQG should be both relativistically invariant and gauge invariant. This implies that action $S_{(P)}$ is invariant under diffeomorphisms of $\mathcal{M}$ as well as local $SO(\bar{\eta})$ transformations (Ashtekar and Lewandowski, 2004).p10:

$$(e,\omega) \to (e',\omega') = (b^{-1}e,\ b^{-1}\omega b + b^{-1}db) \qquad \textbf{(9)}$$

where e is the edge of spin network, and b is a transformation map.

The curvature of the connection Ω in action (4) under the PE-SE transformation (2s) can be written as:

$$\begin{aligned}
&\Omega = d\omega + \omega \wedge \omega \;\to \\
&\Omega' = d\omega' + \omega' \wedge \omega' \\
&= [d\omega + jd(dE) + (\omega + jdE) \wedge (\omega + jdE)] \\
&= [d\omega + jd(dE) + (\omega \wedge \omega) + j(dE \wedge \omega) + \\
&\qquad j(\omega \wedge dE) - (dE \wedge dE)] \\
&= [d\omega + (\omega \wedge \omega) + j(dE \wedge \omega) - j(dE \wedge \omega)] \\
&= [d\omega + (\omega \wedge \omega)] \\
&= \Omega
\end{aligned} \qquad \textbf{(10)}$$

where, we used the properties of
(i) exterior derivative $d(dE) = 0$ and **(11a)**
(ii) wedge product
  (a) $(\omega \wedge dE) = -(dE \wedge \omega)$ and **(11b)**
  (b) $(dE \wedge dE) = 0$. **(11c)**

Eq. (10) implies that the curvature of the connection Ω and hence the action (4) for LQG are invariant under the PE-SE transformation (2s). **(11d)**

The integrand $(e^I \wedge e^J \wedge \Omega^{KL})$ in action (4) under PE-SE transformation (2s) and using (10) for $\Omega' = \Omega$ can be written as:

$$(e^I \wedge e^J \wedge \Omega^{KL}) \to (e'^I \wedge e'^J \wedge \Omega'^{KL})$$

$$= (e^{-j\mathbb{E}^{\mu}} e^{I} \wedge e^{-j\mathbb{E}^{\mu}} e^{J} \wedge \Omega^{KL})$$
$$= (e^{I} \wedge e^{J} \wedge \Omega^{KL}) \qquad \textbf{(12a)}$$

where

$$e^{-j\mathbb{E}^{\mu}} e^{I} \wedge e^{-j\mathbb{E}^{\mu}} e^{J} = e^{I} \wedge e^{J} \qquad \textbf{(12b)}$$

"A G connection A_{α} on a graph α is the set of *g* valued 1-forms A_e defined on each edge *e* of α. For concreteness we will suppose that each A_α is given by the pullback to α of a smooth *g*-valued 1-form on $\mathcal{M}$. Thus, one can think of a connection on α simply as an equivalence class of smooth connections on $\mathcal{M}$ where two are equivalent if their restrictions to each edge of α agree. Denote the space of G connections on α by $\mathcal{A}_\alpha$. This space is infinite dimensional because of the trivial redundancy of performing local gauge transformations along the edges of α. As in lattice gauge theories it is convenient to remove this redundancy to arrive at a finite dimensional space $\tilde{\mathcal{A}}_\alpha$, which can be taken to be the relevant configuration space for any (background independent) theory of connections associated with the graph α. A gauge transformation g_α in $\mathcal{G}_\alpha$ is a map $g_\alpha : x_\alpha \rightarrow G$ from all points x_α on α. Thus, g_α can be thought of as the restriction to α of a G-valued function defined on $\mathcal{M}$. Under g_α, connections A_α transform as (replace ω with A_α and *b* with g_α in (9)):

$$A_{\alpha} \rightarrow A'_{\alpha} = g_{\alpha}^{-1} A_{\alpha} g_{\alpha} + g_{\alpha}^{-1} d_{\alpha} g_{\alpha} \qquad \textbf{(13)}$$

where d_α is the exterior derivative along the edges of α." (Modified appropriately from (Ashtekar and Lewandowski, 2004).p28).

The scalar product between any two cylindrical functions is given by Eq.(11) of (Rovelli, 2008), which is invariant under diffeomorphism and local SU(2) gauge transformations. This scalar product is obtained by transforming the argument of the functionals as:

$$(\Psi_{\Gamma f}, \Psi_{\Gamma h})$$

$$\int_{SU(2)} dg_1 \ldots dg_n\, f^{*}(g_1 \ldots g_n)\, h(g_1 \ldots g_n) \qquad \textbf{(14)}$$

where * indicates complex conjugate. The Eq.(14) is invariant under the PE-SE transformation (20):

$$f^{*} \rightarrow f'^{*} = f\, e^{-j\mathbb{E}^{\mu}} \quad \text{and} \qquad \textbf{(15a)}$$
$$h^{*} \rightarrow h'^{*} = h\, e^{j\mathbb{E}^{\mu}} \qquad \textbf{(15b)}$$

"It is possible to formulate classical mechanics [and quantum mechanics] in a way in which the time variable is treated on equal footings with the other physical variables, and not singled out as the special independent variable. ... this is the natural formalism for describing general relativistic systems. [...] The peculiar properties of the time variable are of thermodynamical origin, and can be captured by the thermal time hypothesis. Within quantum field theory, "time" is the Tomita flow of the statistical state ρ in which the world happens to be, when described in terms of the macroscopic parameters we have chosen ... In order to build a quantum theory of gravity the most effective strategy is therefore to forget the notion of time all together, and to define a quantum theory capable of predicting the possible correlations between partial observables" (Rovelli, 2009).

"Barbour, Hawking, Misner and others have argued that time cannot play an essential role in the formulation of a quantum theory of cosmology. Here we present three challenges to their arguments, taken from works and remarks by Kauffman, Markopoulou and Newman. These can be seen to be based on two principles: that every observable in a theory of cosmology should be measurable by some observer inside the universe, and all mathematical constructions necessary to the formulation of the theory should be realizable in a finite time by a computer that fits inside the universe. [...] the metric, which is invariant under the action of arbitrary diffeomorphisms" (Smolin, 2001).

We many need to enlarge configuration space to accommodate all *potential* SEs/PEs with the understanding *potential* SEs/PEs are the property of mental aspect of space. Since area and volume space can be quantized into elementary cells (at Planck scale), one can consider that each cell has two aspects: physical and mental. The *potential* PEs/SEs are superposed in the mental aspect of elementary area and volume.

The **area operator** $\hat{A}$ elaborated in Eq. (5.9) of (Ashtekar and Lewandowski, 2004) is invariant under the PE-SE transformation (2*l*) because the transformation is mathematically similar to gauge transformation (2j). The area operator is also gauge invariant, i.e., it commutes with the vertex operators generating SU(2) gauge rotations at vertices (Ashtekar and Lewandowski, 2004). "Since its definition does not require a background structure, it is diffeomorphism covariant" (Ashtekar and Lewandowski, 2004)p.44.

