The physical bases to consciousness: Implications of convergent quantifications

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Abstract

When the conceptual and historical limitations of the label "consciousness" are accommodated the physical bases to these phenomena become apparent. Different classes of consciousness coupled to the differences in hemispheric functions are predictable and can be simulated experimentally. Fundamental space-time constants of the cell membrane and the increments of energies associated with dynamics of the action potential are reflected within the surface activity of the total aggregate of cerebral neurons correlated with states of consciousness. The ubiquitous presence of ~10^{-20} J as a fundamental quantum and the congruence of the numerical energy densities during consciousness with the average universal values suggest that the apparent dualisms of brain-mind and matter-energy are illusions that reflect degrees of quantification rather than quality. The quantitative similarities of gravitational-, electromagnetic-, photon (visible light) - and cognition-based energies within the mass and volume occupied by the human cerebrum could accommodate many of the classical theories of consciousness. That the induced magnetic moment from change of angular velocity in an electron from the cerebrum's magnetic field immersed in galactic-level magnetic fields could be protracted for the age of the universe would meet the criteria of temporal persistence for an essential consciousness. Predictions from purely physical bases for consciousness with respect to non-local excess correlations ("entanglement"), representation of cerebral information within space, and the transposition of photon energy from recoil values within the brain could generate novel experimental approaches to the class of phenomena historically described as "consciousness".

Introduction

There is a fundamental assumption within modern Neuroscience: all experience is a consequence of the human brain's structure and its correlative activity. The relationship between experience and brain has been described as dualistic, parallel or reducible. Either from the perspective of extreme idealism that assumes all matter is a consequence of thought or extreme materialism that assumes all thought is determined by matter the reference has been and must be consciousness. This millennial deliberation of a thesis and an antithesis concerning "spirit" and "substance" is still manifested as the contemporary apparent dualism between matter and energy. The conflict converges within the concept of consciousness [1].

If we assume the trend in the history of Science reflects a temporal progression in knowledge, that does not require a teleological process, then the final revelation must involve the measurement process itself: human consciousness and all of its ramifications. There has been a gradual shift away from egocentric interpretations. The earth is no longer the center of the Universe, human beings are no longer the special creation within the Animal Kingdom, and cognitive processes are neither rationale nor independent of brain function. Consciousness may not be unique or special.

All of these shifts in perspective emerged following the systematic quantification of the associated physical processes. They included the precise, multiple measurements of the classification of the stars, the exhaustive taxonomy of species, and the myriad of neuroimaging profiles concurrent with specific cognitive processes. In this brief review, the extensions of the possible quantifications of consciousness, which in many respects is "the final frontier," are developed.We intend no disrespect by not including all of the nuances of the philosophical and theoretical variations to explain and to accommodate "consciousness". Our emphasis is to pursue the validity of the concept through discerning convergence of quantifications from different levels of discourse and interdisciplinary integration.

The limitations of the label

There are three caveats for any examination of "consciousness". The first is that the concept may be analogous to *phlogiston*. Before the modern monad (atomic)-based paradigm dominated western approaches to understanding Nature there was a presumption that matter was composed of air, earth, fire and water. Phlogiston was a special combination that allowed "things to burn". However once modern chemistry dominated human percepts an alternative explanation (oxidation) emerged based upon its processes. In other words phlogiston was an artifact of the conceptual system. We should at least consider the possibility that consciousness is Neuroscience's equivalent of phlogiston.

The second caution is the illusion that derives from the over-inclusion of different and perhaps unrelated processes. One historical example was the term *vapours* or its variants that was employed

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during the 19th century to describe what we now would differentiate as pneumonia, emphysema, lung carcinoma, tuberculosis, influenza, and a severe common cold. If Alexander Fleming had developed penicillin during that century and administered it to patients who were described as exhibiting "vapours", only a small fraction (primarily those who now would be diagnosed with pneumonia) would have been positively affected. The necessary contemporary conclusion would be that penicillin is not useful because it did not cure "all vapours". The term consciousness is an over-inclusive label.

