

## Research Report

# PROTO-EXPERIENCES AND SUBJECTIVE EXPERIENCES: CLASSICAL AND QUANTUM CONCEPTS

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Deterministic reductive monism and non-reductive substance dualism are two opposite views for consciousness, and both have serious problems. An alternative view is needed. For this, we hypothesize that strings or elementary particles (fermions and bosons) have two aspects: (i) elemental proto-experiences (PEs) as phenomenal aspect, and (ii) mass, charge, and spin as material aspect. Elemental PEs are hypothesized to be the properties of elementary particles and their interactions, which are composed of irreducible fundamental subjective experiences (SEs)/PEs that are in superimposed form in elementary particles and in their interactions. Since SEs/PEs are superimposed, elementary particles are not specific to any SE/PE; they (and all inert matter) are *carriers* of SEs/PEs, and hence, appear as non-experiential material entities. Furthermore, our hypothesis is that matter and associated elemental PEs co-evolved and co-developed into neural-nets and associated neural-net PEs (neural Darwinism), respectively. The signals related to neural PEs interact in a neural-net and neural-net PEs emerges from random process of self-organization. The neural-net PEs are a set of SEs embedded in the neural-net by a non-computational or non-algorithmic process. The non-specificity of elementary particles is transformed into the specificity of neural-nets by neural Darwinism. The specificity of SEs emerges when feedforward and feedback signal interacts in the neuropil and are dependent on wakefulness (i.e., activation) attention, re-entry between neural populations, working memory, stimulus at above threshold, and neural net PE signals. This PE-SE framework integrates reductive and non-reductive views, complements the existing models, bridges the explanatory gaps, and minimizes the problem of causation.

*Keywords:* Analytical philosophy; non-computationalism; mind-brain problem; consciousness; neural Darwinism; self-organization; Red-Green opponent channel; neural-net.

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## 1. Introduction

The mind-brain problem is central to consciousness study and is one of the hardest problems we face today. There are many views between two opposite poles of deterministic reductive monism and non-reductive substance dualism of Cartesian type. In monism, phenomenal entities (such as subjective experiences (SEs)) emerge from the non-experiential material entities (such as neural-interactions in the brain), and both types of entities are substantively one, whereas they are distinct in dualism [51]. In monism, the serious problem is the explanatory gap; whereas, in substance dualism, there are two major problems: (i) association or mind-brain interaction problem: how does the non-physical mind interact with the brain, and (ii) problem of mental causation: how can a mental-cause give rise to a behavioral effect without the violation of the conservation of energy and momentum?

In general, Chalmers classified most of the views on the metaphysics of consciousness into six types [15]: **(1)** Type-A materialists [21, 24, 37] deny psycho-physical or explanatory gap. Eliminativism (SE does not exist), analytic functionalism (explaining the functions explains everything), and logical behaviorism fail to explain SE. **(2)** Type-B materialists [11, 38, 50, 52, 73, 103] accept conceptual/epistemic gap, but deny the empirical/ontological gap. They identify SE with certain physical or functional states; **(3)** Type-C materialists [19, 20, 25, 26, 36, 44, 65, 101, 104] accept the deep epistemic gap, but hold that it will eventually be closed by further research. Since this is an unstable view, it will collapse into a version of type-A materialism, type-B materialism, type-D dualism, or type-F monism. **(4)** Type-D dualists or interaction-dualists [6, 28, 39] deny the causal closure of the microphysical, and hold that physical states cause phenomenal states, and phenomenal states cause physical states. This view avoids the “combination problem” of type-F view. Consciousness is an irreducible entity; physical and mental entities are distinct (substance-dualism); and there is downward causation of the mental on the microphysical. **(5)** Type-E dualists or epiphenomenalistic dualists [42] accept the causal closure of the microphysical, and hold that phenomenal properties play no causal role in affecting the physical world. There is **no** downward causation of the mental on the microphysical. Physical states cause phenomenal states, but not vice versa. Consciousness is an irreducible entity; and physical and mental entities are distinct. **(6)** Type-F monists or panprotopsychnists [14, 31, 53, 80, 91, 92, 110] accept the causal closure of the microphysical network, but hold that phenomenal or proto-phenomenal properties are integrated with it and are located at the fundamental level of physical reality. Type-F appears to have property-dualism and substance-monism. In addition, consciousness is constituted by the intrinsic properties of fundamental physical entities, and it plays a causal role. In Type-F view, it is postulated that macro-psycho-physical laws (connecting physical and phenomenal properties) evolved from micro-psycho-physical laws (connecting micro-physical and proto-phenomenal properties). Types A through C are reductive views where subjective experiences are considered as physical processes that do not involve expansion of a physical ontology.

Types D through F are non-reductive views where subjective experiences are considered as entities irreducible in nature, which involves expansion or reconception of a physical ontology.

We define elemental proto-experiences (PEs) as the properties of elementary particles and their interactions. Elemental-PEs are composed of all fundamental subjective experiences (SEs) that are in **superimposed form** in strings or elementary particles (fermions and bosons) and in their interactions. Therefore, elementary particles are not specific to any SE, and hence appear as non-experiential material entities. This is the PE-SE framework. By simply introducing elemental PEs, by hypothesizing elementary particles being the carriers of SEs in unexpressed or latent form, without disturbing physics, no physical laws are violated. Introduction of PEs has an advantage of explaining consciousness and eliminating the explanatory gap (how SEs emerge from non-experiential matter) in complementary way. All physical models remain as they are except consciousness related models are complemented and mystery of emergence is addressed. The PE-SE framework is close to Type F proto-panpsychism (with property-dualism and substance-monism). However, more appropriate term may be “non-reductive physicalism”.

We have assumed that fundamental SEs/PEs should be considered as phenomenal aspect in the dual-aspect model at elemental level to minimize the problems (discussed later). The use of term “fundamental SEs/PEs” is justified because (i) derived SEs/PEs are not included in this term as they can be derived from fundamental SEs/PEs, (ii) terms “SEs” and “PEs” are written as “SEs/PEs” as SEs and PEs are mixed. According to MacGregor and Vimal [56], “Every individual string corresponds to an individual fundamental particle of quantum physics and its vibrational mode defines which type of particle it is”. In addition, all kinds of SEs are superimposed in each elementary particle in PE-SE framework. Therefore, it is hypothesized that all types of SEs are also superimposed in every individual string. In other words, a string may have two aspects: material and phenomenal aspects; its material aspect is embedded in space-time: the four dimensions of string; its phenomenal aspect may be embedded in one or more of the remaining dimensions of string [56].

Furthermore, one could broaden the definition of PEs as those experiences that are not SEs. SEs are first person experiences, which might be chaotic attractors that exist in regions in the state space or might have come from boundary conditions and singularities. Attractors arise from interactions of phenomenological, behavioral, neural, and environmental processes as a nonlinear dynamical system [1]. They are related to the self-organization of brain, which includes essential ingredients of awareness, such as wakefulness, re-entry, attention, memory, and neural-net proto-experiences. In other words, SEs during wakefulness are those experiences that might arise when the essential ingredients, such as above, are satisfied.

What way is PE-SE framework different from the Types A-C straightforward or standard physicalistic views? In these views, SEs are emerged entities in neural-nets from the interaction of non-experiential physical entities, such as feedforward and

feedback neural signals, which has led to the explanatory gap between the internal representation of objects and associated subjective experiences [50] or “hard problem” [16]. The difference is that we acknowledge the existence of proto-experiential entities in physics in the PE-SE framework, where the emergence of SE from proto-experiential entities (such as interaction of neural PEs) is lot less “brute” than that from non-experiential matter.

What way is PE-SE framework different from panpsychism? [93] The history of panpsychist arguments for “experience” as a fundamental aspect of atomic forces are found as far back as Empedocles, and recur in the thinking of Lotze, Priestley, Haeckel, and Troland. However, it is not clear whether their meaning of “experience” was subjective experience or proto-experience. According to Manjaly [58], panpsychism as described by Strawson [93] may lead to elemental substance dualism and causal-interaction problem. The PE-SE framework has substance-monism and property-dualism at elemental level. All kinds of fundamental SEs/PEs are in superimposed form in elementary particles and in their interactions; elementary particles and inert matter are the carriers of SEs/PEs in unexpressed form; they are not even proto-conscious. Therefore, entities are not specific to any SE and behave as non-experiential material entities. In other words, all entities are not conscious as assumed in panpsychism. As the level of co-evolution increases, specificity increases. This implies that at some level, there might be critical specificity for proto-consciousness.

## **2. How Do Nonspecific Proto-Experiences Lead to Specific Subjective Experience and/or How do SEs Emerge from Neural Signal Interactions Related to PEs?**

Our goal is twofold: firstly to investigate if elemental proto-experiences (PEs) co-evolved and co-developed with matter into subjective experiences (SEs) and associated neural-nets; and secondly to investigate the selection process for specific SE.

At every level of evolution, a relevant physical entity has its associated PEs: from elemental PEs to neural-net PEs. For example, one possible source of PE in brain might be the proto-experience related to ions that rush across neural-membrane during spike-generation (including activity in astroglial cells and metabolic energization), which can be called neural-PE. Ionic-PEs have higher specificity than elemental-PEs because, for example, ions in visual system are tuned to vision related SEs even though they are apparently no different from the ions in auditory system if tested in isolation: sodium ions are sodium ions no matter where they are. This is because sensorimotor tuning during co-development (neural Darwinism) enhances the specificity. Furthermore, the neurobiological basis of subjective experience or consciousness is obscure [51, 54, 55].

According to Bruzzo and Vimal [13], “Generically, Lashley *et al.* [48] suggested that consciousness might be associated with neural action potentials (“spikes”).

More recently, Poznanski [77] has cogently argued that volume transmission (extrasynaptic currents, regulator and “second messenger” fluxes, and the like) are a more likely substrate for consciousness because of their global and continuous (non-discrete) character. Our own view, in PE-SE framework, is that consciousness (including Self) might be best seen to have emerged and evolved from a primordial potential or proto-experience in matter [such as elemental PEs]. [...] The PE-SE framework is consistent with both (a) non-computational extracellular “wireless” volume transmission [77] for nonspecific or less specific consciousness (such as thought processing), and (b) synaptic signal transmission in neural-nets for specific SEs. [...] This is because both types of transmissions involve ionic PEs”.

According to Ronald J MacGregor (*personal communication*), “the localization of basic neural PE is likely larger than simply the possibility of the ionic fluxes of spiking. In addition to many deeper levels of neural activity, there is suggestive evidence that consciousness may associate with astroglial cells, and possibly, through this with the metabolic energization of the brain, which would seem an elegant and highly strategic foundation” (see also [51, 54, 55, 57, 79]). All levels of PEs including neural-net PEs are unconscious or subconscious, whereas SEs are conscious in the PE-SE framework. Unconscious/subconscious processing in other frameworks is equivalent to neural/neural-net PEs in the PE-SE framework.

The coherence between feedforward incoming and reentrant feedback signals seems to be a necessary for consciousness as a “conflict-solving process” [29]. For this, contributing factors are (a) reticular activating system; (b) local electrical synchronization; (c) chemical modulation at the synapse; and (d) the N-methyl-D-aspartate (NMDA) mechanism involving  $Mg^{++}$ , glutamate, and  $Ca^{++}$ . The latter two factors (c) and (d), GABA-mechanism, classical  $Na^+/K^+/Cl^-$  system, possibly astroglial cells and metabolic energization of the brain [51, 54, 55], and calcium ions (trapped in astrocytes by a static electric field) interacting with neural electric fields [72] contribute to the substrate for neural-PEs. Thus, the coherence framework and the PE-SE framework are complementary to each other: the latter is the underlying proto-experiential mechanism of the former. Furthermore, coherence-decoherence cycle provides “conscious processing to alter enzyme action” and “control membrane electrical activity and influence behavior” [29]. This rejects the consciousness being an epiphenomenon.

Signals related to neural-PEs interact in a neural-net and neural-net PEs emerge, which are then embedded in the neural-net during co-development. The process of embedding involves genetic disposition, neural Darwinism (co-development of neural-net and its associated PEs, and sensorimotor co-tuning with external stimuli); re-entry (repeated entry of signals in neural-net to form traces for embedding PEs), assignment, and selection of SE. To spell out literally how neural-net PEs can be embedded in a neural net, we assume that co-evolution processes have already co-evolved elemental proto-experiences and matter into genetic proto-experiences and genes, respectively.

In PE-SE framework, co-evolution and co-development processes involve both genetic (DNA-based) and epigenetic (such as language, memory, and cultural evolution) contributions. According to Stapp [90]: “The complexity of the physical carrier has undoubtedly co-evolved with the complexity of the associated experiential reality”, which is consistent with our framework. Johnston [43] reported, “Within a dynamical-systems framework, human behavior is seen as emergent from broad evolutionary processes associated with three basic forms of nature. First, matter, emerged from the big bang some 12–15 billion years ago; second, life, from the first bacteria up to four billion years ago; third, ideology and cultural artifacts (e.g., institutions and technology), with a shift to self-reflective, symbolic thought and agrarianism in humans some 8–40 thousand years ago”. The co-evolution of elemental PEs were formed at Big Bang, and took billions of years to form earth. Then life on earth started about four billion years ago [32]. Subjective experiences might have emerged about 540 millions years ago during Cambrian explosion in multicellular organisms [32]. The co-evolution process continued to human genes, and it is still going on in terms of close interaction between brain, mind, and culture.

The human mind, brain, and culture co-evolved and interacted closely with each other [23]. The three major transitions/stages, in hominid cognitive evolution, coincide with (i) the speciation of *Homo erectus* (~1.5 millions years ago) and archaic *Homo sapiens* (~0.3 millions years ago), during these periods supramodal, motor-modeling capacity (mimesis) created representations for the critical property of voluntary retrievability; (ii) the emergence of spoken language (~45,000 years ago) with a capacity for lexical invention, the descent of the human larynx and the redesign of the supralaryngeal vocal tract, and a high-speed phonological apparatus; and (iii) the invention of visual symbols (15,000–750,000 years ago), external memory storage and retrieval, and a new working memory architecture [23]. All three stages might have introduced new memory features into the human cognitive system. If subjective experiences (SEs) emerged during Cambrian explosion [32], working memory might have emerged in some form millions of years later.

An interesting question is what those entities were from which brain and subjective experience or mind evolved. For the evolution of brain, presumably, the initial *physical* entities were the four fundamental forces of Nature: strong nuclear force, electromagnetic force, weak nuclear force, and gravitational force [4, 96] embedded in mass, charge, and space-time. For the evolution of subjective experiences, our hypothesis is that the initial entities were proto-experiences as discussed in the introduction. In addition, both brain and mind co-evolved.

According to Searle [86], “consciousness is entirely caused by neurobiological processes and is realized in brain structures. [...] “Two common approaches to consciousness are those that adopt the building block model, according to which any conscious field is made of its various parts, and the unified field model, according to which we should try to explain the unified character of subjective states of consciousness”. In both models, consciousness is assumed to emerge from non-experiential material entities. Thus, it is deterministic reductive monism. In PE-SE

framework, elemental PEs are primitive experiential entities and subjective experiences are assumed to emerge from the interaction of experiential PE-signals in neural-nets. The position of PE-SE framework is close to Chalmers' Type-F monism and dual-aspect model, i.e., SEs co-evolved and co-developed from non-reductive fundamental elemental PEs/SEs and both models described by Searle can be used; only difference is that SEs emerge from non-experiential entities in Searle's framework and they emerge from experiential PEs/SEs in PE-SE framework (that is less "brute").

For the co-development of neural-net and its associated PEs during ontogenesis, the "epigenetic landscape" model of embryonic development [107] using neural Darwinism can be used by appropriately recognizing various factors [13]. For example, the initial conditions of self-organization could be genetic disposition because little change in initial conditions has significant effects. Since red-green color vision is genetically X-chromosome linked [75], a small genetic discrepancy in X-chromosome causes significant red-green color anomaly. The "attractors" are the same as in embryonic development in addition to embryonic neural-net proto-experiences.

Post-ontogenically, the co-development of neural-net and its associated PEs is achieved via sensorimotor co-tuning with external stimuli. In this process, re-entry process plays important role, which is a repeated entry of signals in neural-net to form traces for embedding the neural-net PEs. If any of these processes is disturbed, abnormality occurs. For example, if new born is blind-folded and hence does not receive visual stimuli, then the development of visual system will be abnormal [111]. According to Sur *et al.* [95], "functional visual projections can be routed into nonvisual structures in higher mammals, suggesting that the modality of a sensory thalamic nucleus or cortical area may be specified by its inputs during development". Striking reorganization of orientation maps in early life was induced by orientation-restricted continuous visual exposure [98]. Normal red-green genetic information and normal sensorimotor interaction with red-green stimuli will set up appropriate red-green color neural-net that will have all red-green color SEs (such as redness, greenness, and all the intermediate just-noticeable-differences) embedded in it. When long wavelength light keeps on stimulating the visual area V4/V8 color neural-net<sup>a</sup> repeatedly from birth to its critical period, SE *redness* will emerge in it due to re-entrant interactions between feed-forward and feedback signals. This is because neural signals are proto-experiential signals in the PE-SE framework. Each stimulation leaves a trace of a specific neural-net PE in the neural-net in terms of memory; this memory trace is potentiated by repeated stimulation. This is consistent with the self-organization<sup>b</sup> of neural-nets: "the organic structure of

<sup>a</sup>Some supporting data are as follows: The lesion in the fusiform gyrus (where V4 is located) leads to achromatopsia [112]. V1/V4 may serve as the bridge locus for color qualia [7]. V4/V8 neural-net includes all those area that are involved in color SEs including Self-related areas [69].

<sup>b</sup>In self-organization (or self-control), "the control parameters of a system are influenced by the state of the system itself", i.e., "control parameter of one scheme being under the control of another" [1]. For example, groups of neurons in a neural-net can self-organize into a firing-pattern in response to changes in experience [59].

the [connection] matrix [of the brain] facilitates particular patterns of energy flow, which in turn affect the subsequent development of the matrix” [84]. According to Arendt [2], “life-long self-optimization process, epigenetic information remodels the cognitive, behavioral and emotional reactivity of an individual to meet the environmental demands”. Genetics programs the basic wiring pattern of the brain, whereas the neural Darwinism does the fine tuning during ontogenesis, while post-ontogenically other mechanisms are at play [76].<sup>c</sup> Self-organization process specifies neuronal interconnections and continuously reshapes the brain using the epigenetic information obtained from microenvironment (such as biochemical signals generated by local neurons and glial cells) during early development and sensory experiences; and during late development and post-development or adulthood [2, 3, 18]. Although we do not precisely know how, but since brain is non linear dynamic system, *somehow* SEs emerge in neural-nets, which are then embedded in it as neural-net PEs (or latent SEs); the emergence of SEs may involve the random process and self-organization [13]. The embedding process may itself be chaotic memory consolidation process [1] with neural-net PEs being chaotic attractors. According to Sugita [94], “Experience in early infancy is indispensable for color perception”. Before critical period of color vision, new born may be unable to discriminate color well. Four-week-old infants responded only marginally to moving red/green gratings, but nine-week-old infants and adults responded well [100]. Two-month-old infants have some form of color vision [71]. The color vision of three-month-old infants is based on hue and/or saturation, rather than brightness [99]. Covariance channels for color and luminance are interdependent in infants (4–6 months old), whereas they are independent in adults [74]. The tuning functions co-develop after birth by interaction with external stimuli to matured level when adulthood is reached. For example, the spatial frequency tuning functions of red-green mechanisms for 11 year old boy were broader than for adults [70, 105, 106]. A model of activity-dependent self-organization of geniculo-cortical inputs, the exposure to drifting gratings results in orientation tuning [97]. Since a SE and its associated neural-net are the result of co-development, both may influence each other. For example, functional connectivity may change during co-development depending on the SE of stimuli leading to the above tuned mechanisms. The process described above can be called calibration process. Some examples of calibration process are as follows: (1) Brain recalibrates the simultaneity point for perceiving the auditory and visual aspects of a stimulus simultaneously by detecting and reducing time lags between input signals [30]. (2) Calibration of activity-dependent refinement of cortical connectivity is a function of development and sensory experience and involves synaptic scaling [22]. (3) Orientation tuning can be recalibrated by long-term visual SE [87, 109]. (4) Visual SE may recalibrate perirhinal cortical cells, which share similar object preferences [62].

<sup>c</sup>According to McCrone, “The tip of an individual dendrite may swell to expose new synapses, physically strengthening a connection. Or a neuron might sprout extra dendrites. Or whole new neurons might be brought in to swell the pathway. The number of ways of tuning the connection between two brain cells — of wiring in a memory — runs into the dozens, probably even the hundreds. The result of all this careful tuning is a neural landscape sculpted by its experiences”; see also [60].

An elemental PE is *nonspecific* in the sense that it does not represent any *specific* SE because all types of fundamental SEs/PEs are superimposed in elementary particles, i.e., elemental PE involves all fundamental SEs/PEs in superimposed form. The *specificity* of PE increases as it co-evolves to higher level. For example, genetic-PE will have higher *specificity* than elemental-PE. But it will have lower *specificity* than neural-net-PE. Specificity is zero for elemental-PEs because they involve all SEs/PEs, whereas specificity is one for unique hues such as *yellowness* (neither red nor green) because it is not in other SEs. Thus, the non-specificity of proto-experiences develops into the specificity of SEs.

The external objects that reflect long-wavelength lights evoke subjective experience (SE) *redness* in normal trichromats. One could ask how and why the subjective experience *redness* (not *blueness* or *greenness*) was assigned to long wavelength lights. The dynamics of brain's self-organization suggests, "cyclical process of emergent goal seeking, reference and sensory feedback constitute the basis for a subject consciousness" [102]. A self-organizing system, such as the brain, is an *open* system, which is intimately connected with its environment; it can create novel structures and new modes of behavior [13]. Therefore, one could argue that complex SEs (such as *redness*) might have been created by the self-organization process of the brain to cope with its environment during co-evolution. Sensory qualia or SE is largely internal, covert and private; it appeared only after selection shaped it. For example, one could make the statement: "In the past, my ancestors evolved to feel red this way because feeling it this way gave them a real biological advantage" [40, 41]. In other words, during co-evolution of SE, many SEs might have been tried by random processes. The hypothesis that SEs are useful in (a) obtaining the summary of all information related to a physical event that is consistent with [45], and (b) integrating agentic high-level systems that are competing for skeletomotor control [63]. One could further argue that the assignment of a specific SE to a specific stimulus might be via adaptation and selection. For example, natural selection and adaptation selected *redness* experience for those objects that reflect long wavelength lights; *blueness* or other SEs for these objects would not fit the best; SE *redness* for them was the best fit, therefore, this selection remained. Furthermore, the emergence of any entity, by any process, must have its existence before random process acts on, which is consistent with our fundamental postulate that all types of fundamental SEs/PEs are in superimposed form in all elementary particles. These particles act as carriers of SEs/PEs. One could argue that SE co-evolved with its neural correlate from intrinsic elemental-PEs and matter, respectively.

A neural-net-PEs are a set of SEs embedded (and stored as memory traces) in neural-nets in latent or covert form by a non-computation process. For example, specific subjective experience *redness* is selected out of embedded neural-net color PEs in visual V4/V8-red-green-neural-net when a long wavelength light is presented to our visual system. Thus, the selection process could simply be accomplished classically by the signal due to external stimulus, which is capable of activating the related embedded memory trace (i.e., the specific neural-net PE) in the relevant

neural-net as the specific SE. Alternatively, orchestrated objective reduction (Orch OR) model [35], based on quantum coherence in dendritic microtubule-network [27] can also be used for the selection of the specific SE out of many neural-net PEs (embedded in microtubule-network) by collapsing many states (or PEs) into a specific one (SE) depending on the stimulus. The neural-net-PEs embedded in neural-nets can be considered as neural-correlates of Penrose Platonic values encoded in fundamental space-time geometry [34].<sup>d</sup> However, this mechanism is not clear. Similarly, when signals related to neural-PEs travel along the auditory pathway and interact in auditory neural-net, auditory SEs emerge. Thus, the emergence of a specific SE depends on the context, stimuli, and the specific neural-net.