According to (Ashtekar and Lewandowski, 2004).p49, the **volume operator** is gauge invariant and covariant with respect to diffeomorphisms. In addition, the *total* volume operator is diffeomorphism invariant. Since, the PE-SE transformations (2*l*) and (2m) are mathematically similar to gauge (2j) and co-ordinate (2k) transformations, the volume operator is gauge invariant and covariant with respect to diffeomorphisms whereas the *total* volume operator is diffeomorphism invariant under the PE-SE transformations (2*l*) and (2m).

Gauss constraint: The states related to decomposition of Hilbert space are invariant under the PE-SE transformations (2*l*) and (2m), in analogy to these states are invariant under *generalized* gauge transformations (Ashtekar and Lewandowski, 2004).p52, such as the gauge transformation in Eq. (2j).

Diffeomorphism constraint: The physical states are invariant under the PE-SE transformation (2m). This is in analogy to the invariance of these physical states under finite diffeomorphisms (Ashtekar and Lewandowski, 2004).p53, such as the co-ordinate transformation (or diffeomorphism = active co-ordinate transformation) in Eq. (2k).

The LQG cosmology (Ashtekar and Lewandowski, 2004).p68 is also invariant under the above PE-SE transformations.

The PE-SE transformations (2*l*) and (2m) are for dualism. Further research is needed to investigate if the dual-aspect PE-SE transformations (2n) and (2o) also lead to the invariance of (i) area & volume operators and (ii) Gauss & diffeomorphism constraints. It should be noted that Eq.(14) is invariant under the dual-aspect PE-SE transformation (2o).

In the **application of LQG in quantization/kinematics** (Ashtekar and Lewandowski, 2004).p71, there are configuration and momentum operators. The mental aspect configures and moves with physical aspect of space-time under the above PE-SE transformations.

The application of LQG in Big-Bang theory suggests that the 'discrete evolution' simply 'jumps' over the classical singularity without encountering any subtleties (Ashtekar and Lewandowski, 2004).p78. This is consistent with the dual-aspect with superposition based hypotheses $\mathbf{H_1}$ and $\mathbf{H_2}$, which implies that superposed *potential* SEs/PEs in the mental aspect also 'jumps' over the classical Big-Bang singularity along with its physical aspect because of the 'discrete evolution'. This is consistent with the model of Big-Bounce cyclic universe (Ashtekar *et al.,* 2006; Bojowald *et al.,* 2007; Corichi and Singh, 2008a).

2.3. *String theory*

2.3.1. String theory versus loop quantum gravity

(Rovelli, 2008) describes the merits of LQG against string theory as: "In string theory, gravity is just one of the excitations of a string or other extended object, living on some metric space. The existence of such background spaces, in which a theory is defined, is the key technical tool for the formulation and the interpretation of the theory, at least in the case of the perturbative definition of the theory. […] Unlike string theory, loop quantum gravity has a direct fundamental formulation, in which the degrees of freedom are clear, and which does not rely on a background spacetime. Loop quantum gravity is thus a genuine attempt to grasp what quantum spacetime is at the fundamental level. Accordingly, the notion of spacetime that emerges from the theory is profoundly different from the one on which conventional quantum field theory or string theory is based."

(Rovelli, 2008) discusses the merits and incompleteness of string theory as: "The main merits of string theory are (i) its elegant unification of different theories used in known fundamental physics, (ii) its well-defined perturbation expansion, expected to be finite order-by-order, and (iii) its theoretical and mathematical richness and complexity. The main incompleteness is that its nonperturbative regime is very poorly understood, and we do not know the background-independent formulation: in a sense, we do not really know what the theory is, and how to describe its basics degrees of freedom. Thus, we control the theory only in sectors that (because of the numbers of dimensions or the unbroken super-symmetry) are neither Planck-scale physics, nor low-energy physics. More precisely: (i) There is not much Planck-scale physics derived from string theory so far. Exceptions are the investigation of the Bekenstein–Hawking entropy, including Hawking radiation spectrum and greybody factors, for certain peculiar kinds of black holes […] and some very-high-energy scattering amplitudes […] (ii) We are not able to recover the correct low-energy physics, namely the full standard model in 4D, without unbroken supersymmetry, three generations, and the full standard-model phenomenology, from string theory."

(Rovelli, 2008) discusses the merits and incompleteness of LQG as: "The main merit of loop quantum gravity is that it provides a mathematically-rigorous formulation of a background-independent, nonperturbative generally-covariant quantum field theory. It provides a physical picture of the world, and quantitative predictions, at the Planck scale. This has allowed, for instance, explicit investigations of the physics of the Big Bang, and the derivation of black-hole entropy for physical black holes. The main incompleteness of the theory regards the formulation of the dynamics, which is studied along different directions, and in several variants. In particular, the recovery of low-energy physics is under investigation, but no convincing derivation of classical GR from loop gravity is yet available. Finally, recall that the aim of loop quantum gravity is to unify gravity and quantum theory, and not to achieve a complete unified theory of all interactions."

Furthermore, (Rovelli, 2008) argues that string theory and LQG can be viewed as complementary to each other in some sense rather than competing theories: "Strings and loop gravity may not necessarily be competing theories: there might be a sort of complementarity, at least methodological, between the two. Indeed, the open problems of string theory mostly concern its background-independent formulation, while loop quantum gravity is precisely a set of techniques for dealing with background-independent theories. Perhaps the two approaches might even, to some extent, converge."

Moreover, (Rovelli, 2008) points the similarities and differences between string theory and LQG, "Undoubtedly, there are similarities between the two theories: first of all the obvious fact that both theories utilize the idea that the relevant excitations at the Planck scale are one-dimensional objects – loops and strings. But there are also key differences: in an image, strings are one-dimensional objects moving in space, while loops are one-dimensional objects forming space. [...] One can conventionally split the spacetime metric into two terms, consider one of the two terms a background that gives a metric structure to spacetime and treat the other as the quantum field. This is the procedure on which perturbative quantum gravity, perturbative strings, as well as several current nonperturbative string theories, are based. In this framework one assumes that the causal structure of spacetime is determined by the underlying background metric alone, and not by the full metric. Contrary to this, loop quantum gravity assumes that the identification between the gravitational field and the metric-causal structure of spacetime holds, and must be taken into account even in the quantum regime. No split of the metric is made, and there is no background metric on spacetime. Pictorially, GR is not physics over a stage, it is the dynamical theory of everything, including the stage itself." (Rovelli, 2008).

2.3.2. Introduction of the superposition of *potential* experiences in the mental aspect of bosonic and fermionic strings

In the Eq. (221) of (Johnson, 2000), the Polyakov action S can be extended to include the superposition of *potential* experiences in the mental aspect of string, in both bosonic and fermionic strings for hypotheses **H_1** and **H_2** as follows:

$$S = (1/4\pi)\int_{\mathcal{M}} d^2\sigma[(1/\alpha')\partial\chi^{\mu}(\partial\chi_{\mu})^{*} + \psi^{\mu}(\partial\psi_{\mu})^{*} + \varphi^{\mu}(\partial\varphi_{\mu})^{*}] \quad \textbf{(16)}$$

where (i) $\mathcal{M}$ is world sheet, (ii) α′ is Regge-slope, (iii) χ(τ,σ) represents bosonic string, (iv) τ is time-like parameter for string, (v) σ is space-like parameter for string, (vi) ψ(τ,σ) represents fermionic string with leftward motion, (vii) φ(τ,σ) represents fermionic string with rightward motion, (viii) μ represents index-parameter for the Einstein-summation and μ varies from 0 to D-1 (D is the number of string-dimensions), (ix) * indicates complex conjugate, (x) $d^2\sigma = d\sigma\, d\tau$, (xi) the open string world–sheet is the strip $0 < \sigma < \pi, -\infty < \tau < \infty$, and (xii) the closed string spectrum is the product of two copies of the open string spectrum, with right– and left–moving levels matched. The dimension μ varies from 1 to 12 for F-theory.