The third and most challenging technical conceptual limitation to any study of consciousness is we are "measuring the measurer".Because there must be a reference by which to measure there will always be one process that cannot be measured directly. This is the essence of Gödel's incompleteness theorem: "there is an unproved statement within every sufficient complicated logical system".Consequently, regardless of our sophisticated tools, which are extensions of our senses, the ultimate nature of consciousness within the context of contemporary brain structure and activity will only reach an asymptote rather than accommodate one-hundred percent of the variance.

Consciousness, self, the sensed presence and hemisphericity

If structure dictates function then microstructure should dictate microfunction. Cerebral organizations with slightly different structures or configurations should be associated with comparably different characteristics, including the manifestations of "consciousness" if it is indeed coupled to brain structure. Of the approximately 176 gyri and sulci that are discernable upon the normal human cerebral surface, only four sulci are considered similar in location and overall extent in the left and right hemispheres [2].

The general consensus is the left hemisphere is structured for "serial" processing while the right hemisphere is organized for "parallel" processing. The two processes are primarily compartmentalized when one realizes that about 1% of the axons in each hemisphere are directly connected through the corpus callosum to neurons in the other hemisphere. Comparable interhemispheric connections are apparent for the anterior commissure, the primary intercalating pathway for subcortical structures with the ventral temporal hemispheres.This probabilistic "sequestering" of process within two adjacent hemispheric volumes with slightly different properties predicts sensitivity to different external stimuli. For example the activity within the right hemisphere is significantly more affected by ambient, global geomagnetic activity within which every normal brain is immersed [3] than is activity within the left hemisphere [4].

Experimentalists and clinicians have appreciated the intertwined relationships between classical left hemispheric functions, such as language, and the sense of self [5] and "consciousness". Late 19th century cultural scientists, such as the sociologist Emile Durkheim, appreciated that abrupt changes in language and culture during isolated immigration could "disorganize" the self or even contribute to consciousness-induced self-annihilation (suicide). "Self" represents the *conscious experience* of an integrated perspective that is defined by the experiment as unique and is more or less persistent over the approximately two or three Giga seconds of an individual human being's existence.

We have suggested for more than three decades that if the left hemisphere is associated with the sense of "self" due to intrinsic linguistic processes, then there must be an equivalent experience associated with comparable patterns of right hemispheric stimulation [6,7]. Historically and cross-culturally this "experience" has been the sensation of "the other" or "the sensed presence" of a Sentient Being that has been attributed to spirits, gods or angels. The labels attributed to these experiences and consequently the images associated with those labels when episodic (and more precisely autobiographical) memory is engaged, would be derived from the culture. Hence the rich varieties of descriptions do not reflect different hemispheric processes but instead the myriad of different linguistic labels and corresponding learned images.

From this perspective the sense of a presence "of another" is the (usually transient) left hemispheric "awareness" of the right hemispheric equivalent of the "sense of self".This "parasitic consciousness" was described by Huglings Jackson in the late 19th century in populations who displayed what we now label complex partial epilepsy with foci within the (usually right) temporal lobe. The subsequent one hundred years of surgical stimulation within the temporal lobes [8] and more recents LORETA (Low Resolution Electromagnetic Tomography) technology have supported the right hemispheric characteristics of these experiences [9].

Physiologically-patterned weak magnetic fields applied with slightly greater intensity over the right hemisphere compared to the left increase the probability that a person will report a "sensed presence" when sitting blindfolded within a quiet and very dark chamber. St-Pierre and Persinger [10] reviewed the 19 different experiments designed to isolate the specificity of the electromagnetic patterns required to evoke the sensed presence in normal people. They found that psychometric indicators of "creativity" or "temporal lobe sensitivity", which is moderately correlated with alpha power over the temporal regions, facilitated the interaction with only specific patterns of applied magnetic fields.Psychometric and clinical measures of suggestibility did not contribute to the field effects.