### 3. Co-Evolution and Co-Development of Brain and Mind

Our hypothesis implies that non-experiential matter and related elemental proto-experiences (PEs) co-evolved and co-developed, leading to neural-nets and associated PEs, respectively. Had there been no co-development of the mind and brain, we would have some proto-experiences but we would not have subjective experiences. This is further investigated in [56].

There are apparent problems related to the “co-evolution and co-development of mind and brain” and Type-F monism, such as “combination problem”, the “unconscious mentality problem”, the “completeness problem”, the “no sign problem”, and the “not-mental problem” [85]; they are discussed below.

The “co-evolution and co-development of mind and brain” hypothesis addresses the “combination or generation problem”: “how low-level proto-experiential and other properties somehow together *constitute* our complex unified conscious experiences” [17, 85]. In other words, the puzzling question is how a specific SE emerges from the interaction of less specific neural-PEs. To address this, let us take, again, an example of color. Our framework suggests that the “V4/V8 red-green (R-G) neural-net” and associated color neural-net-PEs co-evolved, co-developed and co-tuned with the environment from its constituent physical entities and their proto-experiences. When this neural-net is activated (i.e., when the net is awake, re-entrant, attentive, has working memory, has stimulus-signal above threshold, and has neural-net PEs) by a long wavelength light, the neural-net has the subjective experience *redness*, which is selected from the latent subjective experiences (or “neural-net PEs”) of the net. When the neural-net is not active, then we consider that subjective experiences are latent in it. For example, when “V4/V8 R-G neural-net” is not activated, the subjective experiences of colors such as *redness* to *greenness* are in latent or covert form, which is called “neural-net PEs”. Thus, the combination problem is addressed with the limitation of “mysterious emergence of SEs” that is unpacked below.

<sup>d</sup>The number of possible subjective experiences (SEs) for Orch OR can be reduced by sensorimotor tuning during development in a neural-net (neural Darwinism). For example, the X-linked red-green V4/V8-neural-net embeds only red-green color related SEs as neural-net PEs.

A hypothesis in the neural-based PE-SE framework is that (i) there exist a “virtual reservoir” that stores all possible fundamental SEs/PEs; (ii) the interaction of stimulus dependent feedforward and feedback signals in a neural-net creates a specific neural-net state; (iii) this specific state is assigned to a specific SE from the virtual reservoir during development and sensorimotor tuning by the process of adaptation (neural Darwinism); (iv) this specific SE is embedded as a memory trace of neural-net-PE; and (v) when a specific stimulus, such as long wavelength light, is presented to the neural-net, the associated specific SE, such as redness, is selected by the selection process and experienced by the neural-net. This area needs further research.

The term “virtual reservoir” in our PE-SE framework is consistent our fundamental assumption that all types of fundamental SEs/PEs are in **superimposed form** in all elementary particles. Thus, every elementary particle can be considered as a *virtual reservoir* containing all types of fundamental SEs/PEs. Though apparently different, *virtual reservoir* can also be considered as a sort of “Penrose Platonic world” in Orch OR framework [35], “societies of occasions of experience” or “space for the qualia of material” in Whitehead framework [5, 110], “sub-quantum (SQ) space” in SQ-framework [12], “cosmic consciousness space” cosmic-consciousness-framework [82, 83], and “*Purusha-Vishnu*” or “primordial consciousness” space in RigVedic-Buddhist framework [81, 108]. For an observer to know something, he must build an axis composed of individual measurement cells; the set of cells he owns is the space of possibilities he can conceive, and when measurement reports are placed in that space the possibilities are down selected from the possible to the actual (Wolfgang Baer, *personal communication*). Some of these frameworks may differ significantly from each other and from our framework. Nevertheless, introducing *virtual reservoir* does not necessarily extend physics because of following reasons: (i) We assume that SEs are emerged during the interaction of feedforward and feedback neural-PE signals in neural-nets possibly by the random process of self-organization because this process has ability to create novel entities to meet the environmental demands. All possible fundamental SEs/PEs are in this *virtual reservoir*. (ii) It is simply another useful term for the set of many possible states in quantum-wave function framework. This set is used for *collapsing* the waves into observable subjective experiences during measurement, for example, the selection of a specific SE such as *redness* from the set of color neural-net-PEs in V4/V8 neural-net when a specific stimulus such as long wavelength light is presented.

There is a huge gap between atomic proto-experiences and neural-net proto-experiences. The “co-evolution and co-development of mind and brain” hypothesis fills this gap and addresses the “unconscious mentality problem”: “accepting the mentality of the elemental units of mind while denying that they are actually conscious experiences” [85]. This is because they (inert material entities) are actually *carriers* of SEs/PEs (i.e., proto-experiences) at elementary level, i.e., they are not conscious subjective experiences. This may sound like the problem related to panpsychism. However, it is not the case in its strict form because “an entity has

or carries proto-experience” does not mean “it has subjective experience” as we have. Subjective experience may not even be present in lower forms of life that do not have its essential ingredients such as wakefulness, attention, re-entry, working memory, stimulus at above threshold, and PEs signals. Therefore, not every entity is consciousness (has SEs or first person experiences). For our PE-SE framework, a term closest to panpsychism may be “panprotopsychism” [15]. *Mind* in inert system can be thought of as some kind of *field-like* or *wave-like* entity, which is the *carrier* of SEs/PEs in unexpressed form.

#### 4. Discussion

As in Seager [85], the remaining three problems are addressed as follow. The “completeness problem” is that the inert system should also show sometime causal power of proto-experiences, which is not the case; this leads to incompleteness of physical picture of world. The “no sign problem” is, “there is no evidence whatsoever of a nonphysical dimension to the elemental units of nature” and there is no “sign” of mentality in the basic features of the world. The “not-mental problem” is “if there was some feature of these units we chose to label as “mental”, what possible ground could one provide to justify this label” [85]. To address these problems, it would suffice to say that we are proposing proto-experiences (not conscious experiences) at elementary level and inert matter as the *carrier* of SEs (see introduction). Furthermore, it would be helpful to think how the material aspect (such as atom, molecule, protein, genes, amoeba, cell, neural-net, brain) of an entity evolved.

One could argue that proto-experiences seem to be epiphenomena at elemental level. However, proto-experiences defined as the property of interaction could also be considered as alternative useful interpretation of events that physically occur. After co-evolution and co-development, subjective experiences can also be similarly considered as alternative useful interpretation of physical events, such as a summary of all information related to a physical event (see also [45] for summarizing all information as one of the functions of consciousness).

Moreover, it does not appear that physics needs to be modified/extended, except to note that elemental-PEs were already inherent in physics. Elemental-PEs are defined to be “all types of fundamental SEs/PEs in superimposed form” in elementary particles and their interactions. In addition, this definition avoids the problem of causation at elemental or any higher level because our PE-SE framework is within the scope of physicalism [93].

There are four possible combinations between (substance, property) and (dualism, monism):

- (1) Substance-dualism and property-dualism, i.e., simply dualism (Types D view [15]:) in which matter and mind are on equal footing, i.e., they are distinct entities with respect to both substance (framework or perspective) and property (material vs phenomenal) as in Cartesian dualism. For example, the electron is

- a material (mass and charge) entity; proto-experience (PE) is a phenomenal entity. Both are distinct with respect to perspective (substance) and property.
- (2) Substance-monism and property-dualism, i.e., Type F view [15], in which matter and mind are distinct entities with respect to property, but same with respect to substance. For example, electron has material aspect (mass and charge) and can also have electron-PE, i.e., electron is the same substance (in the same framework or perspective is the same), but has two distinct properties: phenomenal and material. This is a dual-aspect framework; the PE-SE framework is close to this.
  - (3) Substance-dualism and property-monism, i.e., matter and mind are distinct entities with respect to substance, but the same with respect to property. Type E dualism [15] appears to be close to this.
  - (4) Substance-monism and property-monism, i.e., matter and mind are same entities with respect to substance and also with respect to property. Type A-C reductive views [15] appear to be close to this.

The PE-SE framework appears to have property-dualism and substance-monism in an entity, i.e., view (2). However, better term may be “non-reductive physicalism” for the PE-SE framework (Alfredo Pereira Jr., *personal communication*).

The PE-SE framework is somewhat consistent with Chalmers’ view [14]: Experience is somehow fundamental to nature, such as proto-experience associated with every physical process. This would “make a theory particularly elegant and simple, and it may also help integrate experience inside the causal order, rather than having it dangle outside as a sort of epiphenomenon” [14]. It does not suggest that “electrons are having deep thoughts about the protons they’re revolving around!” It is “just some sort of very simple, primitive analog of experience” at elemental level [14]. Strawson [93] also suggests that PEs should be included in physics to address mind-body problem (such as explanatory gap) and to be a *real* physicalist, but see [64].

In the PE-SE framework, the essential ingredients for *access* awareness (that is reportable, accessible to a subject’s reasoning and belief system) include (i) wakefulness; (ii) reentrant interactions among neural populations; (iii) fronto-parietal and thalamic-reticular-nucleus attentional signals that modulate awareness; (iv) memory that retains information for awareness; (v) stimulus at above threshold; and (vi) neural-net PEs (a set of SEs embedded in a neural-net). The attention and ability to report are necessary for *phenomenal* awareness [10, 47]. Block’s [9] *access* consciousness is equivalent to consciousness of consolidated concepts, and his phenomenal consciousness with phenomenal experience [7]. The neural source for the arousal system is the ascending reticular activating system (ARAS) in the brain stem, which brings the thalamocortical neural-nets to wakeful state as a baseline for awareness to occur [88]. Reentrant interactions among neural populations bind stimulus attributes (such as location and features) and entail awareness [25, 36]. Attention could be the results of reentry and competitive interactions [36] that modulates the stimulus related feedforward signal and awareness. We hypothesize that

neural-net and related SEs are the results of the co-evolution and co-development of matter and related elemental PEs (properties of elementary particles and their interactions), respectively. Our hypothesis adds another ingredient in a complementary manner: the existence of PEs for generating SEs.

The PE-SE framework bridges the explanatory gaps and explains Self [13]. There could be three gaps that need to be addressed, namely the gap between (i) subjective experience (SE) of object and the object of SE; (ii) SE of subject and the subject of SE; and (iii) subject and object, where the term “object” means internal representation of object (or associated neural correlates). The first gap is the famous Levine’s explanatory gap [50]: the gap between what we believe subjectively about our qualitative experiences (i.e., SE), and scientific descriptions (i.e., internal representation or associated neural correlates) of those experiences. The hypothesis is that SE, its subject, and its object are the same neural activity in a neural-net, where a neural activity is a proto-experiential entity and/or carrier of SEs/PEs in our framework (call it triad-hypothesis). In this context, neural-net also includes self-related brain areas [68, 69]. This is true because re-entry binds all the neural signals of areas specialized for a particular attribute, such as visual areas V4/V8 for color, V5 for motion, and cortical midline structures<sup>e</sup> for Self. In re-entrant framework [25, 26, 36, 101], signals re-enter repeatedly in a neural-net and bind all the features. We are referring this re-entrant signal related to the triad (subject, object, and related SEs) being the same neural activity. These gaps are actually closed if the triad-hypothesis is not rejected; this triad appears distinct in our daily lives, but it is a sort of illusion because internally, they have the same neural-activity. When information related to “subject experiencing objects” projected (perceptually) outside [49], objects appear in three-dimension with respect to reference subject (self). Alternatively, one could argue that the internal reality of the triad being the same neural-activity in a neural-net is an illusion with respect to the external reality of the triad being distinct (and *vice-versa*). Moreover, the subjective experience of objects could be (a) *phenomenal* awareness that is mostly related to feedforward stimulus dependent processing in primary and association sensory cortical areas and sub-cortical areas, where attention is not necessary; or (b) *access* (reportable) awareness where fronto-parietal attentional feedback is needed to interact with feedforward stimulus dependent signals.

The subjective experience of subject is Self (*I-ness*) [13], which can operate in three levels hierarchically or in parallel depending of various conditions: (i) *proto*, *bodily*, or *physical* self is related to sensory processing in sensory cortical and

<sup>e</sup>Cortical midline structures (CMS) include MOFC (medial orbital prefrontal cortex: BA 11, 12), VMPFC (ventromedial prefrontal cortex: BA 10, 11), PACC (pre- and subgenual anterior cingulate cortex: BA 24, 25, 32), SACC (supragenual anterior cingulate cortex: BA 24, 32), DMPFC (dorsomedial prefrontal cortex: BA 9), MPC (medial parietal cortex: BA 7, 31), PCC (posterior cingulate cortex: BA 23), and RSC (retrosplenial cortex: BA 26, 29, 30) [68, 69]. BA: Brodman areas. This first-person-perspective is consistent with [66] that reported involvement of medial cortical and parietal areas. For the construction of body image of subject (to which it is related) in the brain, somatosensory cortex, posterior parietal lobe, and insular cortex (its lesion or electrical stimulation leads to illusion of feelings of being outside one’s own body) are involved [8, 61, 67].

sub-cortical activations; (ii) *core, minimal, or mental* self is related to self-referential processing in cortical midline structures via deactivation; and (iii) *autobiographical, emotional, spatial, verbal, narrative, or spiritual* self is related to higher order processing in lateral (ventrolateral PFC: VLPFC, dorsolateral PFC: DLPFC) cortical activations [68, 69]. Self-awareness may be related to the higher order processing; *self-referential* processing is only conscious processing whereas *self-related* processing may include unconscious, subconscious, and conscious processing of stimuli in relation to the self; unconscious processing of self-related stimuli (*implicit self*) may involve subcortical and anterior cortical midline area such as VMPFC and the OMPFC [68]. Since areas of all levels interact with each other, self *encompasses* different levels of *self-related* processing and is associated with the *equilibrium* within the whole *embodied* brain that is *embedded* in the environment [68]. Furthermore, SE cannot be objectively measured; it requires subjective research. However, the relative effect of SEs, such as that in color discrimination, can be measured objectively.

The PE-SE framework contributes in the minimizing the problem of causation. Since elemental PEs are the properties of elementary particles and their interactions that are the building blocks of material universe, PEs influence some of the forces in physics, i.e., the cause-effect phenomenon, in our PE-SE framework, is bi-directional (PE  $\leftrightarrow$  matter).

In reductive views, all phenomena can be reduced to the characteristics of elementary particles. However, before the introduction of PE-SE framework, elementary particles are considered as non-experiential material entities. That is why explanatory gap appeared. In PE-SE framework, all strings or elementary particles (fermions and bosons) are considered to *carry* all kinds of fundamental SEs/PEs in superimposed form. Although they are carriers of SEs and behave like non-experiential material entities, all phenomena including mental entities can be reduced to physics; this is physicalism [93], whereas in materialism, matter is non-experiential inert material entity without PEs. Since SEs are also consistent with views, both reductive and non-reductive views can be integrated.

The gist of this article is the hypothesis that elementary particles have two aspects: (i) proto-experiences (PEs) as a “phenomenal” aspect; and (ii) mass, charge, spin as “material” aspect. However, one could argue that this is an excellent proposition as long as we can explain how experimentally it can be proven to support a neural-net which is conscious as opposed to those elementary particles found in a non-living object. In PE-SE framework, elementary particles/non-living object are “carriers” of SEs/PEs in unexpressed form in both living and non-living objects. Therefore, they are not conscious. If a neural-net does not satisfy the essential ingredients of consciousness/SEs (namely wakefulness, re-entry, attention, working memory, stimulus at above threshold, and neural-net PEs), it is not conscious, i.e., it is like inert matter because it will simply be a “carrier” of SEs/PEs in unexpressed or latent form. When these essential ingredients are satisfied and when feedforward and feedback signals interact in the neural-net, then a specific SE arises/emerges.

The experimental evidence is the same as in neuroscience literature which is related to wakefulness, re-entry, attention, stimulus at above threshold, and working memory. For example, when we do not attend, we do not have reportable awareness: there seems to be no (report of) awareness in the absence of attention [46, 47]. Thus, “*no attention means no (reportable) awareness*” appears to be a valid statement. However, top-down selective attention and awareness can be dissociated; for example, subjects can be aware of the pop-out in visual search or the gist of a scene without or very little top-down selective attention; on the other hand, in after effect and priming, subjects can attend but are not aware of invisible objects [45]. Similarly, if we are not awake, we do not have SE.

Furthermore, one could argue that the use of the term “phenomenal” is felleable to the assumption that elementary particles in non-living matter possess the attributes of becoming conscious. It somehow gives an impression that life is common in the universe, although, physical constraints impede the biology. It needs to be explained why elementary particles which are constituents of our brains have proto-experiences (PEs) that lead to subjective experiences (SEs) whilst inert matter also possessing PEs, for obvious reasons does not lead to SEs. As explained above, elementary particles/inert matter are “carriers” of SEs/PEs in unexpressed form in both living and non-living objects. Therefore, elementary particles in brain and inert matter are not conscious. This is simply because inert matter can not satisfy the essential ingredients of SEs and a specific SE cannot arise/emerge in inert matter, even though matter is carrier of SEs/PEs in unexpressed form. Even neural-nets of brain cannot lead to SEs if they do not satisfy the essential ingredients of SEs. It is when they satisfy the essential ingredients of SEs, then only SE arises/emerges, which is consistent with most of neuroscience models such as [25, 26]. Furthermore, specificity index is significantly lower in inert matter than that in neural-nets; SEs can arise only when specificity index is above its critical value.

The concept of “virtual reservoir” needs further elaboration in terms of brains vs other matter (living or non-living). As discussed in Sec. 3, a virtual reservoir stores all possible fundamental SEs/PEs. Moreover, the “virtual reservoir” is greater in brains with a larger constituency of chemicals acting on its dendritic processes: for example, “consider  $m$  = total number of cortical neurons,  $n$  = total number of synaptic connections per neuron, and  $p$  = total number of dendritic clusters of various ionic channels and G-proteins lumped together as “hot-spots” including all types of neural transmitters, different enzymes and other molecular substances, all regulating the neuromodulatory environment per neuron. If  $p = 0$ ,  $m = 10^{10}$  and  $n = 10^3$  [..], then the total number of unique possibilities for local encoding in the cortex (conceptualized on the assumption that neural assemblies are structurally undistributed representations of real neural networks) is about  $10^{13}$ . Whereas a human brain with the inclusion of distributed neuronal systems and their biophysical properties (e.g.,  $p > 10^7$ ), allows the total number of possibilities for local encoding to be infinite. It should be mentioned that in nonhuman species both  $m$ ,  $n$ , and  $p$  are significantly lower. For example,  $n = 800$  in mice and 20,000 in monkeys, but 40,000 in

humans;  $m = 10^6$  in rats,  $10^9$  in macaques and  $10^{11}$  in humans. [...] consciousness or self-awareness is the final product of integration in the brain [...] and not specifically through the thalamocortical pathways that sustain distributed activity patterns” [78].

One could argue that matter cannot “carry SEs/PEs”, because “the existence of matter” is within SE. One should note that the “existence of the SE of matter” is within SE, not “the existence of matter” within SE. Here, matter is defined as material-aspect of entity. Thus, mind and matter interact to produce our SEs.

Furthermore, one could argue that instead of assuming all kinds of fundamental SEs/PEs superimposed at elemental level, assume all (or some) types of fundamental SEs/PEs superimposed at neural-net level. For example, (i) Orch-OR (orchestrated objective reduction) model assumes all types of fundamental SEs/PEs as Platonic values embedded in spacetime geometry [33]; (ii) assume that V4/V8 color related neural-net has all types of fundamental color SEs/PEs superimposed in it; or (iii) assume that specific SE say *redness* related V4/V8 neural-net state is assigned to SE *redness*. In that way, evolution will have less load for co-evolution from elemental level. This is an interesting idea that needs further research. However, it needs to store SEs somewhere and it is closer to dualism, which has the problem of association or mind-brain relationship problem and the problem of mental causation. Thus, so far, the PE-SE framework appears to be the optimized solution. However, one could argue that the dual-aspect of strings or elementary particles (fermions and bosons) puts heavy burden on evolution because matter has to be *carrier* of SEs over billions of years until neural-nets emerged to be capable of having SEs in expressed form. But, one could also argue that “inert matter being a *carrier* of SEs/PEs” is in analogy to “DNA being a *carrier* of inheritance/genetic information”. Therefore, even though it is not an efficient mechanism, it may be a realistic one. Furthermore, it would be nice if a mechanism can be discovered, which can produce PEs or SEs whenever and wherever needed and also address the explanatory gaps.

In PE-SE framework, “emergent property” is unpacked in terms of localized inherent property: all fundamental SEs/PEs are superimposed in elementary particles or in entities at some higher level. The problems with superposition at higher level are (i) association or relationship problem between SEs and brain as in Cartesian (substance) dualism; and (ii) how and where SEs are stored in and how there are assigned. Superposition in entities at levels below critical specificity level may lead us to either consider those entities as *carriers* (therefore they behave like non-experiential material entities), or consider them as proto-experiential entities (for which we do not have evidence). Furthermore, SE does pop out in a suitable system, but that SE would also be in the elements of the system in latent superimposed form. So, here, the term “emerge” has little different meaning. Without essential ingredients (such as wakefulness, attention, re-entry, working memory, stimulus at above threshold, and PEs), SEs would fail to occur even if there is objective reduction (OR) in MT network; so there is causal link (when long wavelength light is presented then only redness emerges, ignoring phosphenes and context dependent color vision for a

moment). Dichotomies (such as SE and content of SE, or form and substance) need to be (or can be) integrated to reveal the truth! In OR, superposed SEs collapse into one specific SE (say when a stimulus is presented), but if you do not attend then you will not have that (reportable) SE. Attention is not needed for phenomenal SE (for example, less than 17 msec presentation in Sperling type experiments [89]), but attention is needed for access or reportable SE. Presumably, OR needs to be orchestrated to make attention, re-entry, and working memory active in wakefulness (ignoring dreams). Orch OR framework, PE-SE framework, and Dichotomistic framework [60] are complementary to each other, with the understanding that the axonal-dendritic, dendritic web, astro-glia-neuronal, and extra-cellular field type transfer of information all play an important role in SEs depending on the context. We should try various techniques (such as multiple regression) to address their percent contributions.

## 5. Summary and Conclusions

The hypotheses of this article are summarized as follows:

- (1) Our main hypothesis is that elementary particles have two aspects: (i) proto-experiences (PEs) as a “phenomenal” aspect; and (ii) mass, charge, spin as “material” aspect; all types of irreducible fundamental SEs/PEs are superimposed in strings or elementary particles such as fermions (e.g., electrons) and bosons (e.g., photons) and their interactions. Therefore, they are not specific to any SE, and hence, behave as non-experiential material entities. This is misleading because it generates an explanatory gap. One could argue that elementary entities such as electrons do not have subjective experiences, but they behave as if they have mind-like or experience-like properties in a rudimentary way; they and inert matter are simply *carriers* of SEs in the PE-SE framework.
- (2) Non-experiential material aspect and related elemental proto-experiences (PEs: phenomenal aspect) co-evolved and co-developed, leading to neural-nets and associated PEs, respectively.
- (3) SEs are emerged during the interaction of feed-forward and feedback neural-PE signals in neural-nets by the random process of self-organization (because this process has ability to create novel entities to meet the environmental demands). All possible fundamental SEs/PEs are stored in a *virtual reservoir*.
- (4) Our neural-based PE-SE framework assumes that (a) the interaction of stimulus dependent feed-forward and feedback signals in a neural-net creates a specific neural-net state; (b) this specific state is assigned to a specific SE from the virtual reservoir during development (neural Darwinism) by the evolutionary process of adaptation and selection; (c) this specific SE is embedded as a memory trace of neural-net-PE; and (d) when a specific stimulus, such as long wavelength light, is presented to the neural-net, the associated specific SE, such as redness,

is selected via a non-computational or non-algorithmic process and experienced by the neural-net.

- (5) The essential ingredients for *access* awareness (that is reportable, accessible to a subject's reasoning and belief system) include (a) wakefulness; (b) reentrant interactions among neural populations; (c) fronto-parietal and thalamic-reticular-nucleus attentional signals that modulate awareness; (d) memory that retains information for awareness; (e) stimulus at above threshold for detection, discrimination and recognition; and (f) neural-net PEs (a set of SEs embedded in a neural-net). The attention and ability to report are not necessary for *phenomenal* awareness.
- (6) There are three types of psychophysical gaps, namely the gap between (a) SE and the object of SE (explanatory gap); (b) SE and the subject of SE; and (c) subject and object, where *object* is internal representation. The SE, its subject, and its object are the same neural activity in a neural-net, where a neural activity is a proto-experiential entity in our PE-SE framework. The SE of subject is Self (*I-ness*). The PE-SE framework helps in bridging the explanatory gap.