We use the PE-SE transformation (2u) for introducing SEs/PEs aspect of consciousness in string theory as follows:

Bosonic string:

$$\chi^{\mu} \rightarrow \chi'^{\mu} = \chi^{\mu} e^{j\mathcal{E}^{\mu}} \quad \textbf{(17)}$$

Fermionic string with leftward motion:

$$\psi^{\mu} \rightarrow \psi'^{\mu} = \psi^{\mu} e^{j\mathcal{E}^{\mu}} \quad \textbf{(18)}$$

Fermionic string with rightward motion:

$$\varphi^{\mu} \rightarrow \varphi'^{\mu} = \varphi^{\mu} e^{j\mathcal{E}^{\mu}} \quad \textbf{(19)}$$

where E^{μ} represents the superposition of *potential* experiences in the mental aspect of bosonic or fermionic string in (16). The imaginary axis is indicated by *j*, which represents the mental aspects of bosonic or fermionic string.

2.3.2.1. Invariance of Bosonic string under the PE-SE transformation

Differentiating (17), we get:

$$\partial\chi'^{\mu} = e^{j\mathcal{E}^{\mu}}[(j\partial\mathcal{E}^{\mu})\chi^{\mu} + \partial\chi^{\mu}] \quad \textbf{(20)}$$

Substituting (20) in the first term of (16), we get:

$$\begin{aligned}&[\partial\chi'^{\mu}(\partial\chi'_{\mu})^{*}]\\ &= e^{j\mathcal{E}^{\mu}}[(j\partial\mathcal{E}^{\mu})\chi^{\mu} + \partial\chi^{\mu}]\\ &\quad e^{-j\mathcal{E}_{\mu}}[(-j\partial\mathcal{E}_{\mu})(\chi_{\mu})^{*} + (\partial\chi_{\mu})^{*}] \quad \textbf{(21a)}\\ &= [(j\partial\mathcal{E}^{\mu})\chi^{\mu} + \partial\chi^{\mu}]\end{aligned}$$

$$[(-j\partial\mathcal{E}_\mu)(\chi_\mu)^* + (\partial\chi_\mu)^*] \quad \textbf{(21b)}$$

$$= [(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^* + \partial\chi^\mu(-j\partial\mathcal{E}_\mu)(\chi_\mu)^* + [(j\partial\mathcal{E}^\mu)\chi^\mu(\partial\chi_\mu)^* + \partial\chi^\mu(\partial\chi_\mu)^*] \quad \textbf{(21c)}$$

$$= [\partial\chi^\mu(\partial\chi_\mu)^*] + [(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^* - (j\partial\mathcal{E}_\mu)\,\partial\chi^\mu(\chi_\mu)^* + (j\partial\mathcal{E}^\mu)\chi^\mu(\partial\chi_\mu)^* \quad \textbf{(21d)}$$

$$= [\partial\chi^\mu(\partial\chi_\mu)^*] + [(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^* - (j\partial\mathcal{E}_\mu)\,\partial\chi^\mu(\chi_\mu)^* + (j\partial\mathcal{E}_\mu)\partial\chi^\mu(\chi_\mu)^*] \quad \textbf{(21e)}$$

$$= [\partial\chi^\mu(\partial\chi_\mu)^*] + [(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*] \quad \textbf{(21f)}$$

$$= [\partial\chi^\mu(\partial\chi_\mu)^*] \quad (\text{if } \partial\mathcal{E}^\mu = \partial_\mu\mathcal{E}^\mu = 0) \quad \textbf{(21g)}$$

where the complex conjugate * is interchanged without changing the overall result and $\mathcal{E}^\mu = \mathcal{E}_\mu$ in (21d) and (21e). In addition,

$$\partial = \partial_\sigma = \partial/\partial_\sigma \ \textbf{ or } \ \partial = \partial_\tau = \partial/\partial_\tau \Rightarrow$$
$$\partial\mathcal{E}^\mu = \partial_\tau\mathcal{E}^\tau + \partial_\sigma\mathcal{E}^\sigma = \partial\mathcal{E}^\tau/\partial\tau + \partial\mathcal{E}^\sigma/\partial\sigma \quad \textbf{(22)}$$

The second term of (21f) can be analyzed as:

$$[(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*]$$

$$= [(\partial_\tau\mathcal{E}^0)(\partial_\tau\mathcal{E}_0)\chi^0(\chi_0)^*] + [(\partial_{x1}\mathcal{E}^1)(\partial_{x1}\mathcal{E}_1)\chi^1(\chi_1)^*] + \ldots \quad \textbf{(23a)}$$

$$= [(\partial\mathcal{E}^0/\partial\tau)[(\partial\mathcal{E}_0/\partial\tau)\chi^0(\chi_0)^*] + [(\partial\mathcal{E}^1/\partial x1)(\partial\mathcal{E}_1/\partial x1)\chi^1(\chi_1)^*] + \ldots \quad \textbf{(23b)}$$

$$= 0 \qquad (\text{if } \partial_\mu\mathcal{E}^\mu = 0) \quad \textbf{(23c)}$$

If $\partial_\mu\mathcal{E}^\mu = 0$, then action S for bosonic string is invariant under this PE-SE transformation (see also Section 2.7 and Eq. (29) of (Vimal, 2010c) for the invariance of Lorentz transformation under the PE-SE transformation (29)). However, One could perhaps interpret this that experiences are independent of time and space in all dimensions, which may not be true in conscious beings because SEs change with subjects across space and time. This fact is revealed in the introduction of SE aspect of consciousness in 'General Theory of Relativity' of classical physics (Vimal, 2010c): (a) For the structure of spacetime (empty space or the vacuum without matter), *potential* SEs are superposed in the mental aspect of spacetime and are embedded in spacetime geometry. (b) For matter field, *potential* SEs are superposed in the mental aspect of each elementary particle (fermion or boson including graviton); wherever these particles move, superposed *potential* SEs must also move with them to conserve SEs, i.e, to make E constant with space and time. (c) Our specific SE is the result of matching and selection processes and can change with space and time. For example, experiencing *redness* has neural correlates of V4/V8/VO-red-green neural-net with redness-state. When a subject moves, the specific SE *redness* also moves with the subject's correlated neural-net. In addition, SEs can change with time as stimuli change. In other words, SEs in a subject change with spacetime. Thus there is no contradiction between (a)-(b) and (c).