From the perspective of a physical explanation for consciousness one would expect that the remarkably different microstructure and general organization of the left and right hemispheres should produce qualitatively different forms of "consciousness" that reflected the functions within that hemisphere. The sensed presence is experienced with greater affective components with the implicit sense of spatial pervasiveness (everywhere) and temporal extension beyond the limits of the self.Considering the structural differences between the amygdala functions and interhemispheric cohesion between the brains of adult men and women, gender differences for the experiential characteristics of the experimentally-induced sensed presence revealed by factor analyses were not unexpected [11].

The modification of consciousness and the elicitation of its "altered forms", such as the "sensed presence", by external application of weak, physiologically-patterned magnetic fields across the temporal lobes may be considered a compelling argument for the physical bases for consciousness. For our experiments we employ average field strengths of ~30 mG or $3 \cdot 10^{-6}$ T. The point duration for each of the discrete voltages (that when presented sequentially produce the physiologically-patterned, frequency-modulated field) is optimal at 3 ms. Hence a pattern composed of 849 integer values (each between 0 and 257), such as the one employed to affect cells and global cerebral function, would be repeated every ~2.55 s for 30 min (The slight discrepancy between the product of 849 and 3 ms and observed recordings is due to the contribution from port times of the computer). The median latency for

the occurrence of the "sensed presences" is approximately 15 min or about 1 ksec.

From the perspective of classical physics, the induced electric field is:

$$V = \delta B \cdot (\delta t)^{-1} \cdot A$$

where B is the average change in field strength per unit time (t) over an area (A) in m^2. Assuming $3 \cdot 10^{-6}$ T, the average rate of change for these complex fields to be around 10 Hz, and the cross-sectional area of the array of solenoids to be $\sim 10^{-3}$ m^2, the resulting electric field within the cerebral space would be between $\sim 10^{-7}$ V and 10^{-8} V. Assuming 2 Ω m for interstitial (cell) fluid, the induced current would be between $\sim 10^{-8}$ to $\sim 10^{-9}$ A. We appreciate the multiple assumptions and the wide range of parameters. They are presented here as values to demonstrate the concept rather than technical precision [12]. What is also clear is that these fields penetrate skull-like and physiological ionic fluids with minimal attenuation [13].

Application of the Biot-Savart law estimates the strength of the magnetic field perpendicular to the direction of the (induced) current. It is:

$$B = \mu I (4\pi r^2)^{-1},$$

where μ is magnetic permeability ($\sim 1.26 \cdot 10^{-6}$ N·A^{-2}), I is current, and r is the distance from the current line. Assuming distances that might be encountered during dynamic changes over the cerebral surface, in the order of 10^{-3} m^2, this secondary magnetic field strength would be $\sim 10^{-12}$ T. Consequently one testable hypothesis is that the subjective experiences described as consciousness are weak volumetric intracerebral time-varying magnetic fields [14] whose patterns change in a manner similar to a tensor. "Interference" patterns induced by *the secondary-magnetic field* from the experimentally applied sources modulate these fields and hence alter consciousness. We have suggested that the latency to evoke the altered experiences reflects the time required for sufficient coherence to occur between a critical mass of neurons that allows the experience of "the consciousness". Rouleau and Dotta [15] have estimated this number should be between 10^6 and 10^7 neurons.

Characteristics of the physical bases of consciousness

The physical bases of consciousness should involve a quantitative similarity between the conventional electromagnetic units of the brain, the neuron, and the properties displayed by the whole system, in this instance the cerebral cortices. There are two compelling elementary examples. The first is the quantitative solution for the *time constant*:

$$\tau = R_m C_m,$$

where R_m (is membrane resistance) and C_m (is membrane capacitance). Because a typical value for the former is $R_m \sim 10^5$ Ω·cm^2 and the latter is $C_m \sim 10^{-6}$ F·cm^{-2} the intrinsic "average" value for a passive neuronal cell membranes is $\tau \sim 100$ msec or 10 Hz which is the most prominent power peak within the quantitative electroencephalographic measurements of the cerebral cortices.