Our framework consists of four hypotheses (dual-aspect primal entities, co-evolution and co-development of subjective experiences and associated neural-nets from elemental proto-experiences and matter, internal-representation, and sensorimotor interaction) that lead to structural and functional coherence [16] between mind and brain. The adaptation, natural selection (*fittest survive*), and calibration can assign specific subjective experiences of subject and objects to the associated specific neural-nets via co-developmental processes such as sensorimotor tuning with external stimuli (neural Darwinism). When a stimulus is presented to the system, the associated subjective experience is selected from the embedded neural-net proto-experiences. Alternatively, since a self-organizing system, such as brain, can create novel structures and new modes of behavior, it can also create complex subjective experiences (such as *redness*) to cope with its environment during co-evolution. Our hypothesis (a) contributes in bridging the explanatory gaps because elemental proto-experiences are introduced, and (b) minimizes the problem of causation because our framework is within the scope of physicalism that accommodates the dual-aspect entities. The PE-SE framework seems to integrate reductive (Types A-C) and non-reductive (Types D-F) views of philosophy [15], and relevant models in psychology, evolution, neurophysiology, chemistry, and physics. Our framework of neural-net PEs critically challenges existing theoretical perspectives that could significantly alter the directions of future research in the neural basis of awareness.

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**Running title:** Conjugate matching and experience

## SELECTION OF A SPECIFIC SUBJECTIVE EXPERIENCE: CONJUGATE MATCHING AND EXPERIENCE

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### Abstract

There are three entities that need to be linked: *structure*, *function*, and *experience*. Various materialistic neuroscience models link *structure* with *function* well, but fail to link them with *experience* that leads to the explanatory gap: how an *experience* can be created from non-experiential matter (such as brain *structure*)? In Vimal (J Integr Neurosci 7:49–73, 2008) [192], to address this explanatory gap, it was hypothesized that strings or elementary particles (fermions and bosons) have two aspects: (i) material aspect such as mass, spin, charge, force, quanta, and space-time, and (ii) mental aspect. The mental aspects of strings, elementary particles, and inert matter are considered as the *carriers* of superimposed fundamental *experiences* (or subjective experiences (SEs)/proto-experiences (PEs)) in unexpressed form. The superposition of multiple possible experiences is based on the hypothesis ‘the mental aspect of wave is wave-like and is a function of experiences’, which is based on the assumption that matter (wave/particle) has double aspects (mental and material aspect). These possibilities are actualized when neural-networks are formed via *neural Darwinism*, and a specific SE is selected by a *matching* process; these processes also bind elemental *micro-minds* into one *macro-mind*. Here, the term *mind* refers to SE. In addition, for example, SE *redness* will never be selected and experienced without the formation of redness-related V4/V8/VO-neural-network. The ‘brute fact’ of dual-aspect is justified because SEs are fundamental, inherent, and irreducible. In this article, (a) the dual-mode concept from the framework of thermofield dissipative quantum brain dynamics (Globus, NeuroQuantology 4: 210-221, 2006; Vitiello, International J. Modern Physics B9: 973-989, 1995) [59, 201] is explicitly incorporated in the PE-SE framework without decreasing the degree of parsimony as it was implicitly already present, and (b) *matching* and *selection* processes are further elaborated. The two modes are: (1) the non-tilde mode that is the material and mental aspect of cognition (memory and attention) related feedback signals in a neural-network of the brain, which is the cognitive nearest past approaching towards present; and (2) the tilde mode that is the material and mental aspect of the feed forward signals due to external environmental input and internal endogenous input, which is the nearest future approaching towards present and is a entropy-reversed representation of non-tilde mode. Furthermore, one could argue that there are at least five pathways for information transfer in the brain dynamics: (i) classical axonal-dendritic neural pathway, (ii) quantum dendritic-dendritic microtubule (MT) (dendritic webs) pathway, (iii) Ca-related astro-glia-neural pathway, (iv) extracellular volume transmission, and (v) soliton propagation. We propose that (a) the *quantum conjugate matching* between *experiences* in the mental aspect of the tilde mode and that of the non-tilde mode is related more to the mental aspect of the quantum MT-dendritic-web and less to that of the remaining non-quantum pathways, and (b) the classical *matching and selection* processes to the mental aspect of the remaining non-quantum pathways. In all cases, a specific SE is selected (a) when the tilde mode interacts with the non-tilde mode to *match* for a specific SE, and (b) when the *necessary* ingredients of SEs (such as wakefulness, attention, re-entry, working memory, stimulus at or above threshold level, and neural-network-PEs) are satisfied. When the conjugate match is made between the two modes, *the world-presence (Now)* is disclosed; its content is the SE of subject (self), the SE of objects, and the content of SEs. The material aspects in the tilde mode and that in the non-tilde mode are matched to link *structure* with *function*, whereas the mental aspects in the tilde mode and that in the non-tilde mode are matched to link *experience* with *structure* and *function*. It is argued that (a) this dual-mode-dual-aspect PE-SE framework has fewer problems (such as the

justifiable 'brute fact' of dual-aspect), and (b) it addresses the problems of other framework including the explanatory gap in materialism. In addition, we have worked through double aspect theory at a level which has not been previously elaborated, which is a significant contribution.

**Keywords:** Quantum physics; classical physics; dual-mode thermofield quantum brain dynamics; entropy-reversed representation; dual-aspect model; elementary particles; string; fermions; bosons; experiences; proto-experiences; subjective experiences; neural Darwinism; conjugate matching; classical matching process; selection process; explanatory gap; classical axonal-dendritic neural pathway; quantum dendritic-dendritic pathway; astro-glia-neuronal pathway; extracellular volume transmission; soliton propagation; hard problem; access and phenomenal awareness; attention; re-entry; memory; wakefulness; threshold; co-evolution and co-development of mind and brain; chaos theory; self; self-organization.

## 1. Introduction

There are three entities that need to be appropriately linked and addressed: *structure*, *function*, and *experience*. For example, there is a *structure* 'V4/V8/VO' color neural-network,<sup>a</sup> which has a *function* of detection and discrimination of wavelengths of light. We know, from psychophysics, that there are three visual channels, namely, luminance, Red-Green, and Yellow-Blue channels; the two color channels are related to this *structure* and *function*. In addition, normal trichromats have color related subjective *experience* (SE),<sup>b</sup> such as *redness*. My quest is to understand precisely how SEs, such as *redness*, occur.

To link and address *structure* and *function*, there are many neuroscience models related to five major pathways: (i) classical axonal-dendritic pathway for the neuro-computation [30, 32, 33, 113, 169], including *neural Darwinism* [40, 41], (ii) dendritic-dendritic pathway for quantum-computation [80], (iii) astro-glia-neuronal transmission [139], (iv) extracellular field, volume transmission, and gaseous diffusion [144], and (v) information transmission via soliton propagation [34, 198]. All five pathways related to information transmission contribute to *structure* and *function*; their percent contribution depends on a specific task, which needs further investigation. Most of neuroscience models [30, 31, 40-43, 49, 68, 96-98, 104, 156, 158, 167, 178] link *structure* and *function*, whereas how precisely a SE occurs/is selected/emerges/explicates/unfolds/arises is missing. These alternatives will be unpacked below. This leads to famous explanatory gap in materialism [26, 109]: how SEs can be created from matter that has no shred of evidence of having SE. A critical integration of all the investigations related to *structure* and *function* and those related to *experiences* (while addressing the criticisms) is seriously needed; these three entities need to be linked and integrated. This is accomplished by the dual-aspect-dual-mode PE-SE framework [192].<sup>c</sup>

Historically, the dual-aspect view (neutral monism) has seen its ups and downs over 6000 years. In RigVedic period (4000 BC-2000 BC: [199]), the dual-aspect framework was conceived along with other views

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<sup>a</sup> The color area 'V8/V4/VO' refers to visual area V8 of Tootell-group [72, 176], visual area V4 of Zeki-group [11], and VO of Wandell-group [207]; they are the same human color area [176]. VO is ventral-occipital cortex.

<sup>b</sup> The terms 'experience', 'subjective experience', and 'phenomenal experience' are interchangeably used. Strictly speaking, the term 'experience' refers to PEs/SEs superposed in the mental aspect of all entities; the term 'subjective experience' refers to experience that is experienced by a subject; the term 'phenomenal experience' refers to experience in phenomenal awareness where attention-related feedback signals do not get time to interact with feed-forward signals and hence these experiences cannot be reported. In access awareness, an experience can be reported. Thus, the term 'experience' is most appropriate in this article.

<sup>c</sup> The proto-experiences (PEs) are those experiences that are not subjective experiences (SEs). A SE is a first person experience that is selected during the interaction/matching between feed-forward signals (tilde-mode) and feedback signals (non-tilde mode) in a neural-network, which satisfies the *necessary* ingredients such as wakefulness, re-entry, attention, working memory, stimulus at above threshold, and neural-network PEs [197].

[146, 147]: *Brahma* (*Prakriti* or matter) and *Vishnu* (*Purusha* or consciousness) were considered as the two aspects of Ādi-Shiva [151, 186, 190, 191]. Spinoza [166] provided extensive arguments for double aspects (neutral monism). Russell [148] was a double aspect theorist too (one aspect known “by acquaintance,” the other “by (scientific) description”). Feigl [47] elaborated double aspect theory and structural realism. Bohm’s implicate/explicate or enfolded/unfolded framework [14, 16, 17] is consistent with a dual-aspect view; he is explicitly a double-aspect theorist. Moreover, the mental and material aspects of fundamental particles (strings or elementary particles (fermions and bosons)) can be considered as implicate (enfolded) order, whereas *structures, functions, and SEs* as explicate (unfolded). In the dual-aspect PE-SE framework [192], the mental aspect of fundamental particles contains *experiences* (PEs/SEs) in superposed form and the material aspect includes mass, spin, charge, force, quanta, and space-time. It is argued that this framework has the least number of problems compared to other views [193], which is elaborated further in Section 3.7.

Pauli [133] suggested that physics and consciousness should be considered as complementary aspects of the same reality, which is a dual-aspect view. Feigl [47] defines (i) physical or physical<sub>1</sub> (or scientific) as, “the type of concepts and laws which suffice in principle for the explanation and prediction of inorganic processes”, and (ii) physical<sub>2</sub> as, “[i]f emergentism is not required for the phenomena of organic life, “physical” would mean those concepts and laws sufficient for the explanation of inorganic as well as of biological phenomena.” My definition of *materialism* is equivalent to physicalism<sub>1</sub> and/or physicalism<sub>2</sub>; and *physicalism* is *materialism* plus *experience* [171], which is consistent with the PE-SE framework [192] because it involves non-reductive physicalism. Moreover, according to Feigl [23], “[i]f mental states have emerged, their very occurrence is supposed to alter the functional relations between the neurophysiological (physical<sub>2</sub>) variables in a manner in principle susceptible to confirmation. [...] the  $\psi$ - $\phi$  (i.e., psycho-neurophysiological) relations or correspondences can be empirically investigated [...] Parallelism [and isomorphism], then, in its strongest form assumes a one-to-one correspondence of the  $\psi$ 's to the  $\phi$ 's. It is empirically extremely likely that these correspondences are not “atomistic” in the sense that there is a separate law of correspondence between each discernible  $\psi_1$  and its correlate  $\phi_1$ . [...] philosophers have been emphasizing much more the action of “mind on matter” -- as in voluntary behavior, or in the roles of pleasure, pain, and attention -- than that of “matter on mind.” This asymmetrical attitude usually comes from preoccupation with the freewill puzzle.” The *dual-aspect* PE-SE framework is one-to-one relationship because mental and material aspects are two sides of the same coin. Therefore,  $\psi$ - $\phi$  (i.e., psycho-neurophysiological or function-structure) one-to-one correlation in *dual-aspect* is similar to that in *materialism*. In addition, the  $\mathcal{E}$ - $\psi$ - $\phi$  (experience-function-structure) correspondence is also 1-1-1 in the dual-aspect PE-SE framework, which is not clear in other views. According to Nagel, “It seems to me more likely, however, that mental-physical relations will eventually be expressed in a theory whose fundamental terms cannot be placed clearly in either category.” [123](p. 450).

Furthermore, Hameroff and Penrose [80] seem to be double aspect and protoconsciousness theorists, and sometimes Stapp conceives double aspect. Hameroff and Powell [81] defend neutral monism (a branch of dual-aspect view), where matter and mind arise from or reduce to a neutral third entity ‘quantum spacetime geometry (fine-grained structure of the universe.)’, and Penrose OR (objective reduction)<sup>d</sup> is the psycho-physical bridge: “Orch OR provides a possible connection between quantum spacetime geometry – a possible repository of proto-conscious experience – and brain processes regulating consciousness”. According to Ashtekar, “Spacetime is not an inert entity. It acts on matter and can be acted upon”, “gravity is geometry”, and “geometry is also a physical entity, on a par with matter” [4]. However, it is not clear how matter and mind arise from or reduce to the neutral third entity ‘quantum spacetime geometry’. According to Stapp [168], “The complexity of the physical carrier has undoubtedly co-evolved with the complexity of the associated experiential reality”, which is consistent with our framework. According to Atmanspacher [5], “Such a “dual aspect” option, although not much emphasized in contemporary mainstream discussions, has a long tradition. Early versions go back as far as Spinoza and Leibniz. In the early days of psychophysics in the 19th century, Fechner [45] and Wundt [211] advocated related views. Whitehead, the modern pioneer of process philosophy, referred to mental and physical poles of “actual occasions”, which themselves transcend their bipolar appearances [208]. Many approaches in the tradition of Feigl [47] and Smart [164], called “identity theories”, conceive mental and material states as essentially identical “central states”, yet considered from different perspectives. Other variants of this idea have been suggested by Jung and Pauli

<sup>d</sup> In OR, the quantum system is reduced from a superposition of multiple possible states to a single definite state.

[100] [see also Meier [117] and Atmanspacher and Primas [6, 7]], involving Jung's conception of a psychophysically neutral, archetypal order, or by Bohm and Hiley [14, 17, 84], referring to an implicate order which unfolds into the different explicate domains of the mental and the material.”

Bohm [14] proposes the inseparable dual-aspect in the active information and the quantum potential constitutes active information, “As with electric and magnetic fields, the quantum field can also be represented in terms of a potential which I call the **quantum potential**. ... at least in the context of the processes of thought, there is a kind of **active information that is simultaneously physical and mental in nature**. Active information can thus serve as a kind of or 'bridge' between these two sides [aspects] of reality as a whole. These two sides are **inseparable**, in the sense that information contained in thought, which we feel to be on the 'mental' side, is at the same time a related neurophysiological, chemical, and physical activity (which is clearly what is meant by the 'material' side of this thought). ... From the mental side, it is a potentially active information content. But from the material side, it is an actual activity that operates to organize the less subtle levels, and the latter serve as the 'material' on which such operation takes place. Thus, at each level, information is the link or bridge between the two sides. ... **the quantum potential constitutes active information** that can give form to the movements of the particles ... At each such level, there will be a 'mental pole' and a 'physical pole'. Thus as we have already implied, **even an electron has at least a rudimentary mental pole**, represented mathematically by the quantum potential. Vice versa, as we have seen, even subtle mental processes have a physical pole. **But the deeper reality is something beyond either mind or matter**, both of which are only aspects that serve as terms for analysis ... These can contribute to our understanding of what is happening but are in no sense separate substances in interaction. Nor are we reducing one pole to a mere function or aspect of the other (e.g. as is done in materialism and in idealism)” (**bold mine**). Moreover, the quantum potential is cybernetic, steering the location of the particle, according to Bohm. The super-quantum potential steers the explication.

Hiley and Pykkänen [85] extends Bohm's double aspect view of active information (that has both a mental and a material aspect) to explain *self* and how mental processes can act on neural processes without violating the energy conservation law as, “the ontological interpretation suggests that a novel type of “**active information**”, connected with a novel type of “**quantum potential energy**”, plays a key role in quantum physical processes. [...] In this proposal, **quantum tunneling would enable the “self” to control its brain** without violating the energy conservation law. [...] Based on the notions of active information and quantum potential energy, we propose a coherent way of understanding **how mental processes** (understood as involving non-classical physical processes) **can act on** traditional, classically describable **neural processes without violating the energy conservation law**. [...] we assume that **mind and matter are two aspects of or ways of looking at an underlying reality** [...] We **follow Bohm** in proposing that such a reality can, for convenience, be analyzed in terms of *levels* that differ with respect to their subtlety. Each level then has both a physical and a mental aspect, and this makes a “two-way traffic” between levels possible. Bohm suggested, radically, that even the quantum level can be thought to have, via active information, a *primitive mind-like quality*, although it obviously has no consciousness. [...] In this way we claim to avoid dualism or idealism without falling into reductive materialism. The whole point of double-aspect approaches is to avoid these extremes. [...] We follow Bohm in assuming that, at each level, information is the link or bridge between the mental and the physical sides. [...] mind can be seen as a relatively autonomous, higher level of **active information, which has both a physical and a mental aspect** ... **mind can have a genuine effect upon neural processes**” (**bold mine**). The term ‘information’ has double aspects to address the implicit explanatory gap of materialism. Beck and Eccles' mind-field [12] has substance-dualism that has 5 problems (Section 3.6), so it is avoided. The dual-aspect PE-SE framework (substance-monism-and-property-dualism) does not have these problems; therefore the dual-aspect active-information based PE-SE framework will have fewer problems. Our assumption of ‘PEs/SEs in superposed form in strings or elementary particles’ is analogous to their [85] ‘*primitive mind-like quality* at the quantum level via active information’ when it is unpacked and the seven problems (Section 3.4) of implicit dual-aspect panpsychism is addressed; moreover, inert matter and ‘life with no appropriate neural-network’ obviously have no specific SE in both frameworks. In addition, their [85] hypothesis that quantum tunneling (via internal quantum potential energy and active information processing) enables the self-related neural-network to control sensorimotor and other neural-networks for mind (function and experience) is interestingly consistent with the PE-SE framework. The motivation of explicating the enfolded ‘PEs/SEs in superposed form in strings or elementary particles’ can be considered as ‘active information’ for the evolution to form neural-networks in our brain so that specific SEs can be eventually unfolded. At neural-network level, the environmental stimulus (such as long wavelength light) dependent active information in feed forward signals (tilde mode) interacts with the active information in the cognition (such as memory and attention) related feedback signals (non-tilde mode) during the

matching and selection of a specific SE (such as redness) in related neural-network (such as V4/V8/VO red-green opponent neural-network). Thus, one could argue that 'information' [26] has two aspects: material and mental. Compare this with string or elementary particles that have two aspects: material (mass, spin, charge, force, quanta, and space-time) and mental (such as SEs/PEs) [192]. If all [14, 26, 192] are correct, 'string or elementary particles' are 'information'.

Velmans proposed [183] an externalist reflexive model to address the explanatory gap, "The reflexive model accepts that experiences of the world result from dynamic organism-environment interactions, but argues that such interactions are preconscious. While the resulting phenomenal world is a consequence of such interactions, it cannot be reduced to them. **The reflexive model is externalist** in its claim that this external phenomenal world, which we normally think of as the "physical world," is literally outside the brain. Furthermore, there are no added conscious experiences of the external world inside the brain. .... **in closing the gap between the phenomenal world and what we normally think of as the physical world, the reflexive model resolves one facet of the hard problem of consciousness"** (bold mine).

In addition, Velmans [181] proposed experiences in external world via perceptual projection: "There are two quite distinct ways in which events that we normally think of as "physical" relate in an intimate way to events that we normally think of as "psychological". One intimate relation occurs in **exteroception** at the point where events in the world become events as-perceived. The other intimate relationship occurs at the **interface of conscious experience with its neural correlates** in the brain. [...] Normal exteroception involves an interaction between an event in the world (an event itself) and the perceptual/cognitive systems of an observer, which results in an event as-perceived. [...] 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" (bold mine). For example, "this print seems to be out here on this page and not in your brain." He calls this empirically observable effect "**perceptual projection**", and notes, "We know that nonconscious processes within the brain produce consciously experienced events, which may be subjectively located and extended in the phenomenal space beyond the brain. We also know that this effect is subjective, psychological and viewable only from a first-person perspective. Nothing physical is projected from the brain. [...] What are the consequences of thinking about the perceived world in this reflexive way? Although we normally think of the objects that we see around us as being "physical", they are in another sense "psychological". This is because they are the objects as they appear to us and not the objects as they are in themselves." [181] (bold mine). One could argue that this is Kantianism.

Velmans then considers the relation between the psychological and physical at the interface of consciousness and brain. "The above analysis rather suggests a seamless universe, of which we are an integral part, which can be known in two fundamentally different ways. At the interface of consciousness and brain it can be known in terms of how it appears (from the outside) and in terms of what it is like to be that universe (from the inside). This is ontological monism, combined with epistemological dualism." He then goes on to ask "If mind grounds and unifies the first- and third-person views we have of it, what can we conjecture about its nature? ... 1 ... the **mind encodes information**. 2 ... the mind can be described as a process, developing over time. ... mind can be thought of as a form of information processing – and the information displayed in experiences and their physical correlates can be thought of as two manifestations of this information processing" [181] (bold mine).

Finally, he asks, "what kind of 'medium' is the mind? ... 1. In the human case, minds viewed from the outside seem to take the form of brains (or some physical aspect of brains). 2. Viewed from the perspective of those who embody them, minds take the form of conscious experiences. [Consequently]... **it is at once physical and conscious experience**. ... [and combining this with the above] mind is a psychophysical process that encodes information, developing over time. [...] If first- and third person accounts of consciousness and its physical correlates are complementary and mutually irreducible, an analogous psychological *complementarity principle* might be required to understand the nature of mind" [181] (bold mine).

Velmans' reflexive-monism framework seems to imply that (i) objects have dual-aspect (material and experiential), (ii) perceptual projection can be unpacked in terms of conjugate matching between the SEs superposed in the mental aspect of stimuli and that of neural-networks, and (iii) since "mind is a psychophysical process that encodes information" [181], the Red-Green psychophysical channel can be viewed as having two aspects: (a) its material aspect is composed of 'V4/V8/VO' neural-network and its activity<sup>e</sup>, and (b) its mental

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<sup>e</sup> "Neural activity exists in pulse densities of axons, wave densities of dendrites and in various forms of thermal, electric, magnetic and especially chemical energy" [51].

aspect consists of SEs redness to greenness. Therefore, reflexive-monism [181, 182] is consistent with the PE-SE framework. The PE-SE framework differs from Velmans in that: PEs/SEs are in superposed form in the mental aspect of fundamental particles in the PE-SE framework (to address the various problems [58, 154] such as combination problem [69]), whereas this is not the case in Velmans' framework. This means that consciousness (SEs) is almost everywhere (wherever fundamental particles are) in unexpressed form. A specific SE, when expressed, is in the mental aspect of both the stimulus and the neural-network, linked by conjugate matching/perceptual projection. However, in Velmans' Framework, a specific conscious experience is in the mental aspect of the external world (stimulus). Furthermore Velmans' reflexive monism framework has at least two problems: (i) Assignment problem: for example, how to assign *redness* (not *blueness*) to objects that reflect long wavelength light, and (ii) plenum problem: where all SEs arise from and where they are stored. In the PE-SE framework, assignment problem is addressed by natural selection and the plenum problem by 'virtual reservoir' as detailed in [192].

If the dual-aspect view with fundamental property dualism (as the PE-SE framework) is correct, then consciousness [188] must have some causal impact [186]. One could argue that consciousness causes [179]: (i) increased flexibility and sophistication of control such as in novel situations, (ii) enhanced capacity for social coordination such as enhanced self-awareness and understanding of other's minds, (iii) more unified and densely integrated representation of reality such as the unity of experienced space, (iv) more global informational access such as in global broadcasting [8], (v) increased freedom of choice or free will such as in the selection of our own action, and (vi) intrinsically motivating states such as in the functional and motivational roles of conscious affective states (e.g., pleasures and pains). In addition, "1. By relating input to its context, consciousness defines input, removing its ambiguities in perception and understanding. 2. Consciousness is required for successful problem solving and learning, particularly where novelty is involved. 3. Making an event conscious raises its "access priority," increasing the chances of successful adaptation to that event. 4. Conscious goals can recruit subgoals and motor systems to carry out voluntary acts. Making choices conscious helps to recruit knowledge resources essential to arriving at an appropriate decision. 5. Conscious inner speech and imagery allow us to reflect on and, to an extent, control our conscious and unconscious functioning. 6. In facing unpredictable conditions, consciousness is indispensable in allowing flexible responses" [180]. Moreover, Moreover, consciousness is necessary in the coordination of skeletal muscles [119, 140]. In addition, "In sum, consciousness appears to be the major way in which the central nervous system adapts to novel, challenging and informative events in the world" [9].