2.3.2.2. Invariance of fermionic string with leftward motion under the PE-SE transformation

$$\psi'^\mu(\tau,\sigma) = e^{j\mathcal{E}^\mu}\,\psi^\mu(\tau,\sigma) \qquad \text{from (18)} \quad \textbf{(18b)}$$

Differentiating (18b) with μ as subscript, we get:

$$\partial\psi'_\mu = e^{j\mathcal{E}_\mu}[(j\partial\mathcal{E}_\mu)\psi_\mu + \partial\psi_\mu] \quad \textbf{(24)}$$

Substituting (24) in the second term of (16), we get:

$$\psi'^\mu(\partial\psi'_\mu)^*$$

$$= [e^{j\mathcal{E}^\mu}\,\psi^\mu]e^{-j\mathcal{E}_\mu}[(-j\partial\mathcal{E}_\mu)(\psi_\mu)^* + (\partial\psi_\mu)^*] \quad \textbf{(25a)}$$

$$= \psi^\mu[(-j\partial\mathcal{E}_\mu)(\psi_\mu)^* + (\partial\psi_\mu)^*] \quad \textbf{(25b)}$$

$$= [\psi^\mu(\partial\psi_\mu)^*] + [(-j\partial\mathcal{E}_\mu)\psi^\mu(\psi_\mu)^*] \quad \textbf{(25c)}$$

$$= \psi^\mu(\partial\psi_\mu)^* \qquad (\text{if } \partial_\mu\mathcal{E}^\mu = 0) \quad \textbf{(25d)}$$

If $\partial_\mu\mathcal{E}^\mu = 0$, then action *S* for fermionic string with leftward motion is invariant under this PE-SE transformation.

2.3.2.3. Invariance of fermionic string with rightward motion under the PE-SE transformation

$$\varphi'^{\mu}(\tau,\sigma) = e^{j\mathcal{E}^{\mu}}\ \varphi^{\mu}(\tau,\sigma) \quad \text{from (19)} \qquad \textbf{(19b)}$$

Differentiating (19b), we get:

$$\partial\varphi'_{\mu} = e^{j\mathcal{E}_{\mu}}[(j\partial\mathcal{E}_{\mu})\varphi_{\mu} + \partial\varphi_{\mu}] \qquad \textbf{(26)}$$

Substituting (26) in the third term of (16), we get:

$$\varphi'^{\mu}(\partial\varphi'_{\mu})^{*}$$
$$= [e^{j\mathcal{E}^{\mu}}\ \varphi^{\mu}]e^{-j\mathcal{E}_{\mu}}[(-j\partial\mathcal{E}_{\mu})(\varphi_{\mu})^{*} + (\partial\varphi_{\mu})^{*}] \qquad \textbf{(27a)}$$

$$= \varphi^{\mu}[(-j\partial\mathcal{E}_{\mu})(\varphi_{\mu})^{*} + (\partial\varphi_{\mu})^{*}] \qquad \textbf{(27b)}$$
$$= [\varphi^{\mu}(\partial\varphi_{\mu})^{*}] + [(-j\partial\mathcal{E}_{\mu})\varphi^{\mu}(\varphi_{\mu})^{*}] \qquad \textbf{(27c)}$$
$$= \varphi^{\mu}(\partial\varphi_{\mu})^{*} \qquad (\text{if } \partial_{\mu}\mathcal{E}^{\mu} = 0) \qquad \textbf{(27d)}$$

If $\partial_{\mu}\mathcal{E}^{\mu} = 0$, then action S for fermionic string with rightward motion is invariant under this PE-SE transformation.

2.3.2.4. Invariance of string under the PE-SE transformation

Substitution of Eqs. (21f), (25c), and (27c) in Eq. (16) yields,

$$S' = S + (1/4\pi)\int_{\mathcal{M}} d^2\sigma$$
$$([(1/\alpha')(\partial\mathcal{E}^{\mu})(\partial\mathcal{E}_{\mu})\chi^{\mu}(\chi_{\mu})^{*}] -$$
$$[j\psi^{\mu}(\psi_{\mu})^{*}(\partial\mathcal{E}_{\mu})] - [j\varphi^{\mu}(\varphi_{\mu})^{*}(\partial\mathcal{E}_{\mu})]) \qquad \textbf{(28a)}$$
$$= S \qquad (\text{if } \partial_{\mu}\mathcal{E}^{\mu} = 0) \qquad \textbf{(28b)}$$

Thus, action S for string is invariant under the PE-SE transformation (2u) if *potential* experiences superposed in the mental aspect of strings are independent of spacetime. If the superposed *potential* SEs are present everywhere (assuming both bosons and fermions constitute space) and if they are present all the time, then action S is invariant under the PE-SE transformation (2u).

2.3.3. Principle of the minimum action

For minimum action from string theory (Johnson, 2000; Vancea, 2001),

$$\delta S = \partial S = 0 \qquad \textbf{(29)}$$

$$\delta S = (1/4\pi)\int_{\mathcal{M}} d^2\sigma[(1/\alpha')\delta(\partial\chi^{\mu}(\partial\chi_{\mu})^{*}) +$$
$$\delta(\psi^{\mu}(\partial\psi_{\mu})^{*}) + \delta(\varphi^{\mu}(\partial\varphi_{\mu})^{*})] \qquad \textbf{(30)}$$

The minimum action condition for varying χ^{μ} and χ_{μ} [subscript b is for bosons and $(\partial\chi_{\mu})^{*} = \partial(\chi_{\mu})^{*}$],

$$\delta S_b = (1/4\pi)\int_{\mathcal{M}} d^2\sigma(1/\alpha')\delta[(\partial\chi^{\mu}\partial(\chi_{\mu})^{*}] \qquad \textbf{(31a)}$$
$$= (1/4\pi)\int_{\mathcal{M}} d\sigma\, d\tau(1/\alpha')$$
$$[\partial(\delta\chi^{\mu})\partial(\chi_{\mu})^{*} + \partial\chi^{\mu}\partial(\delta(\chi_{\mu})^{*}] \qquad \textbf{(31b)}$$

Integration by parts with $\partial(\delta\chi^{\mu})$ and $\partial(\delta(\chi_{\mu})^{*}$ as ∂f:

$$\int_0^{\pi}(\partial f)g\, d\sigma = [fg]_0^{\pi} - \int f\partial g\, d\sigma \qquad \textbf{(32)}$$

$$\delta S_b = (1/4\pi)(1/\alpha')([\int_{\mathcal{M}} d\tau(\delta\chi^{\mu})\partial(\chi_{\mu})^{*}]_0^{\pi} +$$
$$[\int_{\mathcal{M}} d\sigma\, d\tau\,(\delta\chi^{\mu})\,\partial\partial(\chi_{\mu})^{*}] +$$
$$[\int_{\mathcal{M}} d\tau\, \delta(\chi_{\mu})^{*}\partial(\chi^{\mu})]_0^{\pi} +$$
$$[\int_{\mathcal{M}} d\sigma\, d\tau\, \delta(\chi_{\mu})^{*}\partial\partial(\chi^{\mu})] \qquad \textbf{(31c)}$$

which requires that,

$$\partial\partial(\chi^{\mu}) = \partial\partial\chi^{\mu} = \partial^2\chi^{\mu} = \nabla^2\chi^{\mu} = \Box\chi^{\mu} = 0$$
$$\text{(Equations of motion)} \qquad \textbf{(33a)}$$

$$\partial\partial(\chi_{\mu})^{*} = \partial^2(\chi_{\mu})^{*} = \nabla^2(\chi_{\mu})^{*} = \Box(\chi_{\mu})^{*} = 0$$
$$\text{(redundant equations of motion)} \qquad \textbf{(33b)}$$

and

Neumann boundary conditions (b.c.) for open strings are:

$$\partial_\sigma \chi^\mu(\tau,0)=0 \text{ and } \partial_\sigma \chi^\mu(\tau,\pi)=0 \quad \textbf{(34a)}$$

Dirichlet b.c. for open strings are:

$$\chi^\mu(\tau,0)=b^\mu \text{ and}$$

$$\chi^\mu(\tau,\pi)=b'^\mu;\ \partial_n\chi^\mu(\tau,\sigma)=0 \quad \textbf{(34b)}$$

where n indicates normal to the surface.