This is the average time (~ 100 ms) for both the duration of a percept and microstates [16] which are transcerebral electrocortical patterns. They exhibit rapid reconfigurations and accommodate the features of "a binding factor" [17]. Of course there may be more than one [18] temporal binding factor sequestered as recondite higher order derivatives within the first order fluctuations. If there were transient shifts in R_m and C_m such that the $R_m = 10^3 \Omega$·cm^2 and $C_m = 0.1$ μF·cm^{-2} the value would be within the range of the peak of an action potential as

suggested by Lindsay and Rosenberg [19].

The second component is the *space constant*. The classic definition is:

$$\lambda = 1/2 \sqrt{[(d \cdot R_m) \cdot R_i^{-1}]},$$

where d is the diameter of the axon and R_i is the resistance of the axoplasm. Assuming a typical diameter of 1 μm for the intracerebral axon, $10^5 \Omega$·cm^2 for membrane resistance and 50 Ω·cm for the much more conductive axoplasm, the distance where the applied voltage decreases to 63% of that value is about $\lambda = 2$ mm. This value is similar to that estimated by Lindsay and Rosenberg [19]. Considering the ambiguous functional relevance of 63% and the coefficient this "distance" could extend to $\lambda = 3$ to 4 mm.

This length is within the range of thickness of the cerebral cortices. Crosby *et al.* [20] indicated that the average cortical depth for the human brain was 2.5 mm (range 1.5 to 4.5 mm). One of the most conspicuous features of the mammalian cerebral cortices is that the thickness has remained relatively stable over long evolutionary periods [21] although the area has increased. The "constancy" of cortical depth and the temporal increment of flux may have been constrained by the basic parameters of the membrane's time and space constants. "As a result the quality of information processing and consciousness may not have changed but their magnitudes may have been enhanced significantly" [22].

Physical bases to consciousness also assume that equivalence of energy and matter exists within the space occupied by the human cerebrum like any other increment of space within the universe [23,24]. The only potential uniqueness or difference would occur within the microstructure which we presently label as patterns of synapses and spines (average volume of a spine head is $\sim .05 \cdot 10^{-18}$ m^3, Koch *et al.* [25]) on dendrites and configurations of aggregates of axons and soma. Whether or not this structure is qualitatively different from any other increment of non-cerebral or extracerebral space is not essential. It may not be spurious that the estimated numbers of synapses that range from $\sim 10^{13}$ [26] to 10^{14} [27] within the human cerebral cortices is the same order of magnitude as the numbers of "energetic units" derived from composites or "quantum" of $\sim 10^{-20}$ J [28]. That calculation employed original models published in the early 20th century [29].

The space occupied by brain would be subject to the complex possibilities of the multidimensional spaces of Kaluza-Klein as well as the potential energy contained within the structure of space. Matter, defined as protons and electrons, occupy spaces of $\sim 10^{-15}$ m. Between this level of discourse and the smallest conceptual increment of space, Planck's Length ($\sim 10^{-35}$ m), there are inordinate degrees of freedom whose structures could contain latent energy [30].

The boundary of "the smallest space" which has been considered Planck's Length ($1.62 \cdot 10^{-35}$ m), includes the "virtual particles" of the zero point potential of vacuum energies. They are functionally a modern equivalent of the 19th century concept of "ether" or universal medium. These virtual particles exhibit zero point fluctuations or *Zwitterbewegung* [31] which endow the property of "process" or a change as a function of time. Within these point fields, a changing electromagnetic boundary has the capacity to transform virtual particles, through Casimir processes, to "real" particles [32]. Real particles are protons and electrons with the capacity to mediate local causality. Virtual particles would have the capacity to mediate "non-local" causality.

Aggregates of protons and electrons form elements which form

molecules which form organelles which form cells which define the human brain.As assumed by Leibnitz' monads or Democritus' "atoms" there are no distinguishable differences between one proton and any other proton. Any given electron is not any different than any other electron. Because a proton's mass is $1.6 \cdot 10^{-27}$ kg a human cerebrum with a mass of 1.35 kg would contain about 10^{27} proton mass equivalents.