Furthermore, the thermofield quantum brain dynamics [201-204] and the dual-mode-thermofield-*holoworld* framework [60, 64] are dual-mode frameworks. In the dual-aspect PE-SE framework [192], the dual-mode was implicit, which is made explicit here as inspired by these dual-mode frameworks [56, 58-68] and [201-204] (elaborated further in Section 2); therefore the degree of parsimony remains unchanged.

In the dual-aspect-dual-mode PE-SE framework [184, 190-192, 195, 197], there are three competing hypotheses [195]: *superposition* based  $\mathbf{H}_1$ , *superposition-then-integration* based  $\mathbf{H}_2$ , and *integration* based  $\mathbf{H}_3$  where *superposition* is not required.  $\mathbf{H}_3$  is related to the dual-aspect panpsychism. One could argue from the implication related to Dirac's equation of the electron, in analogy to Nunn [129], as follows: The *experiences* (or PEs/SEs) superposed in fundamental particles may simply be *potentialities* or *possibilities* that manifest *reality* only in the context of particular experiments or observations. For example, when long wavelength light is presented to the 'V4/V8/VO' Red-Green neural network, the *potentiality* of SE *redness* turns into *reality* via (conjugate) matching and selection mechanism. One could argue that this *potentiality* can be viewed as one of the motivations for the evolution to eventually form neural-networks in brains so that SEs can be realized. In other words, neural-networks can be viewed as 'attractors' for evolution.

The *matching* process, the topic of this article, is required in all above three hypotheses; whereas, the *selection* process is required only in  $\mathbf{H}_1$  (not in  $\mathbf{H}_2$  and not in  $\mathbf{H}_3$ ). This is because the mysterious *emergence* process is necessary in  $\mathbf{H}_2$  and  $\mathbf{H}_3$  (but not in  $\mathbf{H}_1$ ). In other words, the *matching* and *selection* processes are required in  $\mathbf{H}_1$ ; whereas the *matching* and *emergence* processes are necessary in  $\mathbf{H}_2$  and  $\mathbf{H}_3$  and hence the mystery of *emergence* still remains in the latter two hypotheses. In  $\mathbf{H}_1$ , the mental aspect of the fundamental entities and inert matter is the *carrier* of superimposed fundamental *experiences* (or SEs/PEs) in unexpressed

form. In  $H_1$ , a specific SE is selected in a neural-network as follows: (i) there exist a *virtual reservoir* (plenum) that *stores* all possible fundamental *experiences* (SEs/PEs), such as in the mental aspect of the fundamental entities in superposed form, (ii) the interaction of stimulus-dependent feed-forward (tilde mode) and feedback signals (non-tilde mode) in the neural-network creates a specific neural-network state, (iii) this specific state is assigned to a specific SE from the *virtual reservoir* during *neural Darwinism*, (iv) this specific SE is embedded as the mental aspect of memory trace of neural-network-PE, and (v) when a specific stimulus is presented to the neural-network, the associated specific SE is selected by the *matching* and *selection* process and experienced by this network that includes also self-related neural-network [128]. In addition, the *necessary* ingredients of SEs (such as wakefulness, attention, re-entry, working memory, stimulus at or above threshold level and neural-network-PEs) must be satisfied before the network can experience.

Furthermore, the superposition of a large number of *experiences* (or PE/SEs) in the mental aspect of fundamental particles is (a sort of) related to Bohm's *implicate* order (*enfolding*). The matching and selection theory – the main topic of the paper – has a very long history (Globus, personal communication): It is (a sort of) related to (i) Leibniz's *appetition*, (ii) Bohm's *explicate* order (*unfolding*) [14, 16, 17], (iii) Globus' *holoworld*, *situatedness*, *world-thrownness*, and *conjugate matching* [60, 64] (call it the dual-mode-double-universe-thermofield-*holoworld* or simply *holoworld* framework)<sup>f</sup>, (v) Freeman's *intentionality* [50, 64], (vi) Neisser's ecological approach to cognition [125], (vii) Jerne's selection theory to the brain on analogy from immunology [92-95], and (viii) Edelman's neural Darwinism and evolutionary perspective [41].

Furthermore, the term 'consciousness' was unpacked as [68], "... the vague term 'consciousness' is partially unpacked into ... (1) the self or subject, denoted by 'I', (2) cognition, (3) thrownness in the world, and (4) 'qualia'." Inspired by this, in [188], I "describe meanings (or aspects) attributed to the term consciousness, extracted from the literature and from recent online discussions. Forty such meanings were identified and categorized according to whether they were principally about function or about experience; some overlapped but others were apparently mutually exclusive – and this list is by no means exhaustive. Most can be regarded as expressions of authors' views about the basis of consciousness, or opinions about the significance of aspects of its contents. The prospects for reaching any single, agreed, theory independent definition of consciousness thus appear remote. However, much confusion could be avoided if authors were always to specify which aspects of consciousness they refer to when using the term. An example is outlined of how this can be done (using a 'PE-SE' framework)." However here, as in the PE-SE framework [192], we limit to the SE aspect of consciousness, and consciousness and SE are interchangeably used unless noted. In [193], my goal was "to search for *optimal* (that has the least number of problems) and a *general* definition (that accommodates all views) [of consciousness]; both are theory dependent definitions. My quest is based on the premise that evolution must have optimized our system, which has structure, *function*, and *experience*. There are many views related to consciousness and each view has its own problems; some of them are described in this article. Then I tried to investigate which view has the least number of problems. I found that the PE-SE framework, so far, fits this litmus test. In this framework, I investigated the *optimal* definition of consciousness that has the least number of problems, which is '*consciousness can be optimally defined as a mental entity that has dual-aspect: function and experience*. A more *general* definition is '*consciousness is a mental entity that is a function, an experience, or both depending on the context*'. The term *context* refers to metaphysical views, constraints, specific aims, and so on. The *general* definition appears to accommodate all views."

In previous article [192], the PE-SE framework was presented where classical and quantum concepts related to SEs and PEs were discussed. In this framework, to address the explanatory gap of monistic materialism and 'the mind-brain interaction problem and the mental causation problem' in dualism, we proposed dual-aspect view (non-reductive physicalism) where we hypothesized that all types of fundamental *experiences* (or PE/SEs) are superimposed in the mental aspect of fundamental entities (strings or elementary particles: fermions and bosons). This implies that the mental aspect of inert matter *carries experiences* (or PE/SEs) because it contains all types of fundamental *experiences* (or PE/SEs). Therefore, the inert matter is non-specific to SEs/PEs, and it behaves as a non-experiential entity. When the specificity is higher than its critical value (such as in neural-networks of brain), a specific SE can be selected by *matching and selection* process. In this framework, 'co-evolution, co-development and sensorimotor co-tuning' (*neural Darwinism*)

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<sup>f</sup> Double universes are (i) our-universe (tilde-mode) that is consists of brain, its immediate environment and the rest of environment and (ii) alter-universe (non-tilde mode) that is entropy (or time) reversed mirror image of our-universe, where 'alter' refers to 'future'.

play important role as discussed in [192]. In non-reductive views, fundamental SEs are irreducible and appear unique and independent to each other. Therefore, each fundamental SE/PE must exist on its own as a mental aspect of fundamental entities in superposed form. The PE-SE framework [192] does not reject any neuroscience models rather complements them by providing an ontological interpretation. It is a different story that there is no single neuroscience model that can explain all the data related to *structure* and *function*, and therefore there are many models and further research is needed to sort out the optimum one.

In the PE-SE framework [192], the terms specificity and non-specificity need further clarification. For example, electron (quantum particle), is non-specific because its mental aspect has all fundamental *experiences* (or PEs/SEs) in superimposed form and is found everywhere. However, redness-related neural-network, in classical domain, is specific because its mental aspect has single SE/PE *redness*. The Red-Green neural-network is more specific than cone photoreceptors because the mental aspect of the Red-Green neural-network carries less number of superposed experiences than that of the cones. Furthermore, a neural-network will have a specific SE when all essential ingredients of SE are satisfied in the neural-network; otherwise the mental aspect of the neural-network *carries* PE in embedded form. Co-evolution and co-developmental processes (via sensorimotor tuning) yield neural-networks and associated neural-network-PEs, and higher degree of specificity arises. For example, redness-related V4/V8/VO-neural-network and associated neural-network color PEs are co-developed (i.e., dependently co-arisen [121]), which is basically the mental aspect of the red-green opponent channel containing all color SEs between *redness* and *greenness*. This has higher specificity than elemental PEs. When long wavelength light is presented, specific SE *redness* is selected out of these color-SEs by the *selection* process during matching [192].

Furthermore, the PE-SE framework [192] is now extended to address (i) “the localization of consciousness within the physical matter of the brain consistent with contemporary theoretical physics, molecular and system biology, and neuroscience” via a two-factor approach [115], (ii) Self [20], (iii) phenomenal time [198], (iv) visual awareness [197], (v) emotion [184], (vi) integration of classical, quantum, and subquantum concepts [190], (vii) integration of classical and quantum concepts for emergence hypothesis [191], (viii) an overview of the meanings attributed to the term ‘consciousness’ [188], (ix) optimal and general definition of consciousness [193], (x) linking Dynamic Systems theory (DST) and Fractal Catalytic Theory (FCT) with Standard Representation Theory (SRT) using PE-SE framework [187] and DST-FCT’s “experience arises as an organism mediates (catalyzes) the transitions in its surround” [23], and (xi) the inclusion of consciousness in string theory towards a theory of everything [195].

We hypothesized that elementary particle such as an electron has two aspects: material and mental aspects. However, it is argued in [63] that there are two kind of relations rather than two aspects: (i) The material-aspect of electron should be replaced with ‘describing something (other-relation)’, for example, interaction with other particles. Then, one could argue that how self-interaction, mass, charge, and spin of that electron will fit in. (ii) Mental-aspect of electron should be replaced with ‘the case of being something (self-relation)’. If we hypothesize that the mental aspect of electron *carries* all *experiences* (or PEs/SEs) in superposed form, which is the mental aspect of electron, then how ‘self-relation’ will fit in. It appears that the hypothesis H<sub>3</sub> might fit better with the ‘two kind of relations’ idea because both are close to the *restricted panpsychism* [58].

The *matching and selection* mechanisms (how a specific SE is selected out of many), the topic of this article, can contain quantum and/or classical concepts. The quantum concept of superposition of SEs and classical concept of *matching and selection* process are discussed in Vimal [192]. The quantum concept of *conjugate matching* between two modes is discussed in [56, 58-68] and [201-204]. In this article, the classical *matching and selection* mechanisms are extended further using *quantum conjugate matching* in experiential domain.

## 2. Matching and Selection mechanisms

### 2.1. Quantum Conjugate Matching

The quantum conjugate matching in previous frameworks are described by Globus as follows (**bold** in quotes: mine):

(i) "The Umezawa/Yasue (U/Y) approach, in **which consciousness offers superposed possibilities to the match with sensory input**, is based in the first physical principles of quantum field theory. [...] Consciousness is cybernetic rather than having a random function. [...] What rids U/Y of the randomness at the heart of H/S [Heisenberg/Stapp approach] is that fundamental physical conservation laws come into play, so that the quantum field interactions in the perimembranous bioplasma are symmetry-conserving with respect to sensory input. **Cognition/memory is tied to reality in virtue of the match, and the result of the match conserves real invariance.** [...] So evolution of the neural wave function is not random but optimized under Yasue's principle of least neural action. [...] The key moves in shifting from H/S to U/Y are (1) recognizing that brain substrates uphold second-order quantum fields, and so should not be treated as ordinary physical measuring devices, and (2) **replacing the random collapse of the neural wave function by a complex match which conserves input symmetry in the unfolding of classical orders**" [67] (**bold mine**). The superposition concept is applied in the PE-SE framework, in which the match between sensory input and cognition/memory leads to actuality of specific experience.

Furthermore, "The color of things is on their surfaces, Gibson [54, 55] insists, not in our minds. [...] So all **the term "experience" properly denotes is our thrownness in a world of qualities.** [...] What needs explaining is the world of qualities, not qualitative experiences. What must be accounted for is the redness of that round bulgy object over on the kitchen counter, forget about theoretical red sensations. [...] Electromagnetic frequency and object color nicely correlate, but science doesn't have the right categories to account for world qualities" [62] (**bold mine**). Globus argues that (personal communication): (i) in the dual-mode-double-universe-thermofield-*holoworld* framework [60, 62, 64], the fact is that we always find ourselves already amidst a world of colors, sounds, and so on; (ii) the fact is world-thrownness; (iii) to say that we "experience" this world is to add something to the facticity of world-thrownness, creating a duality; (iv) "experience" is superfluous, a manner of speaking grounded in dualistic metaphysics, a separation between experience and thing, and (v) "I am amidst a world" has the same meaning as "I experience being amidst a world" in this framework. Thus, this *holoworld* framework seems to eliminate SEs and hence *bypasses* the explanatory gap of materialism. On the other hand, the PE-SE framework does not eliminate SEs, but it is designed in such a way that various problems are *bypassed*. Therefore, one could critique that both frameworks commit *bypass*-mistake. However, I argue for the PE-SE framework that the design is robust because SEs are fundamental and irreducible and hence inherently exist. This is elaborated further in [185].

Gibson's and the dual-mode-double-universe-thermofield-*holoworld* frameworks for color appears to be similar to Byrne and Hilbert [22] who argued, "colors are physical properties, specifically, types of reflectance". However, the problem is that how to explain (i) color appearances by trichromats versus achromats for the same long wavelength reflecting objects (addressed in Sections 2.2 and 3.9), and (ii) endogenously generated color phosphenes (addressed in Sections 3.1, 3.2, 3.4). Our hypothesis is that the mental aspect of both fermions and bosons *carries experiences* (or PEs/SEs in superposed form [192], as in hypothesis **H<sub>1</sub>**. It is the *matching and selection* process that leads to a specific SE), such as *redness*. For example, the matching of the *redness* superposed in the mental aspect of the long wavelength light reflected from red color surface matches with the *redness* embedded in the mental aspect of the red-green V4/V8/VO neural-network, as detailed in steps (i)-(v) related to the hypothesis **H<sub>1</sub>** in Section 1 and in [192]. This sensori-motor matching/tuning of visual system with external stimuli is accomplished during co-developmental neural Darwinism. In other words, the long wavelength light reflected from red color object generates feed-forward signal, which activates the red-green opponent channel related V4/V8/VO neural-network. If it is reportable (*access awareness*) then fronto-parietal feedback attentional signal interacts with stimulus-dependent feed forward signal. Attention is not needed for phenomenal awareness. This activated network acquires SE *redness* via *selection and matching* process. The network thus experiences *redness*.

There are four brain substrates for quantum field [67]: (i) Oscillating high dipole moment biomolecules in neuronal membrane related to sensorium quantum field, (ii) nanolevel neuropil consists of microtubules, neurofibrils, and other structures for super-radiance and self-induced transparency within the microtubules, (iii) quasi-crystalline ordered water molecules within nanolevel neuropil for cognition/memory, and (iv) double layer peri-membranous **bioplasma** of ionic charged particles, where sensory and cognition/memory quantum fields interact leading to formation of classical orders, such as in 'V4/V8/VO' visual area. This is consistent with our PE-SE framework [192] because the matching of the specific SE superposed in the mental

aspect of stimulus (tilde mode) with the SEs embedded in the mental aspect of neural-network (non-tilde mode) might be occurring in the above four brain substrates. This matching is via the interaction of feed forward stimulus dependent signal (tilde mode) with feedback attentional/cognitive/memory signal (non-tilde mode). For example, SE *redness* is experienced during the selection of a specific SE *redness* out of many SEs embedded in the mental aspect of color-related neural network (non-tilde mode) by matching with stimulus-related *redness* on external object (tilde mode).

(ii) Furthermore, “Tuned (weighted) conjugate possibilities are spontaneously thrown up by cognitive quantum fields and when a conjugate match is made with input, an actuality is unfolded as classical perceptual order. ... The classical result conserves abstract invariants in the input flux... Control is exercised by tuning the possibilities offered to the match with input. ... The quantum upsurge interacts with the quantum representative of external reality and perception of the world results. An actual thrown-in-the-world existence is continually unfolded out of quantum field interactions. ... But due to fundamental physical conservation laws, the monad is symmetry conserving of physical reality, registering abstract invariants in the energy flux from reality falling upon its sensory receptors” [68].

The conjugate matching is elaborated further as, “The q-brain’s ~mode may be conceived as a plenum of possibility, all interpenetrated, mutually “enfolded,” “implicate” (pace [16]). ... The attunement of memory traces is a “holoworld” of weighted (“tuned”) possible worlds generated by the q-brain in its ~mode. The narrow possibilities contained within the highly ordered input to the q-brain is non~ mode. **When non~ input meets ~attunement and makes a ~conjugate match within the holoworld of tuned possibilities, then lo! Being appears. World is disclosed in the match** ... Being is a special state of dual mode quantum brain dynamics, the q-vacuum state when the dual modes achieve a ~conjugate match between a weighted attunement of re-cognition traces and the flux of input order” [60] (**bold mine**). Here, the modes are imaginary and the match is real, which implies observables, world disclosure.

Globus [59] compared the thermofield-holoworld framework with Bohm’s holomovement and Vitiello’s dual matching modes as follows: “There is a “**holoworld**” of weighted implicate possible worlds, from which actual worlds are explicated in waking and dreaming alike [16]. (The difference is that in waking sensory input strongly influences explication—the unfolding of the wake life—whereas in dreaming explication comes mainly via restless memories, undischarged affect and ungratified wish + nonspecific activation.) ... For **Bohm** the **holomovement** is a kind of Spinozan tertium quid **with two aspects: mind and matter**. Further for Bohm, there is implicate mind and explicate mind, as well as implicate matter and explicate matter—which is unfortunately ontologically profligate and leads to all kinds of complications in Bohm’s theory of consciousness. It is much cleaner, I suggest, to **think of the implicate order as dual mode and the unfolding of explicate order as the dual modes ~conjugate match** ... Vitiello identified consciousness with the vacuum state dynamics of **dual matching modes**. ... I opened a nonHermitean version of **thermofield** quantum brain dynamics [56, 66] in which local differences between modes are permitted, rather than fixed to be zero in the match. ... This adds a degree of freedom, for which the ~conjugate match is a special case. ... **Input to the brain is represented in the non~ mode whereas memory traces of re-cognitions are ~mode. The ~mode provides a fluctuating attunement of weighted self-organizing memory traces for the vacuum state encounter with non~ input order**. ... The monadological brain does not have representative “pictures” of its surround; it holds an experienced surround that is continually unfolded from the neural holoworld in waking and dreaming alike. ... **This “match” [~conjugate match] is between continuously tuned traces of past recognitions and the continual flux of fresh input.**” (**Bold mine**).

In the hypothesis  $H_1$  of the dual-aspect-dual-mode PE-SE framework, the mental aspect of each elementary particle (boson/fermion) carries all *experiences* (or PEs/SEs) in superposed form. However, since long wavelength light (photons) interacts with the visual system, only vision related SEs are relevant (by the principle of relevance/zero-sensitivity for non-relevant SEs). Now consider the equiluminant red-green opponent neural-network, which has SEs redness to greenness as its mental aspect. When long wavelength related signals travel in this neural-network, only color SE *redness* is relevant (by the principle of relevance). Thus, the mental aspect of this input stimulus-signal carries SE *redness*, which is analogous to the representation of sensory input or physical reality (material aspect). During co-developmental *neural Darwinism*, the red-green V4/V8/VO neural-network embeds SEs *redness* to *greenness* as its mental aspect, which is analogous to the cognitive reality. Now, in the matching process, both the neurodynamical input related to red-object and the relevant cognitive representation of such input interact and the specific SE *redness* is selected and experienced by the red-green V4/V8/VO neural-network via the selection process. This can be further elaborated more precisely using the double layer peri-membranous **bioplasma** of ionic charged particles,

where sensory and cognition/memory quantum fields interact leading to the formation of classical order related to the experience of *redness* by the red-green V4/V8/VO neural-network. In the dual-mode-double-universe-thermofield-hologworld framework, the matching is between two modes (*tilde* 'our' mode and a non-tilde 'alter time-reversed' mode), which leads to an actuality unfolded as classical perceptual order. Whereas, in the PE-SE framework, the matching is between the mental aspects stimulus-PEs/SEs (*tilde* mode) and embedded-neural-network-PEs/SEs (non-tilde mode), which leads to the selection of a specific SE; in addition, the matching is also between material aspects (for detail, see Section 2.2 below). In other words, both 'direct realism' [54, 55, 155, 156, 158] and 'indirect realism' (via representation: [40-42, 102, 104]) may contribute to SEs via matching process.

## 2.2. Quantum Conjugate Matching, Classical Matching, and Selection Mechanisms in the PE-SE framework

The concepts of quantum physics are needed, in a complementary way [192], to address the explanatory gap (how SEs arise in brain), where (i) the superposition of multiple possible *experiences* or the superposition of the *possibilities of experiences* in the mental aspect of string and elementary particles are employed for macroscopic adaptive systems (such as ourselves: [53, 120]) and (ii) the matching of external (*tilde* mode) and internal (non-tilde mode) superposed SEs and the selection process lead to a specific SE [20, 115, 192, 198]. For example, the SE *redness* is experienced when long wavelength light is presented to our visual system by (conjugate) matching of *experiences* (or PEs/SEs) in the mental aspect of external stimulus dependent signals (*tilde* mode) with the SEs embedded in the mental aspect of internal V4/V8/VO neural-network (non-tilde mode). Once matched, the selection process selects a specific SE from a set of embedded neural-network PEs (the mental aspect of neural-network) as detailed in Section 1 and [192]. It should be noted that conjugate matching in the PE-SE framework involves both material and mental aspects, as elaborated below.

The complex conjugate matching described by Globus [59, 60] and Vitiello [201-204] and applied in the PE-SE framework is as follows:

$$(a-ib)_{FFinput} * (c+id)_{FBcognition} = (a-ib)_{FFinput} * (a+ib)_{FBcognition} = a^2 + b^2 \text{ if } a=c \text{ and } b=d. \quad (1)$$

where  $a$  and  $c$  are real material aspects in input feed forward neural activities ( $FFinput$ ) and in feedback cognition related neural-network ( $FBcognition$ ), respectively. Similarly,  $b$  and  $d$  are mental aspects (SEs) along imaginary (orthogonal) axis in  $FFinput$  (*tilde* mode) and  $FBcognition$  (non-tilde mode), respectively. One can view the real material aspect as content of experience; for example, the experience *redness* related to red ball for trichromats is represented by the imaginary mental aspect and its content red-ball by the real material aspect in our conventional reality [121, 185]; for achromats, experience will be blackness/dark-grayness related to the same ball and is represented by the imaginary mental aspect and its content black/dark-gray ball by the real material aspect.<sup>§</sup> By maximum power transfer theorem,  $a=c$  and  $b=d$ . In other words, for conjugate matching if the cognition related neural-network signal is  $(a+ib)$ , then input signal must be  $(a-ib)$ , where '+ $ib$ ' in  $(a+ib)$  represents the mental aspect of internal neural-network and its complex conjugate '- $ib$ ' in  $(a-ib)$  represents the mental aspect of external objects. The superposition [126] of multiple possible *experiences* (or PEs/SEs) is represented in the imaginary axis of the complex entity  $(a\pm ib)$ . This is the complex conjugate matching.