Periodic b.c. for closed strings are:

$$\chi^\mu(\tau,\sigma+2\pi)=\chi^\mu(\tau,\sigma) \quad \textbf{(34c)}$$

From Eqs. (29) and (28a), we get the condition for the minimum action in the dual-aspect-dual-mode PE-SE framework (Vimal, 2008b; Vimal, 2010a),

$$\delta S'=\delta S+\delta[(1/4\pi)\int_{\mathcal{M}} d^2\sigma$$
$$[(1/\alpha')(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*]-$$
$$[j\psi^\mu(\psi_\mu)^*(\partial\mathcal{E}_\mu)]-[j\varphi^\mu(\varphi_\mu)^*(\partial\mathcal{E}_\mu)]] \quad \textbf{(35a)}$$

$$=\delta[(1/4\pi)\int_{\mathcal{M}} d^2\sigma$$
$$[(1/\alpha')(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*]-j$$
$$[\psi^\mu(\psi_\mu)^*+\varphi^\mu(\varphi_\mu)^*](\partial\mathcal{E}_\mu)] \quad \textbf{(35b)}$$

$$=(1/4\pi)\int_{\mathcal{M}} d^2\sigma[(1/\alpha')$$
$$\delta[(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*]-j$$
$$\delta[\psi^\mu(\psi_\mu)^*(\partial\mathcal{E}_\mu)]-j$$
$$\delta[\varphi^\mu(\varphi_\mu)^*(\partial\mathcal{E}_\mu)]] \quad \textbf{(35c)}$$

$$=\delta S'_\chi+\delta S'_\psi+\delta S'_\varphi \quad \textbf{(35d)}$$

The hypothesis is that the minimum action condition is invariant under the PE-SE transformation. Let us examine this further for bosonic sting (χ), fermionic string with leftward motion (ψ), and fermionic string with rightward motion (φ).

2.3.3.1. Principle of the minimum action for bosonic strings

The minimum action condition for varying χ^μ, $(\chi_\mu)^*$, and $\mathcal{E}^\mu$ is as follows.

$$\delta S'_\chi=(1/4\pi)\int_{\mathcal{M}} d^2\sigma$$
$$\delta[(1/\alpha')(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*] \quad \textbf{(36a)}$$

$$=(1/4\pi)\int_{\mathcal{M}} d\sigma\, d\tau\,(1/\alpha')$$
$$[\partial(\delta\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*+$$
$$(\partial\mathcal{E}^\mu)\partial(\delta\mathcal{E}_\mu)\chi^\mu(\chi_\mu)^*+$$
$$(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)(\delta\chi^\mu)(\chi_\mu)^*+$$
$$(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)(\chi^\mu)\delta(\chi_\mu)^*] \quad \textbf{(36b)}$$

$$=(1/4\pi)(1/\alpha')($$
$$[\int_{\mathcal{M}} d\tau\,(\delta\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)(\chi^\mu)(\chi_\mu)^*]_{\sigma=0}^{\pi}+$$
$$[\int_{\mathcal{M}} d\sigma\, d\tau\,(\delta\mathcal{E}^\mu)\partial(\partial\mathcal{E}_\mu)(\chi^\mu)(\chi_\mu)^*]+$$
$$[\int_{\mathcal{M}} d\tau\,(\partial\mathcal{E}^\mu)(\delta\mathcal{E}_\mu)(\chi^\mu)(\chi_\mu)^*]_{\sigma=0}^{\pi}+$$
$$[\int_{\mathcal{M}} d\sigma\, d\tau\,(\delta\mathcal{E}_\mu)\partial(\partial\mathcal{E}^\mu)(\chi^\mu)(\chi_\mu)^*]+$$
$$\int_{\mathcal{M}} d\sigma\, d\tau\,[(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)(\delta\chi^\mu)(\chi_\mu)^*+$$
$$(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)(\chi^\mu)\delta(\chi_\mu)^*]) \quad \textbf{(36c)}$$

$$=0 \quad \textbf{(36d)}$$

which requires that

$$\partial\mathcal{E}^\mu=\partial\mathcal{E}_\mu=\delta\mathcal{E}^\mu=\delta\mathcal{E}_\mu=0 \quad \textbf{(37a)}$$

$$\partial(\partial\mathcal{E}_\mu)(\chi^\mu)(\chi_\mu)^*=\partial(\partial\mathcal{E}^\mu)(\chi^\mu)(\chi_\mu)^*=0 \quad \textbf{(37b)}$$

$$[(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)(\delta\chi^\mu)(\chi_\mu)^*+$$
$$(\partial\mathcal{E}^\mu)(\partial\mathcal{E}_\mu)(\chi^\mu)\delta(\chi_\mu)^*]=0 \quad \textbf{(37c)}$$

which in turn requires that

$$\partial\mathcal{E}^\mu=\partial\mathcal{E}_\mu=\delta\mathcal{E}^\mu=\delta\mathcal{E}_\mu=0 \quad \text{and} \quad \textbf{(38a)}$$

$$\partial\partial\mathcal{E}^\mu=\partial\partial\mathcal{E}_\mu=0 \quad \textbf{(38b)}$$

2.3.3.2. Principle of the minimum action for fermionic string with leftward motion

The minimum action condition for varying ψ^μ, $(\psi_\mu)^*$, and $\mathcal{E}^\mu$ is as follows.

$$\delta S'_\psi$$
$$=(-j/4\pi)\int_{\mathcal{M}} d^2\sigma\,\delta[\psi^\mu(\psi_\mu)^*(\partial\mathcal{E}_\mu)] \quad \textbf{(39a)}$$

$$= (-j/4\pi)\int_{\mathcal{M}} d^2\sigma\,[\delta\psi^{\mu}(\psi_{\mu})^{*}(\partial\mathcal{E}_{\mu}) + \psi^{\mu}\delta(\psi_{\mu})^{*}(\partial\mathcal{E}_{\mu}) + \psi^{\mu}(\psi_{\mu})^{*}\partial(\delta\mathcal{E}_{\mu})] \quad \textbf{(39b)}$$

$$= (-j/4\pi)\int_{\mathcal{M}} d^2\sigma\,[\delta\psi^{\mu}(\psi_{\mu})^{*}(\partial\mathcal{E}_{\mu}) + \psi^{\mu}\delta(\psi_{\mu})^{*}(\partial\mathcal{E}_{\mu})] + [\int_{\mathcal{M}} d^2\sigma\,\psi^{\mu}(\psi_{\mu})^{*}\partial(\delta\mathcal{E}_{\mu})]] \quad \textbf{(39c)}$$