The underappreciated and prescient Sir Arthur Eddington [33] during the late 19th and early 20th century derived a quantitative solution that the boundary for numbers of "units" within the universe [34] would be $\sim 10^{79}$. When multiplied by the mass of a proton the universe would exhibit a mass of $\sim 10^{52}$ kg which is the same order of magnitude estimated empirically from stellar masses and by the employment of universal constants [35]. The energy equivalence of that mass is $\sim 10^{69}$ Joules which is a value that is represented in the Cosmological Constant and implicitly in most theories of physical cosmology [36].

Is there a basic quantity of energy for consciousness?

Niels Bohr [37], one of the perspicacious originators of quantum theory, suggested that the experiences of "thinking" and consciousness could involve or actually be patterns of energy that were within the increments of quanta. They are primarily the discrete energies (and corresponding wavelengths or frequencies) of photons associated with the spatial shifts of electrons within specific distances ("electron shells") form a nucleus. His predictions may be accurate.

More than 40 years ago Fong [38] and Wei [39] had shown that the effects of a single action potential with a shift of 120 mV ($1.2 \cdot 10^{-1}$ V) upon a unit charge ($1.6 \cdot 10^{-19}$ A·s) resulted in an energy that is $\sim 2 \cdot 10^{-20}$ J. This is within the same order of magnitude and duration that is required to stack a base nucleotide on a RNA molecule during its synthesis. The obvious implication that "thinking" and consciousness, which we assume are strongly correlated if not caused by the pattern of action potentials, could affect the endogenous process of stacking of base pairs and hence the specific protein that is ultimately synthesized within the brain has not been appreciated by many contemporary neuroscientists.

The ubiquitous presence of 10^{-20} J within biophysical and biochemical processes involved with cell plasma membranes has been described [40]. This quantum of energy also: 1) emerges from the force between the thin shell of potassium ions that is classically assumed to be the primary source of the resting potential, 2) is associated with the "hinge" motion subsequent to sequestering glutamate, 3) constitutes the linear space equivalent of the energy associated with cohesive forces between cell membranes, and, 4) represents the intrinsic energy associated with a single post-synaptic potential with a typical current dipole moment.In fact when the energy derived from glucose metabolism within the volume of the thin shell that defines the plasma cell membrane is calculated, the numbers of 10^{-20} J units would be equivalent to the energy associated with the numbers of charges ($\sim 10^6$ ions) that create the resting membrane potential.

The relationship of this increment to consciousness is more salient when the stacking latencies for a base nucleotide on a fork during DNA replication are considered. This duration is about 20 to 25 ms, or,is the "40 Hz" or gamma activity band [41] that is now considered by many neuroscientists as the primary indicator (and for some definition) of consciousness. The cohesive source of the integrated 20 to 25 ms increments over large areas of the cortical manifold is not constant but undergoes recursive rostral-to-caudal "recreations" as coherent waves or phase-modulations with these latencies [42,43]. McFadden's [14]

model indicates how synchronous firing of cortical neurons affects the brain's electromagnetic field and hence consciousness.

These empirical manifestations of the "re-entrant processes" (effectively second derivatives, i.e., rates of rates of change) described by Edelman [44] and Sommerhoff [45], are consistent with Nunez' [46] precocious treatise on the physics of the neocortex where bulk velocities of ~ 4.5 m·s^{-1} moving along ~ 11 cm functional linear distance (the cube root of the typical cerebral volume is ~ 11 cm), is ~ 40 Hz. The intrinsic resonance within this functional sphere with a perimeter of 0.6 to 0.7 m would be within the theta (4 to 8 Hz) range. The superimposition of "40 Hz" ripples upon theta bursts between the hippocampus and cerebral cortices [47,48] has been considered one of the essential configurations for the intercalation of consciousness and memory [49]. In fact Pribram and Meade [50] suggest that awareness of conscious experience *is* the interlude between the representation of sensory information patterns and the matching to the previous representations of that pattern (memory).