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<sup>§</sup> In achromats, color areas (V4) is damaged [212]. An achromat reported that his world is shade of black, white and grey: "I experience the colour called red as a very dark grey, nearly black, even in very bright light. On a grey-scale the blue and green colours I see as mid-greys, somewhat darker greys if they are saturated, somewhat lighter greys when unsaturated, like pastel colours. Yellow is usually a rather light grey to me, but is usually not confused with white. Brown usually appears as a dark grey and so does a very saturated orange." [127]. Furthermore, one may want to distinguish *red* or *dark-gray* as a property (or quality) of the mental aspect of objects from the SE *redness* or *dark-grayness* as a property of the mental aspect of chromatic or achromatic visual neural-network related to an area of our visual field (see also [90]). In this sense, we use the term 'the superposition of multiple possible experiences or qualities'; we experience *redness* when we 'sense' or 'see' *red*.

Furthermore, according to maximum power theorem, “whenever a source of power, such as an electric signal source, a radio transmitter, or even mechanical sound operates into a load, the greatest power is delivered to the load when the impedance of the load (load impedance) is equal to the "complex conjugate" of the impedance of the source (that is, its internal impedance). For two impedances to be complex conjugates, their resistances must be equal, and their reactances must be equal in magnitude but of opposite signs.”<sup>h</sup> For our case, this implies that a=c and b=d for the optimum performance.

After matching process, SE and its neural correlates of consciousness (NCC) becomes phenomenal reality, i.e., neural-network experiences the SE. If there is no external signal, then endogenous signals, such as from memory, phosphenes, or some other process such as in dream, act like a and b in Eq. (1), leading to SEs. For example, SE of V4/V8/VO Red-Green opponent channel related neural-network

$$\begin{aligned}
 &= (-i b)_{\text{FFinput}} * (+i d)_{\text{FBcognition}} = [-i \sum_j \alpha_j \exp(\epsilon_j)]_{\text{FFinput}} * [+i \sum_j \beta_j \exp(\epsilon_j)]_{\text{FBcognition}} \\
 &= [\sum_j \alpha_j \exp(\epsilon_j)]_{\text{FFinput}} * [\sum_j \beta_j \exp(\epsilon_j)]_{\text{FBcognition}} \\
 &\rightarrow \text{redness} + [(\alpha_{\text{orangeness}} * \beta_{\text{orangeness}}) \text{orangeness}] + [(\alpha_{\text{yellowness}} * \beta_{\text{yellowness}}) \text{yellowness}] + \dots \\
 &\sim \text{redness}, \tag{2}
 \end{aligned}$$

where exponentials (exp) are related to Fechner’s logarithmic law in psychophysics; coefficients  $\alpha_j$  and  $\beta_j$  represents relevance/sensitivity/probability a specific SE  $\epsilon_j$  being experienced. For example,  $\alpha_j$  and  $\beta_j$  are zero for all those SEs that are not color related and are not between redness to greenness; for redness they are 1; for orangeness, yellowness, and greenish-yellowness they are significantly less than 1 but greater than 0; and for greenness they are zero. Since visual stimulus such as long wavelength light is relevant to a specific organ such as eye and photoreceptors,  $\alpha_j$  for other SEs such as taste, olfactory, sound, touch etc are zero. This is simply because of the circuit formed and tuning occurred during co-developmental *neural Darwinism*.

The conjugate matching in the dual-mode-double-universe-thermofield-holoworld and Vitiello’s frameworks are as follows [58]: “In that the dual modes share the vacuum state, their relationship is a crucial variable. Under the usual “Hermitian assumption” [...] of quantum theory the dual modes must make a “match,” in the sense that the complex number (a+bi) “matches” its complex conjugate (a-bi).The product of the dual modes’ “belonging-together” [...] is accordingly a real number. (Recall that (a+bi)(a-bi) = a<sup>2</sup> + b<sup>2</sup>, since the cross terms cancel and i<sup>2</sup> = -1.) In Vitiello’s formulation conscious feelings are the modes’ belonging-together. Conscious feelings are real states of the between-two in which the dual complex-valued modes belong-together. Phenomena appear in the match of the between-two. The world is consciously felt through the “trade” between the brain system and its world environment, the trading in which they optimize a belonging-together.”

The mode-convention in Vitiello’s framework is the same as in the PE-SE frameworks, but is different from that in the dual-mode-double-universe-thermofield-holoworld framework. In the dual-mode-double-universe-thermofield-holoworld framework [56, 58-68] when the interaction occurs between (a) the non-tilde future (*an ‘alter time-reversed’ quantum mode*) approaching towards present and (b) the tilde cognitive past (*‘our’ mode*) approaching towards present and the conjugate match is made, the ‘world-presence’ (‘Now’/‘present’) is disclosed in the match for the ‘belonging-together’ (Heidegger's [83] *zusammen-gehoren* of *die Ursprung=belong together of the origin*) of a specific between-two. This framework explains well the ‘Now’/‘present’ component of the phenomenal time [198], whereas its content (whatever is disclosed phenomenally) remains the ‘brute fact’.

In Vitiello’s dual-mode framework, “The  $\tilde{a}$  [tilde] mode is the “time-reversed mirror image” of the a [non-tilde] mode and represents the environment mode. [...] the tilde-modes can never be eliminated from the brain dynamics: the tilde-modes thus might play a role as well in the unconscious brain activity. ... the role of the  $\tilde{A}$  modes in the self-recognition processes”<sup>1</sup> [201]. Thus, the tilde mode usually represents the external environment and non-tilde mode represents the brain dynamics in Vitiello’s dual-mode framework. However, tilde mode may represent the external environment plus a part of brain dynamics (such as unconscious brain activities and the self-recognition processes) and non-tilde mode the remaining part of brain dynamics (such as conscious/subconscious brain activities). Moreover, the tilde and non-tilde modes are in an entangled state, which means that: (a) the brain and the external world are normally linked because the brain dynamics is a

<sup>h</sup> Quoted from [http://www.experiencefestival.com/a/Impedance\\_matching\\_-\\_Power\\_transfer/id/5155639](http://www.experiencefestival.com/a/Impedance_matching_-_Power_transfer/id/5155639)

dissipative dynamics; any forced isolation of a subject from environment produces pathological states of various kinds; (b) the entangled dual-mode state cannot be divided into two single-mode states; and (c) the non-tilde and tilde modes “share a common, entangled vacuum at each instant of time” [202]. In addition, the brain is a *mixed* system that has two separate but interacting levels: “The memory level is a quantum dynamical level, the electrochemical activity is at a classical level. The interaction between the two dynamical levels is possible because the memory state is a macroscopic quantum state due, indeed, to the coherence of the correlation modes. The coupling between the quantum dynamical level and the classical electrochemical level is then the coupling between two macroscopic entities. [...] the dialog with the Double is “evolutive”, it carries the memory, the story of the past, and it is inserted in the unidirectional flow of time, it is itself a “witness” of the flow of time. [...] the time axis gets divided by a *singular* point: *the origin*, which divides the past from the future. [...] The Now is that point on the time-mirror where the non-tilde and the tilde, reciprocal time-reversed images, join together, in the *present*” [202]. Moreover, the many-body theory bridges the gap between microscopic quantum dynamics (“the disordered phase, where no distinguishable patterns exist”) and macroscopic behavior (the ordered phase). The spontaneous breakdown of symmetry<sup>i</sup> of long-range correlation modes is responsible for ordering the system (that will have more information) and hence “for the collective behavior of the system components”, which “manifests in the order parameter of classical fields” that characterizes the macroscopic system behavior [51]. This provides the link between *structure* and *function*, but does not address *experience*. In Vitiello’s framework [201-204], consciousness is generated *between-two* during the interaction of the brain system and its world environment, which are the two quantum modes. This seems like another form of materialism and hence Vitiello’s framework has the explanatory gap that needs to be bridged.

In the PE-SE framework: (i) the non-tilde mode is the material and mental aspect of the cognition (memory and attention) related feedback signal in a neural-network of the brain, which is the cognitive nearest past approaching towards present and (ii) the tilde mode is the material and mental aspect of the feed forward signal due to external environmental input and internal endogenous input, which is the nearest future approaching towards present and is a entropy-reversed representation of non-tilde mode. Thus, the selected specific SE during conjugate matching between (i) and (ii) is the real explicate state of the between-two in which the dual complex-valued modes belong-together at the juncture of the interaction of feed forward and feedback signals, for example, at V4/V8/VO neurons for color. It is noted that a (= c) is the material aspect and b (= d) is the mental aspect of signals in Eq. (1) for the optimum performance, and the feed forward signal (a-ib) matches its complex conjugate (a+ib) cognition related feedback signal leading to the temporal ‘present’ and its spatial content (SE and its content). The Eq. (1) can be re-written as,

$$[a-ib]_{FFinput} * [a+ib]_{FBcognition} = [a(t_+) - i b(t_+)]_{FFinput} * [a(t_-) + i b(t_-)]_{FBcognition} \quad (3)$$

where time  $t_+$  represents the nearest-future approaching present in tilde mode and  $t_-$  represents the nearest-past approaching present in non-tilde mode. The ‘nearest future’ is in the brain’s immediate environment in field of view, which becomes ‘present’ during memory-update via brain-environment interaction.

To elaborate further, consider the *experience* of long wavelength reflecting object by trichromats and achromats. For trichromats, the experience *redness* or quality *red* superposed in the mental aspect of the object (FFinput signal) is matched with the SE *redness* superposed in the mental aspect of the chromatic V4/V8/VO neural-network related to Red-Green channel (FBcognition) and *redness* is experienced. However, for achromats, the experience *dark-grayness* or quality *dark-gray* superposed in the mental aspect of the same object (FFinput signal) is matched with the SE *dark-grayness* superposed in the mental aspect of the neural-network related to Achromatic channel (FBcognition), and the SE *dark-grayness* is experienced by this achromat’s network. In physicalist (materialist + SE) perspective, classically, the light activates the relevant neural-

<sup>i</sup> “Symmetry is said to be spontaneously broken when the Lagrangian is invariant under a certain group of continuous symmetry, say  $G$ , and the vacuum or ground state of the system is not invariant under  $G$ , but under one of its subgroups, say  $G'$ . The ground state then exhibits observable ordered patterns corresponding to the breakdown of  $G$  into  $G'$ . These patterns are generated by the coherent condensation in the ground state of massless quanta called Nambu-Goldstone (NG) particles, or waves, or modes. These modes, which are the carriers of the ordering information in the ground state, are dynamically generated by the process of the breaking of the symmetry” [51].

network leading to related SE. Psychophysically, the hue, saturation, and brightness attributes of color are elaborated in [200].

For Vitiello, the tilde mode is a quantum thermofield theoretical environment or heat bath of the brain and the non-tilde mode is the brain, and consciousness is generated *between-two*. However, the dual-mode-double-universe-thermofield-*holoworld* framework [56, 58-68] (Globus, personal communication) can argue that the world around is the brain's environment in a local sense; but in the deepest sense, 'world plus environment' have an 'environment' or heat bath that is an *alter-universe*. In this *holoworld* framework, input to the brain is the *alter-universe* that is represented in the non-tilde mode, whereas memory traces of re-cognitions are tilde mode. This convention is different from Vitiello's framework. The essential point is there is neither environment (*Umwelt*) nor brain in either mode. Each mode is purely quantum and each can be considered environment—not *Umwelt* but heat bath—for the other. *Umwelt* and brain are between-two, as is anything worldly.

In the PE-SE framework, each mode contains the material and mental aspects of each entity. The conjugate matching is between these two modes for both material and mental aspects: (i) the material aspect of input feed forward signals (tilde mode) and the material aspect of cognition related feedback signals (non-tilde mode) for relevant *functions*, such as detecting red color stimulus; and (ii) the mental aspect of input feed forward signals (tilde mode) and the mental aspect of cognition related feedback signals (non-tilde mode) for relevant SEs, such as SE *redness*. Since it is a dual-mode-dual-aspect framework, matching of one aspect leads to the matching of other aspect.

In other words, this type of conjugate matching explains the 'Now'/'present' as the juncture of immediate future and immediate past in temporal domain in terms of 'world presence'. In addition, in the PE-SE framework, the matching results the content of 'Now': the SE of subject (*self*), the SE of objects in the spatial domain, and the content of SEs. In Vitiello's framework, the trade is "between the subject and his Double" [202]. In the PE-SE framework, the trade is between the internal cognitive information inside the subject and its Double external information in the brain's environment. Furthermore, the matching process activates (a) the 'state space' [28] in dynamical systems theory (DST: continuous time-varying systems with energy exchange and information processing) and (b) the emergence of the patterns that form conscious episodes from unconscious processing, which soon return to unconsciousness [140]. The DST-state-space [28] can explain (i) unity of consciousness, (ii) qualia [177]/SEs, (iii) spectrum of consciousness (deep sleep to meditative states), (iv) personality (slowly varying pattern of thought and behavior but consistent over time), (v) knowledge (memory), and (vi) intentionality (the content of every mental phenomenon, such as belief and desire, is directed at an object) as discussed in [161]. In addition, "spatiotemporal processing emerges from the interaction between incoming stimuli and the internal dynamic state of neural networks, including not only their ongoing spiking activity but also their 'hidden' neuronal states, such as short-term synaptic plasticity" [21]. Thus, the PE-SE framework tries to integrate some of the relevant concepts from various frameworks, such as (i) the conjugate matching related to 'belonging-together', and 'between-two' for 'Now'/'present' from Globus [56, 58-68] although his framework with double universes is entirely different, (ii) the conjugate matching for 'conscious feelings' from Vitiello [201-204], (iii) the dual-aspect view from Bohm-Hiley-Pylkkänen [14, 15, 17, 84, 85], Chalmers [24-27], and Velmans [181-183], (iv) the *neural-Darwinism* from Edelman-Seth-Baars [38, 40-42, 159], and related environment-organism interaction views [21, 28, 161]. This integration yields the temporal 'present' and its content (SEs and their content) in a spatio-temporal domain using the dual-aspect and dual-mode views while addressing the explanatory gap of materialism [26, 109] and the 'brute fact' of the dual-mode-double-universe-thermofield-*holoworld* framework. One could critique that the PE-SE framework also has a 'brute fact' of the mental aspect that has superposed SEs. That an aspect is 'mental' is a 'brute fact' feature of universe in the PE-SE framework, a way that reality is not derivable from anything else. Though this is true, but I argue that it is also the 'real fact' that SEs, such as *redness*, are fundamental and irreducible and hence must inherently exist.

Furthermore, in the plenum sense, the conception of conjugate match in the dual-mode-double-universe-thermofield-*holoworld* framework may appear different from that of the conjugate match used in Eq. (1) for the PE-SE framework. For the latter, the mental aspects of neural networks are a plenum of possible experiences.

This plenum becomes differentiated (probabilized) by Edelman's *neural Darwinism* [40, 41]. The match actualizes one of the plenum's possibilities. For the dual-mode-double-universe-thermofield-holoworld framework, the plenum is vacuum state symmetry which is undifferentiated. Rather than containing everything, it contains nothing. The match does not select pre-existing experiences but generates them as world-thrownnesses.

### 3. Critiques<sup>j</sup> and Discussion

#### 3.1. Critique related to SEs

One could argue that the term 'subjective experience' is not clear: is SE the quality of the external object or that of the internal brain's neural-network? The meaning of the term 'subjective experience' (SE) is the experience by subjects when they view external objects. For example, we experience *redness* of red-ball. Experiences (PEs/SEs) are in superposed form in all entities (including both external stimuli and internal neural-networks), whereas a specific SE is selected during the matching process and experienced by neural-networks in brain that includes neural-network related to self. The goal is to comprehend how SE such as *redness* (what it's like! [123]) occurs.

In the dual-mode-thermofield-holoworld framework, red is a quality of the long wavelength reflecting objects (such as red-ball), not a quale of a SE (*redness*) while looking at the red-ball because SE (such as *redness*) is eliminated in this framework. In the PE-SE framework, a specific SE (such as *redness*) is in the mental aspect of the neural-network, which is linked to that of the stimulus by conjugate matching and selection process. The PE-SE framework distinguishes SE (such as *redness*) from the content of SE (such as red-quality-object). On the one hand, red is a quality of the long wavelength light reflected/emitted from an object or the object itself in dual-mode-thermofield-holoworld [62], Velmans' [181], Honderich's [87] and dynamic systems theory (DST) based frameworks (such as [22, 54, 55]).<sup>k</sup> It is argued in Section 3.9 that the 'quality' of object is also subjective because a trichromat will 'see' *red* ball whereas an achromat will 'see' *dark-gray* ball when the same long wavelength reflecting ball is viewed. On the other hand, one could also argue that color is our internal phenomenon, somehow emerges in brain (standard representation theory: SRT). Otherwise, how do we explain retinal color phosphenes generated by pressing eyeballs hard, cortical phosphenes generated during electrical stimulation, or meditation-induced color phosphenes when eyes are closed and outside is dark (but see below). A majority of color scientists believes that latter (SRT) is correct for color, whereas a minority believes a color is a quality of an external object (DST). The PE-SE framework implies that both DST and SRT are correct in a complementary manner.

In other words, in the dual-aspect-dual-mode PE-SE framework, both (DST and SRT) contribute. This is consistent with Nāgārjuna's *dependent origination* [121] if we accept that mind and matter co-arise. Furthermore, a SE occurs/is selected/emerges/explicates/unfolds/arises during the matching and selection process in various frameworks (including hypotheses H<sub>2</sub> and H<sub>3</sub> of the PE-SE framework), but a specific SE is selected in the PE-SE framework with the hypothesis H<sub>1</sub>. For example, in the PE-SE framework, (i) the SE *redness* is superposed in the mental aspect of both the stimulus (ball) and the neural-network (*the observer*), and (ii) the *red* is a quality of the ball (*the observed*) and *redness* is a SE while looking at the ball and is experienced by the trichromatic *observer* (the 'V4/V8/VO' color neural-network) during interaction of environment (e.g. stimulus dependent feed forward signals: tilde mode) and organism (cognition related feedback signals in the

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<sup>j</sup> Some of the critiques were from Globus; he is a monadological physicalist and combines insights of idealism with advanced quantum physics.

<sup>k</sup> Krishnamurti's statement "the observer is the observed" (2nd Public Dialogue, Brockwood Park, England, 6th Sept. 1973; <http://www.katinkahesselink.net/kr/observer.html>), which is closer to DST.

color neural-network: non-tilde mode) via the matching and selection process. The PE-SE framework is consistent with both DST and SRT in a complementary manner.

### 3.2. Critique related to the conjugate matching for endogenous SEs

One could argue that conjugate matching works fine for *access* (reportable) awareness in our wakeful life when there are external input signals and conjugate cognition related signals. However, it is not clear for endogenously generated subjective experiences (such as in dreams and phosphenes) where there are cognition related signals but no external input signal, and for non-reportable phenomenal experience where there are input signals for very short time (less than 50 msec) but cognition (such attentional feedback) signal is not available for such a short duration.

To address the above critique, our hypothesis is as follows: Even for endogenous generated subjective experiences (such as in dreams and phosphenes), there may be ‘initiators’ (such as random fluctuation in dreams, phosphene-signals such as in electrical stimulation, transcranial magnetic stimulation, or meditation-induced) which may activate feed forward (FF) pathway that usually carries external input signals during wakefulness. Thus, we can still have conjugate matching between FF signals (tilde mode) and feedback (FB) cognition (such as memory, attention etc) related signals (non-tilde mode). In the case of non-reportable phenomenal experience where input is of very short duration (less than 50 msec) [165], cognition (such as iconic memory) can still act as FB signal, and hence one can have conjugate matching between two modes (FF and FB signals).

In the dual-mode-double-universe-thermofield-*holoworld* framework, however, the states of monads<sup>1</sup>—the state of the *between-two*—are thrownnesses in a “world” of phosphenes, dreams, non-reportable phenomenal experiences, similar to the thrownness in a “world” of wakefulness. In addition, dreaming differs from waking in that the sensory input is blocked and random activation from the brain stem (PGO spikes) drives the system from below while REM-sleepy cognition shapes it from above [61].

### 3.3. Critique related to the application of quantum physics in SEs, single cell framework, sensori-motor contingency framework, Orch OR framework, chaos theory, and conjugate matching

There are some criticisms on the application of quantum physics to consciousness. Since the superposition of multiple possible *experiences* (or PEs/SEs) is for the mental aspect of an entity in the PE-SE framework [192], the physical constraints such as the large timescale discrepancies [44, 73, 175], temperature, decoherence problems, and so on are bypassed simply because the mental aspect is beyond space-time constraints. Consequently, the potential criticisms, such as raised in [113, 114, 120], against the application of quantum concepts for SEs in the PE-SE framework are not relevant, but they are indeed relevant to those quantum theory based models [80] that involve mostly material aspect such as *structure* and *function*; the relevant problems are, however, addressed to some extent in [74]. Nevertheless, the treatment for SEs must follow closely with that for *structure* and *function*. That is, the matching process for SEs must remain consistent with all five pathways for information transmission (see Introduction and below).

Furthermore, Hameroff [74] has tried to address the criticisms of Litt et al. [113]. According to Hameroff [74], “the brain is both neurocomputer and quantum computer” because “Orch OR is based on quantum computation in microtubules within dendrites in cortex and other regions linked by dendritic–dendritic gap junctions (“dendritic webs”) acting as laterally connected input layers of the brain’s neurocomputational architecture. Within dendritic webs, consciousness is proposed to occur as gamma EEG-synchronized sequences of discrete quantum computational events acting in integration phases of neurocomputational “integrate-and-fire” cycles. Orch OR is a viable approach toward understanding how the brain produces consciousness.” However, empirical evidence is still lacking and

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<sup>1</sup> The Leibniz’s monads and parallel (soul ~ experience and body ~ representation) duals [106, 107] seem to address the problems of Descartes and Spinoza, namely, the problematic interaction between mind and matter arising in Descartes’ framework and the lack of individuation (individual creatures as merely accidental) inherent in Spinoza’s framework. Leibniz’s monad could be absolutely simple, “without parts, and hence without extension, shape or divisibility ... subject to neither generation nor corruption [...] a monad can only begin by creation and end by annihilation” [150] (pp. 132, 133).

Hameroff's position (Orch OR is consciousness/SE!) is unclear regarding how precisely SEs arise in the brain, whereas the PE-SE framework is clear on this account. In addition, the PE-SE framework is complementary to all models (including Orch OR) related to *structure* and *function* by providing an ontological interpretation.

Since the superposition is a quantum phenomenon, the 'matching process' and related mechanisms can usefully be described using quantum concepts for 'macroscopic adaptive systems (such as ourselves)' in spite of the criticisms against the relevance of quantum mechanics to philosophy of mind [113, 120]. Since one of the hypotheses is that the brain is both neurocomputer and quantum computer, one could argue that 'classical matching and selection process' is via classical axonal-dendritic integrate-and-fire pathway for neuro-computer and 'quantum conjugate matching and selection process' via dendritic-dendritic gap junctions (dendritic webs) for quantum computer. As mentioned In Section 1, there are at least five pathways: (i) classical axonal-dendritic neural pathway, (ii) quantum dendritic-dendritic gap junctions, (iii) astro-glia-neuronal Ca<sup>++</sup> related, (iv) extracellular volume transmission, and (v) soliton propagation. It appears that the quantum 'conjugate matching' is more for quantum dendritic webs and less for non-quantum pathways, whereas the classical 'matching and selection' is appropriate for the remaining non-quantum pathways. The argument for the classical 'matching and selection' mechanisms for the pathways (iii)-(v) is similar to that for (i) as detailed in Sections 1 and 2 and [192] because we have assumed that they are non-quantum pathways. However, if any of them can be described also in term of quantum physics then the quantum conjugate matching will apply for that pathway as described for (ii) in Sections 1 and 2. One could argue that the underlying mechanism of classical matching is quantum conjugate matching because the underlying mechanism of classical physics is quantum physics.