$$[\int_{\mathcal{M}} d\tau\,\psi^{\mu}(\psi_{\mu})^{*}(\delta\mathcal{E}_{\mu})]_{\sigma=0}^{\pi} + \psi^{\mu}\delta(\psi_{\mu})^{*}(\partial\mathcal{E}_{\mu})] + \int_{\mathcal{M}} d^2\sigma\,[\partial\psi^{\mu}(\psi_{\mu})^{*} + \psi^{\mu}\partial(\psi_{\mu})^{*}](\delta\mathcal{E}_{\mu})] \quad \textbf{(39d)}$$

$$= 0 \quad \textbf{(39e)}$$

which requires that

$$\delta\mathcal{E}_{\mu} = 0 \quad \textbf{(40)}$$

2.3.3.3. Principle of the minimum action for fermionic string with rightward motion

The analysis is similar to (39) and (40) and leads to

$$\delta S'_{\varphi} = 0 \quad \textbf{(41)}$$

which also requires that

$$\delta\mathcal{E}_{\mu} = 0 \quad \textbf{(42)}$$

The substitution of (36d), (39e) and (41) in (35d) leads to

$$\delta S' = 0 \quad \text{where} \quad \textbf{(43a)}$$

$$\delta S'_{\chi} = 0 \quad \textbf{(43b)}$$

$$\delta S'_{\psi} = 0 \quad \text{and} \quad \textbf{(43c)}$$

$$\delta S'_{\varphi} = 0 \quad \textbf{(43d)}$$

We can investigate further if Eq. (43) is true by using the following expressions for the fermionic string with leftward motion (ψ) in below Eq. (44), and fermionic string with rightward motion (φ) below in Eq. (47), using the superposition principle and Fourier decomposition (Johnson, 2000; Vancea, 2001):

$$\psi^{\mu}(\tau,\sigma) = [\sum_n \alpha_n^{\mu} e^{-(2n+1)(\tau-i\sigma)}] \quad \textbf{(44)}$$

$$\psi^{\mu}(\psi_{\mu})^{*} = [\sum_n \alpha_n^{\mu} e^{-(2n+1)(\tau-i\sigma)}][\sum_n \alpha_{n\mu} e^{-(2n+1)(\tau+i\sigma)}] \quad \textbf{(45)}$$

$$[\psi^{\mu}(\psi_{\mu})^{*}]_n = = [\alpha_n^{\mu} e^{-(2n+1)(\tau-i\sigma)}][\alpha_{n\mu} e^{-(2n+1)(\tau+i\sigma)}] \quad \textbf{(46)}$$

$$\varphi^{\mu}(\tau,\sigma) = [\sum_n \alpha_n^{\mu} e^{-(2n+1)(\tau+i\sigma)}] = (\psi_{\mu})^{*} \quad \textbf{(47)}$$

$$(\varphi_{\mu})^{*} = [\sum_n \alpha_n^{\mu} e^{-(2n+1)(\tau-i\sigma)}] = \psi_{\mu} \quad \textbf{(48)}$$

$$[\psi^{\mu}(\psi_{\mu})^{*} + \varphi^{\mu}(\varphi_{\mu})^{*}] = [\psi^{\mu}(\psi_{\mu})^{*} + (\psi_{\mu})^{*}\psi^{\mu}] = 2[\psi^{\mu}(\psi_{\mu})^{*}] \quad \textbf{(49)}$$

From the last term in (39d), we have

$$[(\psi_{\mu})^{*}\partial\psi^{\mu} + \psi^{\mu}\partial(\psi_{\mu})^{*}](\delta\mathcal{E}_{\mu}) = [(\psi_{\tau})^{*}\partial_{\tau}\psi^{\tau} + \psi^{\tau}\partial(\psi_{\tau})^{*}](\delta\mathcal{E}_{\tau}) + [(\psi_{\sigma})^{*}\partial_{\sigma}\psi^{\sigma} + \psi^{\sigma}\partial(\psi_{\sigma})^{*}](\delta\mathcal{E}_{\sigma}) \quad \textbf{(50)}$$

Let $V = \partial[\psi^{\mu}(\psi_{\mu})^{*}](\delta\mathcal{E}_{\mu})$

$$= [(\partial\psi^{\mu})(\psi_{\mu})^{*} + \psi^{\mu}\partial(\psi_{\mu})^{*}](\delta\mathcal{E}_{\mu}) \quad \textbf{(51a)}$$

$$= [(-\sum_m \alpha_m^{\tau}(2m+1)e^{-(2m+1)(\tau-i\sigma)}] \sum_n \alpha_{n\tau} e^{-(2n+1)(\tau+i\sigma)} + \sum_m \alpha_m^{\tau} e^{-(2m+1)(\tau-i\sigma)} \sum_n \alpha_{n\tau}(2n+1)e^{-(2n+1)(\tau+i\sigma)}](\delta\mathcal{E}_{\mu}) + \ldots \quad \textbf{(51b)}$$

$$= \sum_m [(-\alpha_m^{\tau}(2m+1)e^{-(2m+1)(\tau-i\sigma)} \alpha_{n\tau} e^{-(2n+1)(\tau+i\sigma)}) + (\alpha_m^{\tau} e^{-(2m+1)(\tau-i\sigma)} \alpha_{n\tau}(2n+1)e^{-(2n+1)(\tau+i\sigma)})](\delta\mathcal{E}_{\mu}) + \ldots \quad \textbf{(51c)}$$

$$= \sum_{mn} [(-\alpha_m^{\tau}\alpha_{n\tau}(2m+1) + (\alpha_m^{\tau}\alpha_{n\tau}(2n+1)] e^{-(2m+1)(\tau-i\sigma)} e^{-(2n+1)(\tau+i\sigma)}(\delta\mathcal{E}_{\tau}) + \ldots \quad \textbf{(51d)}$$

$$= \sum_{mn} [-(2m+1) + (2n+1)]\,\alpha_m^{\tau}\alpha_{n\tau}$$

$$e^{-(2m+1)(\tau-i\sigma)}e^{-(2n+1)(\tau+i\sigma)}(\delta\mathcal{E}_{\tau})+\ldots \quad \textbf{(51e)}$$

$$=\sum_{mn}[-2(m-n)]\,\alpha_{m}^{\tau}\alpha_{n\tau}\; e^{-(2m+1)(\tau-i\sigma)}e^{-(2n+1)(\tau+i\sigma)}(\delta\mathcal{E}_{\tau})+\ldots \quad \textbf{(51f)}$$

$$=\sum_{mn}V_{mn} \quad \textbf{(51g)}$$

where

$$V_{mn}=[-2(m-n)]\,\alpha_{m}^{\tau}\alpha_{n\tau}\; e^{-(2m+1)(\tau-i\sigma)}e^{-(2n+1)(\tau+i\sigma)}(\delta\mathcal{E}_{\tau})+\ldots \quad \textbf{(52a)}$$

$$=[-2(m-n)]\,\alpha_{m}^{\tau}\alpha_{n\tau}\; e^{-[2(m+n+1)\tau-i2(m-n)\sigma]}(\delta\mathcal{E}_{\tau})+\ldots \quad \textbf{(52b)}$$

$$V_{mn}=0 \qquad \text{for } m=n \quad \textbf{(53a)}$$

$$V_{mn}=-(V_{mn})^{*} \qquad \text{for } m\neq n \quad \textbf{(53b)}$$

Thus, the requirement (40) $[\delta\mathcal{E}_{\tau}=0]$ is necessary, i.e., $\mathcal{E}_{\mu}$ is constant in spacetime.