There is quantitative support for the relevance of 10^{-20} J to consciousness. Recently, on the bases of the physical properties of global QEEG data applied to other physical parameters [51], we found that one median intensity of the magnetic field associated with "consciousness" is $\sim 3 \cdot 10^{-12}$ T or about 3 pT. Because the magnetic energy within a volume can be estimated by E=$B^2 \cdot (2 \cdot 4\pi \cdot 10^{-7}$ N·A$^{-2})^{-1} \cdot$m^3, the solution for an intrinsic magnetic field (B) of this strength within ~ 1350 cm^3 would be $2 \cdot 10^{-21}$ J. Fluctuating around 10 Hz (s^{-1}) this would be about 10^{-20} J per s. Here we are referring to the strength of the global magnetic field within the cerebral volume. Local strengths near axons could be more intense [52].

Most phenomena within a level of discourse exist within a narrow range of amplitudes or energies within which the information is maintained or propagated. Applications of less intense or more intense energies result in no phenomena. The classic example is vision where frequencies faster than the ~ 400 nm wavelengths or frequencies slower than the ~ 800 nm wavelengths are not detected as light. The threshold for human hearing is about 20 μN·m^{-2} or 20 μPa. On the other hand barometric pressure is about 100 kPa, a magnitude difference of 10^{10}. We hear human whispers and usually understand them; most people do not "hear" barometric pressure.

Consequently the concern that the earth's magnetic field, in the order of $5 \cdot 10^{-5}$ T, would mask the likely "cerebromagnetic" correlate of consciousness within the 10^{-12} T range may not be valid. There are multiple natural phenomena generated within the earth-ionosphere wave guide that contain complex information which is quite resilient to even massive geomagnetic storms. These Schumann Resonance fields are in the order of 10^{-12} T and a few tens of mV per meter.In other words the average magnetic and electric field strengths within the harmonics of ~ 8 Hz, 14 Hz, and potentially 20 Hz, and 26 Hz peaks are within the same order of magnitude as those within the cerebral volume of the human brain. Recently Saroka and Persinger [53] demonstrated that the Schumann Resonance frequencies within the QEEG data of dozens of subjects were correlated with those generated within the earth-ionospheric waveguide. The power densities of both were coherent in real time. The duration of these intermittent coherences of power within the first three harmonics was the time required for a single microstate, that is, in the range of 100 to 300 ms.

The quantity of energy 10^{-20} J has direct application to the neuroquantum approaches to consciousness [12,54]. The most popular is the "collapse of the wave function" [55] as cogently articulated by

Hameroff and Penrose [56]. Their recent articulate article entitled "Consciousness in the universe: a review of the 'ORCH OR' theory" reviews the essential concepts. The dichotomy of the existence of the electron as a particle or a wave within space is reflected by its classical width, of about $2 \cdot 10^{-15}$ m and its Compton wavelength, 10^{-12} m, derived from quantum concepts. Although there are several interpretations for this discrepancy, what is important here is that the discrepancy in length according to the Lorentz contraction requires a specific discrepancy between the speed of light ($3 \cdot 10^8$ m·s^{-1}) and some very negligible value less than that velocity.

The difference in energy equivalence for the electron at the velocities that would accommodate the Lorentz contraction is in the order of 10^{-20} J. This could suggest that the increment of energy required for the "collapse of the wave function" is congruent with the quantum increment associated with a single action potential. By extension, millions of action potentials would affect millions of these functions. That the action potentials from only *one* neuron could affect the global state of the entire cerebral cortices has been reported by Li *et al.* [57]. Energies in the order of a few increments of 10^{-20} J have been shown experimentally to alter the probability of an overt response [58].