Each cell that satisfies the essential ingredients of SE, can have SE. This is possible only if that privileged cell is an experiential entity. For example, the mental aspect of all material entities, including the mental aspect of retinal and V4/V8/VO cells carries irreducible SEs in superposed form. However, V4/V8/VO cells, for example, become privileged<sup>m</sup> to have specific color related SEs (not smell and not taste related SEs) because they are part of color related neural-networks (Red-Green and Yellow-Blue color opponent channels) that satisfy the essential ingredients of SEs. A specific SE is selected by some processes, such as classical/quantum matching process and/or Orch OR quantum mechanism via *neural Darwinism*. A neural-network may be composed of all those cells (including receptors for signal transduction and deeper 'lower' parts of the brain) that are involved directly or indirectly in awareness. That privileged neuron in neural-network receives both stimulus dependent feed forward signals (tilde mode) and feedback attentional signals (non-tilde mode), and both modes interact/match with each other to result micro-awareness. The re-entrant process binds the local signals related to relevant single-cell micro-awareness, which results the unified global awareness. When a neural-network is formed, specificity of SE increases [192]: the mental aspect of elementary particles has all types of *experiences* (or PEs/SEs) in superposed form and hence the lowest specificity, whereas V4/V8/VO red-green cells have higher specificity because they are specific to colors between redness and greenness (SEs related to taste, smell, touch, sound and even blueness are excluded) and hence have smaller number of superposed SEs. Thus, it is the tuning of a neural-network (the *structure*) with external stimuli during developmental *neural Darwinism* that generates the specificity of *experiences* and the *function* of that structure. To sum up, the dual-aspect-dual-mode PE-SE framework is complementary to the single cell framework [43], and, in general, all materialistic frameworks by providing an ontological interpretation.

In the PE-SE framework, SE/awareness involves the matching and selection process: the selection of a specific SE out of many irreducible SEs embedded in the mental aspect of a neural-network by the matching process. However, a neural-network needs to be formed via co-developmental *neural Darwinism* for the matching and selection mechanism. If we isolate a single cell in vitro, then all SEs will be in superposed form and it will be very hard to select a specific SE. That is, the mental aspect of cell will act like a *carrier* of many

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<sup>m</sup> By the term 'privileged', I mean, for example, V4/V8/VO neuron is privileged to have awareness of color because it satisfies essential ingredients of awareness, namely, wakefulness, re-entry, attention, memory, and so on. Some privileged neurons have local/micro-awareness and many such neurons are needed in a neural-network for global/macro-awareness. Retinal cell is not privileged to have awareness/SEs because it is not awake and not attentive, and there is no re-entry from front-parietal area.

SEs just like the mental aspect of any inert matter is a *carrier* of a large number of superposed SEs in unexpressed form. This means that a neural-network is needed for selecting a specific SE. The single neuron hypothesis of micro-consciousness [43] needs to be supplemented by at least 3 more hypotheses: (i) developmental *neural Darwinism*, (ii) combination rule for global/macro awareness, and (iii) the PE-SE framework to close the explanatory gap.

In sensorimotor contingency (functionalism) framework, the attributes, such as visualness, forcible presence, ongoingness, and ineffability of SE, were explained by the concept of corporality ('bodiliness': movement of body affects sensory stimulation) and alerting capacity ('grabiness': sudden object-motion grabs attention and affects sensory stimulation) [130, 131]. However, one could argue that SE or 'subjective consciousness' could not be explained by the sensorimotor contingency hypothesis because these concepts are for the processing of information related to function or 'functional consciousness'. Similar argument can be made against 'radical externalism' [87]. Specifically, one could argue that the sensorimotor contingency hypothesis is for the tuning of internal neural activities with external objects by the sensorimotor interaction with external stimuli. For normal cortical development, sensory experience is required as shown by sensory deprivation and pharmacological manipulation in the cortex [105]. Unlike ocular dominance, early visual experience is necessary for the development of direction selectivity in visual cortex [110]. For O'Regan and Noë, the sensorimotor contingency is *itself* SE [131]; for us, sensorimotor interaction is needed for the co-development and co-tuning of a neural-network with relevant external stimuli. According to O'Regan and Noë [131] "We experience red because we take our sensory stimulation to be governed by the relevant laws". This statement needs unpacking because '*the relevant laws*' may be those laws that govern the co-development of mind and brain including the sensorimotor tuning process with external world during development. In general, the hypotheses of sensorimotor interaction, internal representation, and the co-development of mind and brain play important role in the developmental process. However, the sensorimotor contingency hypothesis [130, 131] and 'radical externalism' [87] can be integrated with the PE-SE framework if we invoke conjugate matching [59, 60, 68] between external input signals and cognition related internal signals. Similarly, this conjugate matching framework can also integrate apparently contradicting models: standard representation theory (SRT), dynamic system theory (DST), and fractal catalytic theory (FCT) [23, 34, 198].

There are at least two mechanisms for the matching and selection of a specific SE: (i) classical axonal-dendritic mechanism: in this mechanism, the a specific SE is selected from SEs **embedded in** the mental aspect of a **neural-network** based on the stimulus-dependent signals by matching process during the interaction of feed forward stimulus-dependent signals with fronto-parietal cognition (attention, memory, etc) related feedback signals, and (ii) quantum dendritic-web mechanism: this is quantum Orch OR mechanism in MT network [78, 80], where SE say *redness* is selected from SEs **embedded in spacetime geometry** by objective reduction (collapse) of superimposed SEs in the mental aspect of neural-network to the specific SE say *redness* when stimulus say long wavelength light is presented. The coherence (consistency) between feed-forward incoming and reentrant feedback signals is necessary for quantum conjugate matching related to SEs (see Section 2.2). Therefore, both mechanisms may involve matching process during the interaction of feed forward stimulus-dependent signals (tilde mode) with cognition related feedback signals (non-tilde mode). Here, the SEs embedded in the mental aspect of neural-network/spacetime geometry match with the SE superimposed in external and/or internal stimulus-related signal for the selection of a specific SE. The neural-network-PEs [192] embedded in the mental aspect of neural-networks can be considered as neural-correlates of Penrose Platonic values encoded in fundamental space-time geometry [78]; however, the latter mechanism [78] is not clear. The number of possible SEs relates to Orch OR can be reduced by the sensorimotor tuning during development in a neural-network. For example, the mental aspect of the X-linked red-green V4/V8/VO-neural-network embeds only red-green color related SEs as neural-network-PEs. In the Orch OR framework, as discussed before, the quantum conjugate matching between the specific external input signal (tilde mode) and the cognitive signal related to SEs embedded in the mental aspect of spacetime geometry of specific neural-network (non-tilde mode) will lead to a specific SE.

Alternatively, there may exist a mechanism by which SEs emerge in the neural-networks of brain, such as chaotic process of self-organizing system. According to chaos theory, a self-organizing system, such as brain, is

an *open* system, which is intimately connected with its environment; it can create novel structures and new modes of behavior [20]. SEs are *emerged* during the interaction of feed-forward signals (tilde mode) and feedback neural-PE signals in neural-networks (non-tilde mode). This mysterious *emergence* of a specific SE could be by the chaotic process of self-organization (because this process has ability to create novel entities to meet the environmental demands). Since a self-organizing system, such as brain, can create novel structures and new modes of behavior, it might also create complex SEs (such as *redness*) to cope with its environment during co-evolution. In chaos theory, attractors (SEs) need to pre-exist, which is equivalent to SEs in classical axonal-dendritic or in the Orch OR framework. Although, the Orch OR mechanism has its own problems, there is significant effort to address them [76-79, 134-138]. Furthermore, Nanopoulos has applied string theory in MT network that supports “a superposition of coherent quantum states [...], representing an external or mental order, for sufficient time needed for efficient quantum computing. Then the quantum superposition collapses spontaneously/dynamically through a string derived mechanism for collapse” [124]. Thus, the quantum conjugate matching and/or classical ‘matching and selection’ mechanism can address the matching involved in the chaotic process of self-organization framework. Further investigation is needed.

### 3.4. Critique related to the panpsychism, panprotopsychism, panexperientialism, panprotoexperientialism, and dual-aspect view

According to Skrbina [162], “Panpsychism is the view that all things have a mind, or a mind-like quality.” There are panpsychist dualists, functionalists, identists, reductive materialists, and so on [163] including panpsychists with dual-aspect monism (substance monism but property dualism) [161]. However, there are seven problems [193] in panpsychism, panprotopsychism [25], panexperientialism and panprotoexperientialism<sup>n</sup>, and dual-aspect view (such as our *integration* based hypothesis **H<sub>3</sub>**); some of the problems are described in [154, 163] and discussed further in [191, 193, 195]. The seven problems adapted from [193] are as follows: “(1) **Combination problem**: This problem is “how low-level proto-experiential and other properties somehow together *constitute* our complex unified conscious experiences” [154], i.e., how a specific SE can *emerge* from the PEs of constituent elements in a related neural-net [191, 194]. In other words, “sub-minds, such as those of atoms, cannot be conceived to combine or sum into complex, unified minds such as humans have. Hence panpsychism is not an adequate account of mind” [163](p.265). (2) **No sign or not testable problem**: The problem is “there is no evidence whatsoever of a nonphysical dimension to the elemental units of nature” [154] and there is no ‘sign’ of mentality in the basic features of the world. In other words, there are “no ‘new facts’ or empirical basis on which to evaluate the panpsychist claim. ... This includes the assumption that non-verifiable theories are invalid in some fundamental sense” [163](p.265). However, Nunn argues that it is simply not true. Quantum counterfactuals (e.g. the Elitzur-Vaidman bomb test) show clearly that what one might term *knowledge* is built into the foundations of physics. A related problem, the **completeness problem**, is that the inert system should also show sometime causal power of proto-experiences, which is not the case; this leads to incompleteness of physical picture of world [154, 194]. However, Nunn argues that if [154] is implying that the physical is causally closed, then it only thought to be true if *causal* is confined to efficient (spontaneous or chance) causation. It is not true otherwise as Henry Stapp and Hans Primas have shown with their *Heisenberg choice* arguments. (3) **Inconclusive analogy or not-mental problem**: “The purported analogical basis between humans and other objects is groundless” [163] (p.265). The variant ‘not-mental’ problem [154] “objects to identifying the conjectured ‘inner nature’ of, say, an atom with something we can reasonably call mental” [163](p.262-263). However, one could argue it out as in problem (2). (4) **Physical emergence problem**: “Emergence is in fact possible because we see it in other realms of the physical world; mind is not ontologically unique; hence emergence of mind *is* conceivable” [163](p.265). A related problem is **unconscious mentality problem**, which is “accepting the mentality of the elemental units of mind while denying that they are actually conscious experiences” [154]. In other words, “how can consciousness emerge from unconsciousness?” [163](p.262-263). (5) **Implausibility problem**: “Panpsychism is so implausible and counter-intuitive that it cannot be true. Also known as the ‘*reductio ad absurdum*’ objection” [163](p.265). (6) **Eternal mystery problem**: “Mind-body problem is unsolvable in principle, and hence panpsychism, which purports to offer a solution, must be false” [163](p.265). (7) **Restricted panpsychism problem**: “Quantum thermofield dynamics does in fact prescribe a lower boundary below which there can be no cooperative dynamics, and without cooperative dynamics there is nothing mind-like [...] If qualia were

<sup>n</sup> See <http://en.wikipedia.org/wiki/Panpsychism>

...tied to the coherence of cooperative dynamics, then the descent into panpsychism would halt at the coherence length [of about 50 microns]" [57]." Furthermore, Edelman rejects panpsychism based on evolution (environment and the bodies give rise to minds) [39](p.212)."

The dual-aspect-dual-mode PE-SE framework [192] with hypotheses  $H_1$  and  $H_2$  (elaborated in Introduction) do not have the above seven problems [193] because the concept of *superposition* is used. In other words, (i) *experiences* (or PEs/SEs) are *superposed*<sup>o</sup> in the mental aspect of fundamental particles (subquantum strings or quantum bosons and fermions). (ii) The mental aspect of matter *carries* experiences (or PEs/SEs) in *superposed* unexpressed form leading to matter as non-protococonscious until neural-networks are formed or *unfolded* (always above the threshold of *coherence length* related to quantum thermofield dynamics). (iii) External stimulus (environment, object) dependent feed-forward signals (tilde mode) interact with feedback (organism's cognition related) signals in awake neural-networks (non-tilde mode). (iv) The matching and selection mechanisms act. And (v) *necessary* ingredients for a specific SE during waking (such as wakefulness, re-entry, attention, memory, stimulus at or above threshold contrast, and so on) are satisfied. For endogenously generated experiences (such as in dreams, phosphenes, and so on) the last three steps are modified as (iii') endogenous feed forward signals interact with feedback (organism's cognition related) signals in neural-networks. (iv') The selection mechanism selects experiences embedded in the mental aspect of neural-networks after matching between two modes. And (v') *necessary* ingredients for an endogenous specific SE (such as re-entry, attention, memory, and so on) are satisfied.

### 3.5. Critique related to the dual-mode-double-universe-thermofield-holoworld and holomovement, and the PE-SE frameworks

For the dual-mode-double-universe-thermofield-holoworld framework, "*The holoworld is a plenum of all possible worlds in implicate form*" [64]. One could argue that *experiences* (or PEs/SEs) are not part of *holoworld* because *experiences* (or PEs/SEs) are not perceptual/qualitative entities; rather they are cognitive and not enfolded to the *holoworld*. However, one could argue that (i) the quality of object is also subjective (the *red* ball for trichromats is the *dark-gray* ball for achromats: see Section 3.9) and (ii) *experiences* (or PEs/SEs) are left unexplained and the explanatory gap is not bridged in *holoworld* [64] and *holomovement* [14, 16] frameworks. Whereas, these problems are not present in the dual-aspect-dual-mode PE-SE framework [192] because *experiences* (or PEs/SEs) are the mental aspect of fundamental particles (strings or fermions and bosons) in superposed form. Moreover, the *holomovement* [14, 16] and the dual-mode-double-universe-thermofield-holoworld [64] frameworks have association problem (e.g., how to associate a specific experience redness or object-quality red with a specific 'between-two'). In other words, what makes the belonging-together of a particular *between-two* disclose a red tomato instead of a green one? The *between-two* states may differ coordinate with sensory input differences, but why should one *between-two* have the look of red and another *between-two* have the look of green. In the dual-mode-double-universe-thermofield-holoworld, the best answer is that these are "brute facts" (that's just the way it is), which have no explanation; the brute fact is that the 'looks' are already there and is unavoidable. In addition, from where the qualitative world or subjectivity (intentionality) originates is not clear. Moreover, from the explanatory gap and SE perspectives, one could argue that how our 'experience' is 'our thrownness in a world of qualities' and where SEs such as redness pops up from during quantum conjugate match. One could, however, elucidate that the above "brute fact" might be related to the assignment problem: Ecological environment-organism interaction, sensori-motor tuning, and natural selection ('fittest survive') might assign a specific quality to specific object and a specific experience to a specific neural-network. This assignment mechanism might make the belonging-together of a particular *between-two* disclose a red tomato instead of a green one because it is the best fit via natural selection. In the PE-SE framework [192], I have argued a similar assignment mechanism via matching and selection process during developmental *neural-Darwinism*. However, it is still not clear how the 'brute fact' related to the first person/subjective experience (such as SE *redness* related to a ripe red-tomato for trichromats but SE *dark-*

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<sup>o</sup> The rationale for the superposition of multiple possible experiences is given in the abstract and Sections 3.8 and 4.

grayness for achromats) can be addressed without the complementary dual-aspect-dual-mode PE-SE framework. For example, this 'brute fact' is addressed in Section 2.2 by incorporating the dual-mode concept of dual-mode-double-universe-thermofield-*holoworld* framework in the dual-aspect PE-SE framework.

In quantum-thermofield framework (*restricted panpsychism* or panpsychism above coherence length) [58], subjectivity (intentionality) tunes the belonging-together of the *between-two*. In general, there are three entities, *structure*, *function*, and *experience* that need to be linked; mind is composed of *function* and *experience*. In the dual-aspect-dual-mode PE-SE framework, PEs/SEs are in superposed but unexpressed form in the mental aspect of strings or elementary particles, i.e., inert matter acts as if it is non-experiential entity. A specific SE is selected/expressed when a relevant neural-network is formed which is presumably above coherence length of 50 microns in the PE-SE framework (this assumption gets rid of problems!). Therefore, the PE-SE framework is not inconsistent with dual-aspect *restricted panpsychism*. However, *restricted panpsychism* has some of the six problems of panpsychism [154], such as combination problem [69]. Whereas, these problems are addressed in the dual-aspect-dual-mode PE-SE framework [192].

At subquantum plenum level, however, all three frameworks appear to be more or less similar. For example, the *holomovement* or the dual-mode-thermofield-*holoworld* framework, when unpacked, is close to the PE-SE framework at sub-quantum plenum level [190, 191]. In other words, the concept of selection from plenum is more or less similar for all frameworks. Various plenums are: (i) *holoplenum* (the symmetry of quantum vacuum/ground states of the symmetry-breaking type) for the dual-mode-double-universe-thermofield-*holoworld* framework, (ii) Platonic world in Penrose-Hameroff framework, (iii) cosmic-consciousness plenum [152, 153], (iv) sub-quantum (SQ) field plenum [18] based on Bohm's Implicate Order [15], (v) RigVedic-Buddhist primordial consciousness plenum, unitary dimension of fundamental reality, Supreme Unified Consciousness, unified quantum field, or Universal Mind plenum [35, 108, 132, 146, 147, 151, 205, 206], (vi) virtual reservoir plenum in the dual-aspect-dual-mode PE-SE framework, and so on. Though there are enormous differences in various plenums, all have a common problem of fundamental assumption, such as (i) dual-aspect in the PE-SE framework, (ii) dualism in Cartesian framework, (iii) emergent property of neural network in materialism/emergentism, (iv) neutral monism in Feigl's framework, (v) the 'brute fact' in *holoplenum*, and so on. In my view, at present state of knowledge, the best we can do is to address problems in each view and investigate which view has the minimum number of problems (see below).

### 3.6. Critique related to the relation between material and mental aspects

One could argue that the difficulty is not the mental aspect as a superposition but the relation between a material superposition and a mental superposition. The *superposition* of multiple possible *experiences* (or PEs/SEs) in inert matter is *potentiality* or *possibility*. This simply means that a specific SE is realized/actualized when neural-networks are formed, two modes are matched, the SE is selected, and the essential ingredients of SEs are satisfied. This is one of the ways to close the explanatory gap of materialism. Matter and mind are different aspects/sides of the same entity. The relationship between mental and material aspects becomes clearer when a specific neural-network is formed. The formation of neural-network is via developmental *neural-Darwinism*, where sensori-motor tuning and the matching and selection mechanisms facilitate the formation. For example, consider the SE *redness*. The related neural-network is red-green 'V4/V8/VO'-neural-network and the psychophysical channel is the Red-Green channel. When the long-wavelength light from red-ball is presented to this network, the matching (between stimulus-SEs and neural-network-SEs) and selection mechanisms during the interaction between stimulus-dependent feed forward signals and cognition/attention/memory related feedback signals create a state, call it *red-state*. This *red-state* has two aspects. The mental/experiential-aspect is *redness* and the material-aspect is the related neural-network and its activity. We do not get *redness* from that state. *Redness* is already there along with other SEs (as their *possibilities/potentialities*) in the mental aspect of both neural-network and the stimulus. It is the matching and selection mechanisms that do the required task of raising the specificity to 100%. That is, when the Red-Green channel is formed, the specificity of a SE is raised and the specific SE actualizes. In other words, Red-Green channel is specific only to SEs between *redness* to *greenness* (not to *blueness*, not *painfulness*, etc). Whereas,

constituent elements such as electrons within it are non-specific as their mental aspect *carries* all *experiences* (or PEs/SEs) in superposed and unexpressed form; electrons are present also in other channels. When the *red-state* is created, its two aspects are observed depending on the observation. If observed subjectively then the network experiences *redness*. If observed objectively such as in fMRI we see activity in V4/V8/VO visual area. The relationship between the mental/experiential and material aspects could be 1-1. In other words, it all depends on how we perform an experiment on it. If a subjective experiment (first person experiment such as simply looking at the stimulus) is performed then the *red-state* (the state of the Red-Green psychophysical channel) is SE *redness*. If we perform objective experiment (such as an fMRI third person experiment) then the *red-state* is the V4/V8/VO-network and its activity. This is in analogy to wave-particle duality: if we perform wave-type (such as slit-interference-type) experiment, an electron is a wave; if we perform particle-type (such as in photoelectric effect), the electron is a particle; in other words, the electron has two material aspects: wave and particle. Here also, the relationship between the two material aspects is 1-1.

Strawson [171] rejects dual-aspect view based on 'no real distinction between a substance and its properties' because he is unable to understand (a) how these two aspects belong to the same substance, (b) how they are related to each other, and (c) how there is no distinction between them. However, these two aspects have 1-1 relationship, which becomes obvious during measurements. For example, when first person psychophysical experiment is performed experience is revealed, whereas when third person physiological experiment such as fMRI is performed its material aspect is uncovered in terms of activities in the relevant neural-network. This is in analogy to wave-particle measurements. Therefore, the dual-aspect view cannot be rejected. In addition, the problems raised by various commentators on Strawson's article [171] on panpsychism and reviewed by Stubenberg are addressed by the dual-aspect-dual-mode PE-SE framework.

### 3.7. Critique related to parsimony used in the PE-SE framework and category mistakes

One could argue that the dual-aspect concept is an assumption or a 'brute fact'. Our rationale for the dual-aspect-dual-mode PE-SE framework is as follows: (i) it is parsimonious in the sense that it minimizes the inherent problems of dual-aspect view, panpsychism, and other frameworks, i. e., it has optimization parsimony. (ii) Since SEs are fundamental and irreducible, they are not necessarily brute-facts rather they are real facts in conventional/ mind-dependent reality. One can further critique: that we have SEs is factual but those SEs are superposed in the mental aspect of elementary particles is brute. This is addressed in Section 3.8. And (iii) it accommodates many views in a complementary way by providing an ontological interpretation. One can further argue that such parsimony is *frame-relative*. We address these criticisms by describing various types of parsimony, the rationale for using mental aspect as another category, and how they are relevant to our framework, and then argue for the PE-SE framework in detail.

According to Feigl [46] or Hubbard [88], there are three types of simplicity or parsimony: (i) material simplicity or epistemological parsimony, (ii) Occam-simplicity or ontological parsimony, and (iii) formal simplicity or linguistic parsimony.

According to Baker [10], "Within philosophy, Occam's Razor (OR) [simpler theories are better if other things are equal] is often wielded against metaphysical theories which involve allegedly superfluous ontological apparatus. Thus materialists about the mind may use OR against dualism, on the grounds that dualism postulates an extra ontological category for mental phenomena. [...] This distinction is between qualitative parsimony (roughly, the number of types (or kinds) of thing postulated) and quantitative parsimony (roughly, the number of individual things postulated [i.e., the desire to minimize the number of individual new entities postulated]). [...] Unrestricted Occam's Razor favors monism over dualism, and nominalism over platonism. By contrast, 'concretized' Occam's Razor has no bearing on these debates, since the extra entities in each case are not concrete. [...] [In addition,] Walter of Chatton, proposed the following counter-principle to Occam's Razor [i.e., the principle of explanatory sufficiency]: "[I]f three things are not enough to verify an affirmative proposition about things, a fourth must be added, and so on" (quoted in Maurer 1984 [116], p. 464) ... "The variety of entities should not be rashly diminished" (Kant 1950 [103], p.541)."

In addition, according to Hubbard [88], "We began with the physicalist's objection to the use of mental terms on the grounds of ontological parsimony. Concerns with linguistic parsimony showed the need for mental terms to be included in our vocabulary. A reductionist can agree to the use of these terms by saying that they could be reduced to

physical states. [Reductionism is the most parsimonious solution to the mind-brain problem.] However, because the mind has fundamentally different properties than any physical object, it exists as a fundamentally different type of entity". Therefore, the dual-aspect view that has property dualism but not Cartesian substance dualism is better than reductionism.

Moreover, one could still argue that although mind has fundamentally different properties than material entities, parsimony is *frame-relative* and is in the eye of the beholder and is not an absolute but a social construct. However, the above three principles of parsimony are not usefully applicable to the mind-brain problem because mental states (SEs such as *redness*) cannot be reduced to material descriptions [88] and the principle of explanatory sufficiency cannot be rejected [10, 103, 116].