2.3.4. Boundary conditions

Furthermore, both (Neumann and Dirichlet) boundary conditions (see page 62 of (Johnson, 2000)) must remain invariant under the introduction of consciousness in string theory, which can be understood as follows:

Neumann boundary conditions in the dual-aspect PE-SE framework (below *n* means normal to the surface) are

$$\partial_n\chi'^{\mu}(\tau,\sigma)=\partial_n[e^{j\mathcal{E}^{\mu}}\,\chi^{\mu}]$$
$$=e^{j\mathcal{E}^{\mu}}[j\chi^{\mu}\partial_n\mathcal{E}^{\mu}+\partial_n\chi^{\mu}]$$
$$=0 \quad \text{if } \partial_n\mathcal{E}^{\mu}=0 \text{ and } \partial_n\chi^{\mu}=0 \quad (54)$$

$$\partial_n\psi'^{\mu}(\tau,\sigma)=\partial_n[e^{j\mathcal{E}^{\mu}}\,\psi^{\mu}]$$
$$=e^{j\mathcal{E}^{\mu}}[j\psi^{\mu}\partial_n\mathcal{E}^{\mu}+\partial_n\psi^{\mu}]$$
$$=0 \quad \text{if } \partial_n\mathcal{E}^{\mu}=0 \text{ and } \partial_n\psi^{\mu}=0 \quad (55)$$

$$\partial_n\varphi'^{\mu}(\tau,\sigma)=\partial_n[e^{j\mathcal{E}^{\mu}}\,\varphi^{\mu}]$$
$$=e^{j\mathcal{E}^{\mu}}[j\varphi^{\mu}\partial_n\mathcal{E}^{\mu}+\partial_n\varphi^{\mu}]$$
$$=0 \quad \text{if } \partial_n\mathcal{E}^{\mu}=0 \text{ and } \partial_n\varphi^{\mu}=0 \quad (56)$$

From Eq. (5) p.5 of (Vancea, 2001), Dirichlet boundary conditions in the dual-aspect PE-SE framework are:

$$\delta\chi'^{\mu}(\tau,\sigma)|_{\partial\Sigma}=\delta[e^{j\mathcal{E}^{\mu}}\,\chi^{\mu}]|_{\partial\Sigma}$$
$$=e^{j\mathcal{E}^{\mu}}[j\chi^{\mu}\delta\mathcal{E}^{\mu}+\delta\chi^{\mu}]|_{\partial\Sigma}$$
$$=0 \quad \text{if } \delta\mathcal{E}^{\mu}|_{\partial\Sigma}=0 \text{ and } \delta\chi^{\mu}|_{\partial\Sigma}=0 \quad \textbf{(57)}$$

$$\delta\psi'^{\mu}(\tau,\sigma)|_{\partial\Sigma}=\delta[e^{j\mathcal{E}^{\mu}}\,\psi^{\mu}]|_{\partial\Sigma}$$
$$=e^{j\mathcal{E}^{\mu}}[j\psi^{\mu}\delta\mathcal{E}^{\mu}+\delta\psi^{\mu}]|_{\partial\Sigma}$$
$$=0 \quad \text{if } \delta\mathcal{E}^{\mu}|_{\partial\Sigma}=0 \text{ and } \delta\psi^{\mu}|_{\partial\Sigma}=0 \quad \textbf{(58)}$$

$$\delta\varphi'^{\mu}(\tau,\sigma)|_{\partial\Sigma}=\delta[e^{j\mathcal{E}^{\mu}}\,\varphi^{\mu}]|_{\partial\Sigma}$$
$$=e^{j\mathcal{E}^{\mu}}[j\varphi^{\mu}\delta\mathcal{E}^{\mu}+\delta\varphi^{\mu}]|_{\partial\Sigma}$$
$$=0 \quad \text{if } \delta\mathcal{E}^{\mu}|_{\partial\Sigma}=0 \text{ and } \delta\varphi^{\mu}|_{\partial\Sigma}=0 \quad \textbf{(59)}$$

Thus, adding mental aspect in the string theory does not affect the physical aspect of the behavior of system, and physics remains invariant. From (38) and (54)-(59), we have:

$$\partial\mathcal{E}^{\mu}(\tau,\sigma)=\partial_n\mathcal{E}^{\mu}(\tau,\sigma)=\delta\mathcal{E}^{\mu}(\tau,\sigma)|_{\partial\Sigma}=0 \quad \textbf{(60)}$$

From (60), we conclude that $\mathcal{E}^{\mu}(\tau,\sigma)$ is independent of the parameters (τ,σ). This is interpreted as follows: (i) a string is dual-aspect entity and (ii) all fundamental *potential* SEs/PEs superposed in the mental aspect of the string remain invariant with parameters (τ,σ).[14]

[14] Experiences need further elaboration. According to (Feigl, 1967), "where is the feeling of motherly love located? [...] The feeling of motherly love is a universal, an abstract concept, and it makes as little sense to ask about its spatial location as it does in regard to the (physical) concept of temperature. [...] Colors are usually perceived as surface qualities of extradermal objects, or in the case of looking at the skin of one's own arms or legs, as surface qualities of those limbs. Colors seen when pressing one's eyelids (closed eyes) are vaguely located either immediately in front of one's eyes, or even

In other words, the introduction of mental aspect in this manner suggests that: (i) superposed *potential* experiences are constant in spacetime, i.e., present everywhere and present all the time in strings and inert entities. (ii) However, for conscious subjects, from the analysis of general theory of relativity in classical physics (Vimal, 2010c), when a subject moves, the specific SE *redness* also moves with the subject's correlated neural-net. In addition, SEs can change with time as stimuli change. In other words, SEs in a subject change with spacetime. And (iii) the mental aspect of string could be in all dimensions: both (3+1)D real dimensions and also in the hidden dimensions that are compactified (curled up).

3. Conclusions

3.1. Theory of everything

The M-theory and F-theory might be close to theory of everything (TOE). However, the critical problem of observer dependent reality still remained, and the theory of everything must explain subjective experiences (SEs) aspect of consciousness (Chalmers, 1996). This problem was qualitatively addressed in a dual-aspect-dual-mode framework (Vimal, 2008b; Vimal, 2010a).

3.2. The three competing hypotheses of the PE-SE framework

There are three competing hypotheses: *superposition* based $\mathbf{H_1}$, *superposition-then-integration* based $\mathbf{H_2}$, and *integration* based $\mathbf{H_3}$ where superposition is not required. In $\mathbf{H_1}$, the fundamental entities and inert matter are the *carriers* of superimposed fundamental *potential* SEs/proto-experiences (PEs). In $\mathbf{H_2}$, the fundamental entities and inert matter are the *carriers* of superimposed fundamental *potential* PEs (not SEs); there is a PE attached to every level of evolution, which are *integrated* by *neural-Darwinism* (co-evolution, co-development, and sensorimotor co-tuning). Here, the (mysterious) principle of *emergence* of SEs from proto-experiences is required. In $\mathbf{H_3}$, a string has its own string-PE; matter is not a *carrier*; rather matter has two aspects at every level. These two aspects are rigorously *integrated* together by *neural-Darwinism*. $\mathbf{H_3}$ is a dual-aspect proto-panpsychism that has seven problems including the combination problem (Vimal, 2010a; Vimal, 2010b).