Furthermore, according to Stubenberg [173], "The "immense simplification" (Russell 1959, 103-4) [149] afforded by neutral monism therefore supports it on two counts: its makes neutral monism ontologically simpler and epistemologically less risky than its rivals." He defines neural monism and compares it with materialism, idealism, panpsychism, and emergentism as: "Neutral monism ... takes mental and physical phenomena to be real but reducible to the underlying neutral level. [...] [Materialism reduces everything to material entities;] phenomenalism reduces everything to mental entities; neutral monism reduces everything to neutral entities. [...] Panpsychism is the doctrine that every physical particular enjoys some measure of mentality. ... Neutral monism reduces mental and physical phenomena [to constructions of neutral entities], panpsychism does not; neutral monism holds that the "materia prima" is neutral, panpsychism does not. And neutral monism assumes that there are genuinely physical (i.e., nonmental) phenomena that need reducing, panpsychism does not. [...] As complexity increases physical and/or mental features emerge from the neutral basis. ... Ultimate reality—that upon which everything else depends—is neutral and monistic. And in its more developed form this world also contains emergent features. ... Neutral monism is a reductive thesis; emergentism is not. ... Emergent features—be they mental or physical—cannot be reduced to the lower level features from which they arise. ... Both monism and neutrality are lost if emergentism is added onto neutral monism." He then elaborates how the neutral monism is related to other dual-aspect theories: "The dual aspect theory takes many forms. Its relationship to neutral monism is therefore difficult to discern. All versions of the theory appear to be committed to the view that there are certain substances—god or nature (Spinoza 1677) [166], persons (Strawson 1959) [172], body or brain (Thomas Nagel, 1986) [122], information (a view explored by David Chalmers 1996 [24])—that are intrinsically neither material nor mental. Nevertheless these substances can present themselves under the aspect of the mental and the aspect of the physical. And these aspects are distinct yet inseparable and basic in the sense of being irreducible to each other or to anything else. ... According to neutral monism a given group of neutral elements is mental or physical depending on which other groups it happens to be connected with. That is, the features of mentality and physicality are independent of each other. A given group of elements might have both features, or one or the other, or neither. It all depends on the company the group keeps. Therefore the two aspects of materiality and mentality are not inseparable. The irreducibility claim fares no better. A group's being mental and/or physical just consists in it's occurring in a certain context. That is, in the neutral monistic framework the features of mentality and physicality are paradigms of reducibility."

The PE-SE framework and the neutral monism are different versions of dual-aspect theory; however, *experiences* (or PEs/SEs) are superposed (or possibilities) in the mental aspect of strings or fermions and bosons in the PE-SE framework, but not (clear) in the neutral monism. Therefore, the neural monism needs to address the problems of panpsychism and needs to explain how material and mental entities reduce to neutral entities. The problems raised by various commentators on Strawson's article [171] on panpsychism and reviewed by Stubenberg are addressed by the dual-aspect-dual-mode PE-SE framework.

One could argue that hypothesizing a framework that has least number of problems compared to other frameworks is optimization parsimony. There are many metaphysical views related to consciousness and each view has its own fundamental assumption and/or has a number of other inherent problems. Although it is very hard to address the fundamental assumption, my justification for the dual-aspect PE-SE framework is that it is an optimum framework that has the least number of problems compared to other frameworks. This is a sort of consistent with Leibniz's optimization principle [64]. In other words, I understand that the fundamental assumption of dual-aspect (but in a special way: superposition of multiple possible *experiences* (or PEs/SEs) in the mental aspect of fundamental particles) is the only one problem in the PE-SE framework (but see below). It is easy to assume whatever one likes to, but then one has to address all the problems involved. I justify my assumption on the basis of optimization, which leads the PE-SE framework to have the problem of

the dual-aspect assumption, whereas other views have more problems in addition to their own inherent fundamental assumption (some listed in Section 2 of [193]). Physics also have many assumptions but they are justified by experimental results. It would be interesting to design some subjective/objective experiments to reject/maintain/critically examine various views. Further research is needed to address the problem of the fundamental assumption.

If the PE-SE framework is rejected due to its fundamental assumption of dual-aspect view, then we may end up with a framework that may have more problems in addition their own fundamental assumption. For example, (i) materialism/emergentism has the problem of explanatory gap: how experience can emerge from non-experiential matter such as brain. In addition, it has 3 major assumptions [161]: material is the ultimate reality, material reality is essentially objective and non-experiential. (ii) Substance dualism has 5 problems: the association or mind-brain interaction problem, the mental causation problem, zombie problem, ghost problem, and neurophysiological problem as discussed in [195]. (iii) Panpsychism, proto-panpsychism, and proto-experientialism have 6 problems as discussed in Section 3.4. (iv) Idealism has reverse-explanatory gap problem: how matter can emerge from mind. (v) The *holoworld* framework has 'brute fact' problem as discussed in Section 3.5. (vi) Other views also have their own problem. Thus, the PE-SE framework is the most optimum framework as of now. I agree that further research is needed for better framework.

Furthermore, the brute fact of 'PEs/SEs superposed (unexpressed) in the mental aspect of string or elementary particles, inert matter as their carrier, and a specific SE is expressed/selected when neural-network is formed' can be further unpacked. Since our SEs are fundamental and irreducible, they are the inherent facts; they are neither brute facts nor fundamental assumption. In other words, this brute fact is the real fact as mass, spin, charge, space-time, force, and quanta are facts.

Feigl [46] believed that "those thinkers who maintain that a "category mistake" is involved in mixing phenomenal and physical language [... are] essentially right. [...] the difference between logic and psychology is just as fundamental as that between, say, logic and physics. To disregard the difference amounts to making one of the most glaring category mistakes. This sort of category mistake is fundamentally different from a. violations of Russell's type rule; b. confusions of language levels, e.g., object language and metalanguage; c. mixing of phenomenal with strictly physical concepts; d. confusion of dispositions (capacities, propensities) with occurrences (episodes, events, processes); e. mistaking purely emotive (i.e., pictorial, emotional, and/or motivative) expressions and appeals for cognitively meaningful sentences." To avoid the category mistake between mental and material aspects in the PE-SE framework, we have clearly qualified experiential entities by 'the mental aspect of'.

One could argue that Gödel's theorems might be applicable to the problem related to fundamental assumption. However, "Hilary Putnam (1960) [145] suggested that while Gödel's theorems cannot be applied to humans, since they make mistakes and are therefore inconsistent, it may be applied to the human faculty of science or mathematics in general. If we are to believe that it is consistent, then either we cannot prove its consistency, or it cannot be represented by a Turing machine."<sup>p</sup> Supposing Putnam's hypothesis is rejected, my impression is that even if the mind-dependent-reality (MDR) is related to the mind-independent-reality (MIR), we cannot prove that this relationship is valid/invalid/complete according to Gödel's first incompleteness theorem because mind is inferred in both MDR and MIR. If we try to do that then we end up with contradiction. However, the term 'mind' is used in MIR but 'mind' (SE) is excluded from MIR, therefore the contradiction doesn't really hold. The same argument applies in the fundamental assumptions related to all views, including the dual-aspect assumption that even if the fundamental assumption in a framework appears valid using the rationale of parsimony and optimal-framework, we may not be able to prove or disprove it within the same framework. However, we try to justify the fundamental assumption based on parsimony as done for the dual-aspect PE-SE framework on this basis of optimization parsimony.

Furthermore, one could argue that the dual mode thermofield is not an assumption but a requirement for quantum field theory to have a true thermodynamical degree of freedom. The *brute fact* in the PE-SE framework is that an aspect is experiential. The *brute fact* in the dual-mode-double-universe-thermofield-*holoworld* framework is not that the between-two is an explicate order but that the explicate order is qualitative.

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<sup>p</sup> Adapted from [http://en.wikipedia.org/wiki/Godel's\\_Incompleteness\\_Theorem](http://en.wikipedia.org/wiki/Godel's_Incompleteness_Theorem)

All theories have a brute fact somewhere — the issue is plausibility and a parsimony that generates richness of explanation, and the PE-SE framework passes this litmus test.

The dual-aspect-dual-mode PE-SE framework has the dual-aspect everywhere in each mode and also in the between-two: coming from the past (cognitive feedback signals, non-tilde mode), coming from future (stimulus dependent feed forward signals, tilde mode) and the Now (between-two modes). For example, the mental aspect of a *between-two* is SE *redness* and the material-aspect of the *between-two* is the related V4/V8/VO neural-network and its activity when a trichromat views a red-ball. It is still parsimonious because it is the most optimum framework. However, in the dual-aspect-dual-mode framework, one could ask: what is the point of the between-two being real if it has two modes like the duals do? For example, in the dual-mode-double-universe-thermofield-*holoworld* framework [56, 58-68], the dual modes that are interfering in the vacuum state collapse to an explicate order: we "get something" out of the match, gain ontologically, gain the riches of world-thrownness from a purely quantum thermofield theoretical description, voila! The rabbit is out of the quantum hat (Globus, personal communication). To address this critique, I argue for the dual-aspect-dual-mode PE-SE framework as follows: (i) we get everything what other frameworks can offer as above; in addition, (ii) we gain the content of Now, namely, SEs and their contents in the *between-two* by the matching the two modes; (iii) we bridge the explanatory gap of materialism, which can be best done by the dual-aspect-dual-mode PE-SE framework; and (iv) we address the brute-fact (that's just the way it is!) of other frameworks including the dual-mode-double-universe-thermofield-*holoworld* framework. Although one can still critique that the assumption of mental aspect is a 'brute-fact', one cannot deny the real-fact that SEs are fundamental and irreducible in the mind-dependent reality (MDR) or subject-inclusive reality (SIR) in the PE-SE framework. This is the rationale for hypothesizing that SEs are in superposed form in the mental aspect of fundamental particles and a specific SE is selected during matching and then the relevant specific neural-network experiences it. In the mind-independent reality (MIR) or subject-exclusive reality (SER), SEs are still in superposed form in the mental aspect of entities, but 'what it's like' can only be experienced in MDR. In addition, one could still criticize that there is another type of subquantum Type-2 explanatory gap: how it is possible that our SEs (such as happiness, sadness, painfulness, and similar SEs) were already present in primal entities in superposed form, whereas there is no shred of evidence that such SEs were conceived at the onset of universe. This is addressed elsewhere [190]: (i) Since superposition of SEs/PEs in elementary particles refers to possibilities that actualize when neural-network is formed and we know that these SEs are indeed real in our daily mind-dependent reality, it is justified that all types of SEs/PEs could be considered possibilities at the onset of universe. In addition, one could further argue that SEs might have been one of major motivations for evolution to form neural-networks. (ii) Alternatively, in the hypothesis  $H_1$ , the SEs that entail this gap are secondary SEs derived from primary fundamental irreducible PEs/SEs. However, one has to explain how they can be derived, i.e., there is the combination problem [69]. If all SEs lead to Type-2 explanatory gap, then they are derived from some superposed PEs and the hypothesis  $H_1$  becomes equivalent to the hypothesis  $H_2$ . (iii) In the hypothesis  $H_2$ , PEs (not SEs) are superposed form in inert matter to avoid this Type-2 explanatory gap. There is no matching of mental aspects and there is no selection of a SE in the hypothesis  $H_2$  (whereas there is matching of mental aspects and there is the selection of a specific SE in the hypothesis  $H_1$ ). In the hypothesis  $H_2$ , a specific SE *emerges* during matching of material aspects; but then one has to explain how it emerges, and hence the combination problem [69] exists in  $H_2$ . Further research is needed to investigate problem-free framework.

### 3.8. Critiques on the use of superposition

In the matching and selection process, the 'superposition of multiple possible experiences' and the superposition of the *possibilities* of experiences' are used, which need further elaboration.<sup>q</sup> One could critique

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<sup>q</sup> "Quantum superposition is the fundamental law of quantum mechanics. It defines the allowed state space of a quantum mechanical system. [...] The probability in quantum mechanics is equal to the square of the absolute value of the amplitude. [The values of the wave function are probability amplitudes — complex numbers — the squares of the

that the 'superposition of multiple possible experiences' is not possible because it alters the meaning of 'experience'. Waves are superposed but experiences are not wave-like.<sup>r</sup> Therefore, 'superposed experiences' seems self-contradictory. On the other hand, the 'superposition of the possibilities of experiences' is possible but possibilities are not mind-like; they do not have mind-like qualities; they are a different ontological category altogether; hence, the PE-SE framework is not panpsychism, rather it is a quantum version of double aspect theory. I address both critiques as follows.

My goal has been to address the problems of other views and to search for a framework with fewer problems. The dual-aspect view was used (substance-monism-property-dualism) to address the problems of materialism (explanatory gap) and dualism (substance-dualism-property-dualism) and the concept of superposition was used to bypass the seven problems of dual-aspect panpsychism [193] and to select a specific SE by classical matching and quantum conjugate matching mechanisms. The classical superposition of waves and quantum superposition possibilities of complex waves seem to be linked.<sup>s</sup> The classical *superposition of multiple possible experiences* is needed to select one specific experience during classical matching in classical axonal-dendritic neural pathway. Quantum *superposition of the possibilities of experiences* is needed to collapse/actualize many possibilities of experiences to one specific SE in the selection process during quantum conjugate matching.<sup>t</sup> This is related to Orch-OR in quantum dendritic-dendritic (MT-network) pathway. One could argue that both types of superpositions are linked because classical and quantum physics are linked (see below).

Are experiences wave-like? This question is similar to: are positions waves or wave-like? Both questions do not seem right! Here is a justification: In the dual-aspect framework, a string or an elementary particle (boson or fermion) has material and mental aspects. In addition, matter or each of elementary particles could behave as a wave or a particle depending on a measurement-method. Therefore, both particle and wave have mental and material aspects. For example, an electron has material aspect and mental aspect. Its material aspect is a function of mass, spin, charge, and space-time. Its mental aspect is a function of experiences. Waves interact with each other such as in interference. The bridge between wave and particle theories is  $E = mc^2 = hv$ , where  $E$  is energy,  $m$  is mass of the particle,  $c$  is speed of light,  $h$  is Planck constant, and  $v$  is frequency of the related wave. Positions are independent variables (such as  $x, y, z$ ) in the material aspect and do not interact with each

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absolute values of which, give the probability distribution that the system will be in any of the possible states.] [...] the only time probability enters the picture is when an observer gets involved. If you look to see which way the atom is, the different amplitudes become probabilities for seeing different things. [...] Observations have different outcomes described by probabilities, while microscopic events are described by amplitudes."

([http://en.wikipedia.org/wiki/Quantum\\_superposition](http://en.wikipedia.org/wiki/Quantum_superposition) and <http://en.wikipedia.org/wiki/Wavefunction>).

<sup>r</sup> There are a number of investigators who propose that mind as field or wave-like. For example, Libet [111] hypothesizes conscious mind as a field. A field is related to wave. Popper et al [143] and Lindahl and Arhem [112] proposed mind as a force field. Pockett [141] identifies consciousness with "certain spatiotemporal configurations" of the cortical electromagnetic field (EM). John [99] theorizes that "consciousness is a property of quantumlike processes, within a brain field resonating within a core of structures". One could, however, critique (Globus, personal communication) that to say that conscious mind is a field does not reconcile conscious mind properties with field properties since conscious mind is, at least prima facie, not wave-like. Pockett's "identification" does not have the rigor of Leibniz's law of identity of indiscernibles. Is *res cogitans* spatiotemporal? Descartes showed no. Then how identify with cortical EM? John's hypothesis like the others is based on psi-phi correlation (see Section 1 related to Feigl [23]: the  $\psi$ - $\phi$  correlation is the psycho-neurophysiological correlation). Consciousness correlates with brain field resonance perhaps but this does nothing to resolve philosophical perplexity.

<sup>s</sup> See [http://en.wikipedia.org/wiki/Superposition\\_principle](http://en.wikipedia.org/wiki/Superposition_principle) and [http://en.wikipedia.org/wiki/Quantum\\_superposition](http://en.wikipedia.org/wiki/Quantum_superposition).

<sup>t</sup> "The physical meaning of the components of  $\psi$  is given by the wave function collapse postulate: If the states  $|\phi_i\rangle$  have distinct, definite values,  $\lambda_i$ , of some dynamical variable (e.g. momentum, position, etc) and a measurement of that variable is performed on a system in the state  $|\psi\rangle = \sum_i c_i |\phi_i\rangle$  then the probability of measuring  $\lambda_i$  is  $|c_i|^2$ , and if the measurement yields  $\lambda_i$ , the system is left in the state  $|\phi_i\rangle$ " (<http://en.wikipedia.org/wiki/Wavefunction>).

other. Experiences are fundamental and independent variable in the mental aspect and do not interact with each other. The wave function of an electron (wave or particle) provides a complete description of how the electron behaves. One can write the wave function as  $\psi(\text{position, time, experience})$  and where  $|\psi|^2$  is equal to the chance of finding the electron at a certain position, time, and experience.

The material aspect of electron can be in a state which is the superposition of positions. Similarly, the mental aspect of electron can be in a state which is the superposition of multiple possible experiences.<sup>u</sup> Thus, 'are positions or experiences wave-like (or waves)?' does not seem a right question because they are independent variables. The right question is: 'is the material aspect of wave is wave?' Answer is definitely 'yes': nobody will disagree on this! 'Is the mental aspect of wave is wave or wave-like?' In the dual-aspect view, I assume, the answer should be 'yes' because it is the wave that has the mental aspect in addition to the material aspect. Therefore, the 'superposition of multiple possible experiences' should be valid. In other words, since material aspect of wave is a wave, the mental aspect of wave should be at the least wave-like. The superposition principle has been so far applied to material aspect. The mental aspect has 1-1 relation with material aspect. If the concept of superposition can be applied to the material aspect of wave, the same concept of superposition should be applicable to its mental aspect otherwise the 1-1 relation will be violated.

Next, I address that the *quantum superposition of the possibilities of experiences*. According to Hameroff and Powell [81], "Atoms and sub-atomic quantum particles may exist in two or more states or places simultaneously, more like waves than particles, and existing as multiple coexisting possibilities known as *quantum superposition*, governed by a quantum wave function." From this, I argue that the mental aspect of elementary particles may exist in two or more experiences simultaneously, and existing as multiple coexisting possibilities of experiences, as in *quantum superposition of multiple coexisting possibilities of states or places for their material aspect*. Moreover, these *possibilities of experiences* can be actualized into a specific experience via Orch OR and quantum conjugate matching. In addition, many different fundamental irreducible experiences (such as redness, greenness, blueness, and so on) are possible, in analogy to many waves with different frequency/wavelength are possible. The basis of *quantum superposition* for the mental aspect is the multiple coexisting possibilities/potentialities of *experiences*, as above [81] in the *quantum superposition* for the material aspect. The possibilities of SEs are actualized when neural-networks are formed via *neural Darwinism*, and a specific SE is selected by a *matching* process.

I further argue that the *quantum superposition of the possibilities of experiences* is equivalent to the *superposition of multiple possible experiences*. The superposition is elaborated as: "The principle of superposition states that if the world can be in any configuration, any possible arrangement of particles or fields, and if the world could also be in another configuration, then the world can also be in a state which is a superposition of the two, where the amount of each configuration that is in the superposition is specified by a complex number. [...] A particle can have any position, so that there are different states which have any value of the position  $x$ . These are written:  $|x\rangle$ . The principle of superposition guarantees that there are states which are arbitrary **superpositions of all the positions** with complex coefficients:  $\sum_x \psi(x) |x\rangle$  [...] The quantity  $\psi(x)$  is called the wavefunction of the particle. If a particle can have some discrete orientations of the spin, say the spin can be aligned with the  $z$  axis  $|+\rangle$  or against it  $|-\rangle$ , then the particle can have any state of the form:  $C_1 |+\rangle + C_2 |-\rangle$ . If the particle has both position and spin, the state is a **superposition of all possibilities** for both:  $\sum_x \psi_+(x) |x, +\rangle + \psi_-(x) |x, -\rangle$  (**bold mine**).<sup>v</sup> If the particle has only position, the state is a **superposition of all possibilities for position**:  $\sum_x \psi(x) |x\rangle$ . This is the same as the **superpositions of all the positions**:  $\sum_x \psi(x) |x\rangle$ . This implies that the 'superposition of positions' has the same meaning as the 'superposition of the possibilities of positions'. This implies that the terms 'the superposition of multiple possible experiences' and 'the superposition of the possibilities of experiences' are equivalent. Other terms can also be equivalently used, such as 'the superposition of eigenstates of experiences' (see also [160]), 'the superposition of multiple possible states of experiences' (see also [80, 167, 179]), or 'the superposition of experiences that are possible'. In all cases,

<sup>u</sup> A dictionary meaning of the term 'superposition' is "the placing of one thing on top of another" (<http://en.wiktionary.org/wiki/superposition>). See also [http://en.wikipedia.org/wiki/Superposition\\_principle](http://en.wikipedia.org/wiki/Superposition_principle) and [http://en.wikipedia.org/wiki/Quantum\\_superposition](http://en.wikipedia.org/wiki/Quantum_superposition).

<sup>v</sup> [http://en.wikipedia.org/wiki/Quantum\\_superposition](http://en.wikipedia.org/wiki/Quantum_superposition).

there is a collapse of quantum reality from a superposition of multiple possible experiences to a single definite experience when a measurement is made, such as in conjugate matching (Section 2.2).

According to Skrbina [163], "...mind is best conceived as a general phenomenon of nature. As such, mind would exist, in some form, in all things. This concept is called panpsychism. Panpsychism, roughly speaking, is the view that all things have mind or a mind-like quality." (p.2). In the PE-SE framework, the 'superimposition of multiple possible experiences' in the mental aspect of strings, elementary particles, and inert matter leads them to behave as if they are non-experiential entities, and hence bypass the six problems of panpsychism (Sections 3.4 and 3.7). The remaining the *combination problem* is bypassed because of the matching and selection processes. In other words, inert matter carries experiences in superposed and unexpressed form; matter behaves as if it is non-experiential entity. Thus, strictly speaking, the PE-SE framework is not panpsychism; rather, it is a quantum version of double aspect theory as suggested by the critique.

To sum up, in the dual-aspect view: (1) it is hypothesized that the mental aspect of wave is wave or wave-like and is a function of experiences; therefore, 'superposition of multiple possible experiences' is valid; (2) the 'superposition of multiple possible experience' is equivalent to 'superposition of possibilities of experiences'; and (3) thus the 'superposition of multiple possible experiences' in the mental aspect of elementary particles is valid concept in the dual-aspect view.

### 3.9. Bridge between the dual-mode-double-universe-thermofield-hologworld framework and the dual-aspect-dual-mode PE-SE framework

In general, there are two types of models for linking *structure, function, and experience*: standard representation theory (SRT) and dynamic system theory (DST); the latter is an anti-representational view. The PE-SE framework is closer to SRT and the *hologworld* framework [56, 58-68] seems to be closer to DST. However, all are based on the organism-environment interaction.<sup>2</sup> We discuss two types of bridges between these frameworks: (A) When we unpack the term 'interaction' we may find a bridge between them. One could ask where the interaction is. If the interaction is considered at neural-network level then we find a sort of bridge between them because the organism's cognition related feedback signals in neural-networks interact with environmental stimulus-dependent feed forward signals for both frameworks.

(B) A major difference is that *hologworld* framework rejects SEs and instead proposes 'our thrownness in a world of qualities', and subjectivity (intentionality) and *situatedness*<sup>w</sup> in us. A bridge may be found if we unpack the various terms. For example, consider 'looking at a red ball':

(I) In *hologworld* framework, the SE *redness* is eliminated, the quality red is the property of the ball (non-tilde mode, alter-universe), the subjectivity<sup>x</sup> (intentionality [91] = reference to a content, direction toward an object (real/fictitious), or directedness, and self but not the SEs of objects) and *situatedness* (being-in-the-world) are properties of brain (tilde mode, our-universe), and the 'experience' is denoted by the *between-two*: 'our thrownness in a world of qualities'. Furthermore, the brute fact in *hologworld* framework is: what makes the belonging-together of a particular *between-two* disclose a red tomato instead of a green one? This can be

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<sup>w</sup> Situatedness is a global attunement, *befindlichkeit* (German: Heidegger), affectedness, disposition, where-you're-at-ness, being disposed, disposedness, already-having-found-itself-there-ness, or state-of-mind. It might be approximated by logical rules but functions as a whole. Subjectivity is situatedness; "I" denotes situatedness (Metzinger's "no one" [118]). John Searle [157] calls situatedness as "background," for Husserl [89] it is "horizon," and for Heidegger it is "being-in-the-world" [83]. One might think of it as "conditions of satisfaction" where all the conditions are convolved, interpenetrated. It is what we bring to the intersection with the input flux -- we are situated by desires, affects, beliefs, thoughts, expectations, and so on; all these and more function as global constraints on the evolution of brain states. One might even think of it as a fluctuating "topography" of N-dimensional state space. Situatedness is not a feeling, nothing phenomenally experienced. Situatedness is not between-two but is one of the two. (Globus, personal communication).

<sup>x</sup> "Subjectivity refers to a subject's perspective, particularly feelings, beliefs, and desires. It is often used casually to refer to unjustified personal opinions, in contrast to knowledge and justified belief." (<http://en.wikipedia.org/wiki/Subjectivity>).

unpacked by assuming that object-qualities are also superposed in addition to SEs in the mental aspect of elementary particles in the PE-SE framework; a specific quality in a specific object is expressed via natural selection ('fittest survive') and adaptation principles of evolution, and sensorimotor tuning as elaborated in Section 3.5. It appears that subjectivity (intentionality) can be explained using 'restricted panpsychism' [58], which needs further investigation to address some of the six problems of panpsychism [193]. The belonging-together has three constraints (factors): (i) sensory input from external stimuli to receptors and its further processing that leads to feed forward signals in, for example, the Red-Green, Yellow-Blue, and luminance channels for trichromats but only the luminance channel for 'complete' achromats, (ii) intentional input (such as endogenously generated input, subjectivity or intentionality, and *situatedness*), and (iii) re-trace (such as cognition and attention related feedback signals). The subjectivity (intentionality) tunes the belonging-together of the *between-two* modes (tilde and nontilde modes). What belongs-together is sensory input and situatedness, and this match explicates world-thrownness. Which constraint on the belonging-together of the *between-two* is different between achromats and trichromats? That constraint is the processing of external sensory input to receptors, but this processing varies with subjects, i.e., it is 'subjective' in the *holoworld* framework. What about other two constraints? One could argue that second constraint, intentional input, is endogenously generated in the subject's brain, therefore, it could also vary with the subject because the brain and their activities could vary with subjects. The third constraint is cognition and attention related signals, again they are the properties of the subject's brain, therefore, it could also vary with the subject. Thus, all three constraints on the belonging-together of the *between-two* could be different between achromats and trichromats, and hence vary with subject; therefore, they are subjective, i.e., varies with subject. What is independent of subject? It is the external world, i.e., mind-independent reality (MIR: the world as it is, in-itself) that is brain-independent, but it is unknowable: "A thing can never come before us except in appearance" [102](p.286). One could argue that the MIR or "the existence of a world beyond experience can only be an inference, speculation, or article of faith."<sup>y</sup> Whatever is known always involves brain. Thus, our daily conventional reality is mind-dependent reality (MDR: the world as it appears to us). One could argue that the *between-two* is fully phenomenal -- world-like -- in the belonging-together of sensory input, intentional input (subjectivity) and re-traces. However, the 'world-like', the *phenomenal* or *access* awareness [13] of world is mind-dependent reality. Thus, one could argue that the *between-two* (that denotes 'experience' and, in my view, equivalent to SE in the PE-SE framework for bridging purpose) also depends on the subjects. That is why, one could argue that the *between-two* for achromats is black-white world and that for the trichromats is color-world. If MIR were disclosed during the match, then the *between-two* would be independent of subject, but this is not possible because MIR is unknowable. In *holoworld* framework, it seems that the match discloses MIR, but this is not the case unfortunately; otherwise, the disclosed world would be the same for both trichromats and achromats.

(II) In the PE-SE framework, an 'experience' is the property of the mental aspect of both long wavelength light reflected from the ball (tilde mode) and redness-related V4/V8/VO-neural-network (non-tilde mode) for trichromats; SE *redness* is selected during matching as discussed before, and the content of SE *redness* is the color red that is the property of ball. In this scenario, the relationship between experience, its subject, and its content [170] should be established<sup>z</sup>: here, (a) experience is the SE *redness* in the mental aspect of the structure

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<sup>y</sup> Adapted from <http://tech.groups.yahoo.com/group/jcs-online/message/6658>.

<sup>z</sup> According to Strawson [170], "Where there is experiential content, there is necessarily experiencing, and where there is experiencing, there is necessarily an experiencer – a subject of experience. This is the polarity that, so far, seems well expressed by ... [E = S:C] ... It simply states that an experience-occurrence is a subject-entertaining-a-content-occurrence ... [E = S = C] ... if two concrete particulars [S = C] can't exist apart, and are therefore at most conceptually distinct rather than really distinct, then they must be numerically identical ... [if S = object and C = property, then S = C has ] Class A category mistake ... Nagarjuna talks in the same vein of the complete codependence of things and their attributes [121] ... 'the properties are not in fact subordinated to it [object], but are the mode of existing of the object itself' [101] ... that in any and all cases of experience the process-stuff [P<sup>E</sup>] that is the experience just is the process-stuff [P<sup>S</sup>] that is the subject, which in turn just is the process-stuff [P<sup>C</sup>] that is the content. We cannot section P<sup>E</sup> into regions, a P<sup>S</sup> region and a P<sup>C</sup> region. In which case [the triple identity is] [E = S = C]" .

‘redness related V4/V8/VO-neural-network’ and its neural correlate is the material aspect of this structure and related activities for trichromats; (b) the subject of experience (self) is the mental aspect of ‘self related neural-network,’ such as cortical midline structures (CMS) [128] and its neural correlate is the material aspect of such structures and related activities; the subject may include (a) specifically when, for example, CMS is lesioned; and (c) the content of experience is the mental and material aspects of the stimulus (such as long wavelength reflecting surface of the object ball), which is represented in the feed forward retina-LGN-V1-V2 signals. The neural correlate of the content of experience is the material aspect of such structures and related activities. The external object (the red ball) has representation in the ‘redness related V4/V8/VO-neural-network’ that includes all activated areas when this stimulus is presented. Alternatively, one could argue for the triple identity experience (E) = subject of experience (S) = content of experience (C) [170]; for this further research is needed.

In both frameworks, the observer is the V4/V8/VO-neural-network (assuming bridge-A is accepted), the observed is the red ball, and the process of observation is information processing during matching process. The subjectivity and *situatedness* are the properties of brain in both frameworks. The main difference is that the SEs are eliminated from the subjects and instead whatever is ‘experienced’ is considered (a) as our thrownness in a world of qualities (such as the quality of red ball) or (b) simply as the qualities of objects in the *holoworld* framework. Whereas, in the PE-SE framework, whatever is ‘experienced’ (what it’s like!) is considered as the subject’s SE (and its content is the object). In other words, one can interpret: (a) object-quality (such as quality *red* of the object red-ball) as the content of experience, which may be the function of both material and mental aspects of object, i.e., the reification/manifestation of experience *redness* superposed in the mental aspect and that of the surface reflectance of the material aspect of the object; this content of experience can also be represented as feed forward signals as explained above in the PE-SE framework for bridging purpose; and (b) the ‘subjective *between-two*’ in the *holoworld* framework can be considered equivalent to ‘subjective *experience*’ in the PE-SE framework for bridging purpose. The *between-two* appears *subjective* because, for example, the *between-two* is the dark-gray ball for an achromat and the red ball for a trichromat for looking at the same long wavelength reflecting ball.

Furthermore, (i) some investigators (such as eliminativists [29, 36, 37, 62, 209]) eliminate experiences, (ii) some (such as reductionists/materialists [38, 40-42, 159]) put them in brain, (iii) some (such as externalists [87, 181-183]) outside of the brain, (iv) some (such as dual-aspect-dual-mode PE-SE framework [192]) in both but experiences in superposed form as discussed before, SEs occur in brain, and the spatiotemporal content of SEs are outside, (v) some (such as dualists [12, 48, 86, 142]) *nowhere*, and (vi) some (such as panpsychists [162, 163]) *everywhere*. One could ask: why such a large variation in this type of research? The concept of bridging various frameworks is based on the notion that if the two or more frameworks can explain the same truth, then there is a possibility to bridge them, in analogy to the bridge between wave and particle theories (Section 3.8). Further research is needed to address the bridging problem.

### 3.10. Binding problem

One could ask that how are the superposed experiences of large number of elemental *micro-minds* bound to result in one *macro-mind* or one stream of human awareness<sup>aa</sup> and what makes the neural network so special to have SEs? This type of binding problem is solved (a) by forming a neural-network such as the red-green V4/V8/VO-neural-network via the co-evolution and co-development of material and mental aspects and developmental sensorimotor tuning (*neural-Darwinism*) [40, 41] as discussed in [192] and (b) then by selecting a specific SE such as *redness* using the matching process as discussed in Section 2. In addition, (c) the network experiences the SE when *necessary* ingredients of awareness (such as wakefulness, attention, re-entry, memory and so on) are satisfied as discussed in [196]; re-entry also plays important role in the binding process [41, 82]. Moreover, every protein imbedded in nerve membrane plays a *functional* role including the topological or spatial distribution of both the proteins and the connectivity of neural networks. There is signaling going on

<sup>aa</sup> Here, the term ‘*mind*’ or ‘*awareness*’ refers to SE.

continuously via one or more of the five pathways (Sections 1, 3.3, and 3.8), but one could argue that it is difficult to decompose the *function* from large molecules such as GABA to elementary particles. However, it is not difficult to explain how *experiences* occur in neural-networks in the dual-aspect-dual-mode PE-SE framework: the SEs are in superposed and unexpressed form at elemental, atomic and molecular levels. In other words, inert matter, proteins, neurotransmitters and neuromodulators including all those levels which do not satisfy the *necessary* ingredients of SEs will not have SEs. It is only the neural-network level when these *necessary* factors/conditions of SEs are satisfied and when a specific SE (such as *redness*) is selected by the matching process then only a specific SE will occur in a specific neural network (such as *redness* will occur in the red-green V4-/V8/VO-neural-network). Even the retina is not privileged to have SEs because it does not satisfy the essential ingredients of awareness [196], although retina is essential for vision as discussed in Section 3.3. The retinal opponent and non-opponent networks (such as red-green and yellow-blue opponent cells and luminance non-opponent cells), however, will have higher specificity than cones and rods, which in turn will have higher specificity than molecules, atoms, and electrons.

The development of specificity of a system needs further elaboration. From strings or elementary particles to molecules, all experiences are superposed in their mental aspect in unexpressed form and hence they are non-specific to experiences. The specificity to experiences is generated by the formation of organs and related sensory systems —such as eyes and photoreceptors for visual system, ears and hair cells for auditory system, tongue and taste buds for gustatory system, nose and its receptors for olfactory system, and skin and its receptors for somatosensory system— and other systems —such as amygdala-neural-network for emotions [184], cortical mid line structures for *self* [128]. For example, visual system is specific to experiences related to vision only, and it is not sensitive to sound, taste, smell, touch, hot, cold, and pain. In other words, visual system will not lead to experiences related to sound, taste, smell, touch, hot, cold, and pain (here, we are not considering synesthesia though an argument for the specificity of its neural-network can be similarly made). It should be noted that the electrons, proteins, chemicals, molecules, neurotransmitters, neuromodulators, and so on could be same or similar in all systems, which are non-specific as all experiences are superposed in their mental aspect in unexpressed form. In other words, a specific sensory system has high specificity, even though its constituents are non-specific, via developmental *neural-Darwinism* and sensorimotor tuning. Without these developmental processes, the specificity of a neural-network cannot be achieved. For example, according to Sur et al. [174], “functional visual projections can be routed into nonvisual structures in higher mammals, suggesting that the modality of a sensory thalamic nucleus or cortical area may be specified by its inputs during development”. To elaborate further, each of the three psychophysical visual channels (Red-Green, Yellow-Blue, and achromatic/luminance channels) has higher specificity than photoreceptors. For example, the Red-Green channel and its neural correlates (Red-Green V4/V8/VO-neural-network) are specific to experiences between redness to greenness, i.e., just noticeable differences (JNDs) between redness and greenness, which are just a few in number such as redness, orangeness, orange-yellowness, yellowness, yellow-greenness, greenness and JNDs in-between. This channel will not lead to experiences such as blueness, painfulness, saltiness, and experiences related to sound, smell, touch, hot, cold, and so on. When long wavelength light is presented to the visual system, the Red-Green V4/V8/VO-neural-network enters into a specific state via matching and selection process; the related network is the redness-related V4/V8/VO-neural-network, which is specific to only one experience: the *redness*. If this network satisfies the necessary ingredients of consciousness [196], then it experiences redness, even though its constituents are less specific or non-specific. This is a neuroscience model with built-in superposed experiences, which bridges the gap between consciousness [193] and the neural-correlates of consciousness (NCC).

For hypothesis **H<sub>1</sub>**, how a specific SE arises in a neural-network is concisely described by steps (i)-(v) in Section 1. Furthermore, there are four factors that evolve from elemental level to neural-network level for the occurrence of a specific SE (such as *redness*): the number of superposed SEs, the specificity, the selection-matching process, and the *necessary* ingredients of SE. For example, (I) at elemental, atomic, and molecular levels, the number of superposed SEs in their respective mental aspects are very large because all or a large number of multiple possible experiences are superposed in unexpressed form. Therefore, the specificity to a specific SE is zero or very low at these levels. There is no selection and matching processes active and *necessary*

ingredients of SE are not satisfied. Therefore, systems at these levels do not have a specific experience. (II) At neural-network level, the number of superposed SEs in its mental aspect is very low because a few multiple possible experiences are superposed in unexpressed form. For example, there are a few ‘just noticeable differences’ (JND) from SEs *redness* to *greenness* in the red-green V4/V8/VO-neural-network. Therefore, its specificity to a specific SE is very high. When a long wavelength light is presented to the visual system, a specific SE such as *redness* is selected from this small set of embedded SEs in this network via matching process (Section 2). In quantum physics language, we say that multiple possible experiences are actualized by the quantum conjugate matching process and wavefunction collapse [80]. If the *necessary* ingredients of SE are satisfied, the specific SE *redness* is experienced by this neural-network that also includes the self-related areas (such as cortical midline structures) [128]. If the specificity does not reach to 100%, a specific SE will not occur. The specificity is partly related to threshold contrast. If the criterion level of the threshold contrast is 75% percent ‘seen’ [189], then the specificity of the related neural-network to a specific SE must have been 100% when ‘seen’ for 75% of the presentations of a stimulus at threshold contrast and below 100% when not ‘seen’ for 25% of the presentations of the stimulus. Furthermore, one can similarly fill in the details for all the remaining levels between the molecular-level to the neural-network-level by further research.

Other types of binding problems are discussed in [75], for example, how to bind (i) various aspects in one modality (such as visual shape, color and motion), (ii) different modalities (such as sight and sound), (iii) temporal synchronous events sensed asynchronously (such as sight and touch) and (iv) egocentric (personal point of view), enteroceptive (bodily sensation), and allocentric (simulated external world) spaces into single unified moment of awareness [70]. “Visual processing acts as a prism, splitting visual information from the retinal image into separately processed features such as color, shape, and orientation. Binding refers to the set of cognitive and neural mechanisms that re-integrate these features to create a holistic representation of the objects in the visual field. The binding problem in vision refers to how this integration is achieved” [19]. The three major types of binding, namely, the binding of features within objects, the relational binding among objects, and the binding between temporally related events, are discussed in [19]. The issue of various binding problems is one of the most interesting problems in neuroscience that needs to be addressed, but it is beyond the scope of current article.

#### 4. Conclusion and future direction

In previous article [192], the dual aspect of the PE-SE framework was elaborated and the dual-mode was implicit. In this article, the dual-mode from the Vitiello and colleagues’ framework [1-3, 201-204] and the dual-mode-double-universe-thermofield-*holoworld* framework [56, 58-68] is utilized in the PE-SE framework (without decreasing the degree of parsimony), and the matching and selection mechanisms are detailed.

In the PE-SE framework, the link between *structure* and *function* is addressed by the quantum conjugate matching and/or classical matching between the material-aspect (neural activities) of input/stimulus dependent feed forward neural activities (tilde mode) and that of the feedback cognition related neural activities (non-tilde mode). The link between *structure-function* and the *experience* is addressed by (i) the quantum conjugate matching and/or classical matching between the mental aspect (*experiences* (or PEs/SEs)) of input feed forward signals (tilde mode) and that of the feedback cognition related signals (non-tilde mode) and (ii) the selection mechanism. For example, a SE could be *redness*, the related *function* is the detection or discrimination of red color stimulus, and the related *structure* is the Red-Green V4/V8/VO neural-network.

When the conjugate match is made between the two modes, *the world-presence (Now)* is disclosed with its content: (a) the SE of subject (self), (b) the SE of objects, and (c) the content of SEs.

Furthermore, the specific SEs are selected from the *a priori* possibilities by a matching process. The *reservoir* for selection is superposed *a priori* experiences (PEs/SEs) on the mental aspect side. The selection rules are embedded in the feed forward signals which are dependent on external sensory input (and/or endogenously generated input) to the neural networks. All entities including sensory input have a mental aspect. Selection is by matching between two modes: (i) the experiential aspect of input, which is selecting, and (ii) the

experiential aspect of neural networks (feedback signals), which is selected. This process of selection by matching takes place at both classical and quantum levels. The matching is for both material aspect (to link *structure* and *function*) and mental aspect (to link *experience* with *structure-function*).

There are five major pathways of information transmission in the brain: (i) classical axonal-dendritic neural pathway, (ii) quantum dendritic-dendritic pathway, (iii) astro-glial-neuronal pathway, (iv) the pathway for extracellular volume transmission, and (v) soliton propagation. The *quantum conjugate matching and selection* for the quantum dendritic-dendritic pathway and classical *matching and selection* mechanisms for the remaining non-quantum pathways lead to the realization of a specific SE in the mental aspect of a specific neural-network. Thus, all three entities (*structure*, *function*, and *experience*) can be linked along all five pathways of information transmission in the brain.

All metaphysical views have fundamental assumptions that still need to be addressed, for example, the PE-SE framework assumes dual-aspect entities, materialism/emergentalism assumes that SE emerges in neural-network, dualism assumes substance-dualism, and *holoworld* framework assumes its own 'brute fact', and so on. However, so far, the dual-aspect-dual-mode PE-SE framework is the most optimum framework because it is parsimoniously optimized and the problems of other frameworks are addressed. It is argued that (i) the superposition of multiple possible experiences is justified on the ground that the mental aspect of wave is assumed to be a wave-like and is a function of experiences (a consequence of dual-aspect view), and there are multiple coexisting possibilities/potentialities of experiences, which are actualized when neural-networks are formed via *neural Darwinism*, and a specific SE is selected by a *matching* process, (ii) the *neural Darwinism*, the matching and selection mechanisms, and the *necessary* ingredients of awareness such as re-entry bind elemental *micro-minds* into one *macro-mind* (*mind* here refers to SE), and (iii) the 'brute fact' of dual-aspect (mental and material aspects) is justified on the ground that SEs are fundamental, irreducible, and inherent, for which further research is needed.

The dual-aspect-dual-mode PE-SE framework suggests that a specific SE (such as redness) cannot be experienced until related neural-network (such as Red-Green color opponent V4/V8/VO neural-network for redness to greenness) is formed, functionally active, and the *necessary* ingredients of SEs (such as wakefulness, attention, re-entry, working memory, stimulus at or above threshold level, and neural-network-PEs) are satisfied. Therefore, it would be interesting to investigate the specific neural-networks for specific SEs. This can be done by experimental techniques such as fMRI [128] and related functional connectivity modeling [52] and perhaps simulation method [82]. Thus, the dual-aspect-dual-mode PE-SE framework has a good contribution and touches 'bottom' because we have worked through double aspect view at a level which has not been previously elaborated.

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The author declares that he has no competing financial interests.

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<sup>1</sup> The term “time-reversed mirror image” should be replaced by less confusing term ‘entropy-reversed representation’ because brain does not have a mirror image of environment rather brain has many topographic representations in coded form in various brain-areas. In addition, (positive) ‘time’ should be replaced with (positive) entropy and ‘negative time’ with ‘negative entropy’.

Furthermore, the use of the term ‘time’ is elaborated in [1] as, “the system evolves in time by running over unitarily inequivalent representations. The generator of time evolution is related to the entropy operator. [...] the entropy for both A and B increases as the system evolves in time. Moreover, the difference  $S_{A(\theta)} - S_{B(\theta)}$  is constant in time [...] Since the B-particles are the holes for the A-particles,  $S_{A(\theta)} - S_{B(\theta)}$  is in fact the (conserved) entropy for the closed system. [...] The generator of time evolution is related to the entropy operator, which indeed reflects the irreversibility in time evolution

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(the arrow of time).” In addition, “Non-unitary time evolution is described as a trajectory in the space of the representations. The generator of time evolution is related to the entropy operator. The thermodynamic arrow of time is shown to point in the same direction of the cosmological arrow of time. [...] We find that, also consistently with Penrose and Hawking discussions, our quantum formalism implies that the thermodynamic arrow of time (the direction of time in which entropy increases) is in accordance with the cosmological arrow of time (the direction of time in which the Universe expands)” [2]. This seems to mean that Vitiello’s time is physical time as in  $(x, y, z, t)$  and is related to entropy.

The term ‘double Universe’ is elaborated in [2] as, “An essential ingredient in the canonical formalism for quantum dissipation is the doubling of the system degrees of freedom [...] Such a doubling allows to take into account not only the system under consideration but also the thermal bath (or environment) in which it is embedded. [...] The doubling of the degrees of freedom [DF] reflects itself on the metric structure in such a way we have the doubling of the  $h_{\mu\nu}$  partial waves. In this sense we speak of “double Universe”. [...] The physical interpretation is that the doubled degrees of freedom introduce the *complement* to the inflating system, thus *closing* it, as required by the canonical quantization procedure. This points to the root of the mathematical difficulty in the canonical quantization of inflating evolution [...] The physical reason to double the degrees of freedom of the dissipative (damped) system relies in the fact that one must work with closed systems as required by the canonical quantization formalism. [...] “deflating” [contracting] Universe, complementary to the inflating one. [...] From the thermal properties perspective the physical interpretation of the doubled degrees of freedom is the one of the thermal bath degrees of freedom; from the point of view of the vacuum structure the one of *holes* of the relic gravitons; from [from] the hamiltonian formalism point of view the one of the *complement* to the dissipating (inflating) system.” Since dissipation is involved in the inflation model of universe, the DF is doubled to close the open system for not violating the law of conservation of energy. This leads to the mathematical construct of ‘Double universe’ (inflating universe and deflating/contracting universe) in loop quantum gravity. It is a theoretical (thermodynamical) requirement. Bridging the two universes may solve the Big-Bang’s singularity problem [3], which is solved in string theory in a simple way by assuming string in place of point. For the dual-aspect-dual-mode PE-SE framework, the doubling of the degrees of freedom is the degree of freedom of the brain *plus* the degrees of freedom of the brain’s environment that act as a thermal bath for the brain.

<sup>2</sup> The DST-related situated cognition and embodied cognition and SRT-related traditional cognition need further elaboration. "Thinking is situated in physical and social contexts. Cognition, including thinking, knowing, and learning, can be considered as a relation involving an agent in a situation, rather than as an activity in an individual's mind" ([71], p.135). "The mind must be understood in the context of its relationship to a physical body that interacts with the world" ([210], p.625). "Situated cognition acknowledges the existence of an agent/environment interaction, where the agent acts on information that is available. Therefore, direct perception keeps the agent in touch with the world, and perception and action interact directly ‘on the fly.’ [...] The situated cognition perspective focused on "perception-action instead of memory and retrieval [...] Perception and action were co-determined by the effectivities [the abilities of the agent that determined what the agent could do, and consequently, the interaction that could take place] and affordances [properties in the environment that presented possibilities for action and were available for an agent to perceive directly and act upon], which acted 'in the moment' together [...] The traditional cognition approach assumes that perception and motor systems are merely peripheral input and output devices [...] However, embodied cognition posits that the mind and body interact ‘on the fly’ as a single entity [the nature of the human mind (such as ideas, thoughts, concepts and categories) is largely determined by the form or aspect of the human body (such as perceptual system, intuitions, activities and interactions with our environment)]. An example of embodied cognition is seen in the area of robotics, where movements are not based on internal representations, rather, they are based on the robot’s direct and immediate interaction with its environment [210]. " ([http://en.wikipedia.org/wiki/Situated\\_cognition](http://en.wikipedia.org/wiki/Situated_cognition)).