3.3. Prediction of PE-SE framework

Since strings, loops, elementary particles, and inert matters are *carriers* of SEs/PEs (as in $\mathbf{H_1}$ and $\mathbf{H_2}$), inert matters behave as if they are non-experiential entities. Therefore, the prediction of hypotheses $\mathbf{H_1}$ and $\mathbf{H_2}$ of the PE-SE framework is that physics remains invariant with the introduction of the SE aspect of consciousness. This prediction is tested in this series of three articles.

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inside them. Similarly musical sound images (especially in the eidetic's case) either appear inside one's head or seem to come from the outside as in a concert hall. The taste of an apple is clearly experienced within the mouth. [...] Phenomenal time and physical time differ from, and are related to, each other very much like phenomenal space and physical space. Experienced durations may seem very long in the case of tiresome waiting, while time packed full with exciting events seems to "pass quickly." But the physically measured durations may be exactly the same." (Velmans, 2008) suggested that, "According to dualists, S's experience of a cat [an entity in the world] is "nowhere"; according to reductionists, S's experience of a cat [that entity] is in her brain; according to the reflexive model, both former models misdescribe what S actually experiences … the objects that we experience seem to be out there in the world, not in our head or brain." For example, "this print seems to be out here on this page and not in your brain." According to (Vimal, 2010a), the dual-aspect-dual-mode PE-SE framework differs from Velmans in that: "PEs/SEs are in superposed [latent] form in the mental aspect of fundamental particles in the PE-SE framework (to address the various problems (Globus, 2008; Seager, 1995) such as combination problem (Goff, 2009)), whereas this is not the case in Velmans' framework. This means that consciousness (SEs) is almost everywhere (wherever fundamental particles are) in superposed and unexpressed [latent] form in the PE-SE framework. A specific experience, when expressed, is in the mental aspect of both the stimulus (in the form of qualia) and the neural-net (in the form of its SE), linked by conjugate matching/perceptual projection. However, in Velmans' framework, a specific conscious experience is in the mental aspect of the external world (stimulus)." Thus, SEs when expressed can be described to have certain location, but when unexpressed/latent such as superposed in string, they are wherever strings are.

3.4. Introduction of SEs/PEs aspect of consciousness in classical, orthodox quantum physics, and modern quantum physics

We introduce the subjective experience (SE) aspect of consciousness in **(Part I)** classical physics (Vimal, 2010c), **(Part II)** orthodox quantum physics (Vimal, 2010d), and **(Part III)** modern quantum physics (Section 2) by using the methodology of investigating invariance in critical components of respective theories under the PE-SE transformations. We find that physics is indeed invariant.

3.5. Invariance in classical, orthodox quantum physics, and modern quantum physics

We found that the followings in physics are invariant under the PE-SE transformations (2a-2t): **(Part I)** electromagnetic strength tensor, electromagnetic stress-energy tensor, the electromagnetic theory (Maxwell's equations), Newtonian gravitational field, the entropic force, special theory of Relativity and Lorentz transformation, geodesic equation, general theory of relativity: the metric $g_{\mu\nu}$ (generalization of the gravitational field), Ricci curvature tensor $R_{\mu\nu}$, Ricci scalar curvature R, the cosmological constant Λ, and the stress-energy tensor $T_{\mu\nu}$; **(Part II)** Schrödinger equation, current, Dirac Lagrangian, the Lagrangian for a charged self–interacting scalar field, Standard Model (the Lagrangian for free gauge field and Lagrangian for the electromagnetic interaction of a charged scalar field (Higgs Mechanism)); **(Part III)** loop quantum gravity and string theory.

3.6. Introduction of SEs/PEs aspect of consciousness in loop quantum gravity (LQG)

The following critical components of LQG/LQC appear invariant under the PE-SE transformations: the Palatini action related to LQG, the scalar product between any two cylindrical functions, area operator, volume operator, the states related to decomposition of Hilbert space (Gauss constraint), the physical states under finite diffeomorphisms such as the active co-ordinate transformation (diffeomorphism constraint), and loop quantum cosmology (LQC: the model of Big-Bounce cyclic universe).

3.7. Introduction of SEs/PEs aspect of consciousness in string theory for hypotheses H_1 and H_2

In this series of three articles, for hypotheses $\mathbf{H_1}$ and $\mathbf{H_2}$, we quantitatively introduce the superposition of *potential* SEs/PEs or PEs in the mental aspect of bosonic and fermionic strings using the Polyakov action. We find that *potential* experiences are independent of the time-like and space-like parameters (τ, σ). This is interpreted as follows: (i) a string is dual-aspect entity, and (ii) all fundamental *potential* SEs/PEs superposed in the mental aspect of the string remain invariant with time and space. The introduction of mental aspect in this manner suggests that (iii) the mental aspect of string could be in all dimensions: both (3+1)D real dimensions and also in the hidden dimensions that are compactified (curled up). In addition, the Neumann and Dirichlet boundary conditions were also satisfied. These led us to conclude that the physical aspect of the behavior of system in string theory remains invariant under the introduction of *potential* experiences in the mental aspect of strings as a function of experiences. For hypothesis $\mathbf{H_3}$, the equations of string theory remain the same; we simply need to acknowledge that a string has dual-aspect; its mental aspect is string-PE.

3.8. Implications of the introduction of SE aspect of consciousness in string theory

The introduction of SE aspect of consciousness in string theory can be interpreted to imply that *potential* experiences are independent of time and space in all dimensions for strings and inert entities; however, this may not be true for conscious beings because SEs change with subjects across space and time. This fact is revealed in the introduction of SE aspect of consciousness in general theory of relativity of classical physics (Vimal, 2010c): (i) SEs are embedded in spacetime geometry for structure of spacetime (empty space or the vacuum without matter). (ii) Similarly, for matter field, *potential* SEs are superposed in the mental aspect of each elementary particle (fermion or boson including graviton); wherever these particles move, superposed *potential* SEs must also move with them to conserve SEs. However, (iii) since our specific SE is the result of matching and selection processes, the SE can change with space and time. For example, experiencing *redness* has neural correlates of V4/V8/VO-red-green neural-net with redness state. When a person moves, the specific SE redness also moves with this neural-net of that person. Realized/actualized specific SEs also changes with time as stimuli change. In other words, realized/actualized specific SEs in a conscious subject change with spacetime depending on stimuli and contexts, although superposed *potential* SEs in the mental aspect of strings and inert entities remain invarient with spacetime.

3.9. Introduction of SEs/PEs aspect of consciousness in string theory for hypothesis H_3

For hypothesis $\mathbf{H_3}$, the equations of string theory remain the same; we need, however, to acknowledge that string has two aspects: physical and mental aspect (string-PE).

3.10. Unification and TOE

From above, it is possible to unify consciousness with known fundamental forces, which leads us closer to the theory of everything.

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