Mind-body dualism as matter *vs.* energy

The arbitrary dichotomy between functional and organic diseases during the early 20th century (an implicit extension of mind-body dualism) was in large part due to the absence of the concept and measurement of quantum levels of energy. The properties of matter, such as molecules, are determined by their spatial patterns while the properties of energy, such as electromagnetic fields, are determined by their temporal configurations. This reflects the differences between force and energy. Dropping a 0.5 gm candy from 0.5 m onto a table produces in the order of a milliNewton of force and when released over a millimeter of space produces an energy (microJoules) that is barely detectable on the hand. However if this energy was applied in the visible wavelength to dark adapted eyes (~10^{-17} J) it would be sufficient to induce a light sensation within every normal human eye on the planet [59].

If we assume there are about 20 billion neurons [60] within the human cerebral cortices and each neuron discharges, on average, around 10 Hz, the total energy per s for the 10^{-20} J associated with each action potential would be ~10^{-9} J·s^{-1} (Watts). In comparison, the energy involved with glucose metabolism from the cerebrum is in the order of 20 Watts or J·s^{-1}. The discrepancy between the energy associated with the neuronal activity coupled with consciousness (a nanoJoule) and the energy required to maintain the biochemical and cellular "machinery" of the brain is a factor of more than a billion.

From the perspective of quantitative neuroscience the difference between the apparently "nonphysical" features of "mind" or "spirit" and the "physical" features of "matter" or "body" is simply *the magnitude of the energies*. This relationship does not eliminate a vector property whereby they display different "directions". The critical feature is there is no qualitative difference. A similar approach has been developed by Fingelkurts *et al.* [61]. To ignore this challenge would be to repudiate the fundamental question coupled with the ramifications of considering the physical etiologies for the phenomena of consciousness.

In this context "spirit" does not necessarily include theological associations but designates the long history of different cultures' attempts to understand forces or energies for which only the effects could be perceived. Variants of *animus cedere*, the ancient Latin idiom

for death or "dissolution of consciousness", means "to escape in spirit". Some Ancient Greeks assumed that "thought" and "consciousness" moved as "spirits" through tubes. In some respects this is conceptually very similar to our current description of the electromagnetic components of an action potential moving along the axon barrel. The difference is the capacity for quantification.

Recently Dotta and his colleagues [62,63], pursuing the hypothesis by Bokkon [64] and Bokkon *et al.* [65] that "thought" and "consciousness" are actually fields of photons within the cerebral volume, have shown that specific types of imagery are associated with increases in photon emissions from the cerebrum. By employing appropriate arrangement of photomultiplier devices while subjects sat in very dark rooms they found that voluntary elicitation of imagery was coupled with changes of $0.5 \cdot 10^{-11}$ W·m^{-2} in photon emissions from the right hemisphere. The quantitative shifts in radiant flux densities were strongly (0.90) correlated with quantitative shifts (μV^2·Hz^{-1}) in QEEG measures over the left prefrontal region [66].

This coupling, superficially at least, might reflect a causal connection between intention (left prefrontal activity) and photon emissions from the right hemisphere. This hemisphere is the one most inter-correlated with global geomagnetic activity, suggestibility, the "sensed presence", intuition and creativity. Biophotons from mitochondria have been hypothesized to affect membrane activity through microtubules [67]. The essential component of these "hollow cylinders" (17 nm inner diameter and 25 nm outer diameter) are tubulin dimers each of which exhibit approximate dimensions of 4 nm by 6 nm by 8 nm or a volume of ~$1.6 \cdot 10^{-25}$ m^3. If one assumes the upper limit of the rest mass of a photon is ~10^{-52} kg [68] and the mass of the universe is ~10^{52} kg, then there would be ~10^{104} photon equivalents in the universe. With an estimated volume of ~10^{79} m^3, the average volume per "photon equivalence" would also be ~10^{-25} m^3. This is a remarkably important containment that could be congruent with Hameroff and Penrose's [56] statement that:

"*Consciousness results from discrete physical events; such events have always existed in the universe as non-cognitive, proto-conscious events, these acting as part of precise physical laws not yet fully understood*".

Assuming that the total surface area of human cortices is approximately 10^{-1} m^2 [60], this would mean that the energy of the photons associated with thinking would be about 10^{-12} Joules per second. This is equivalent to about 10 to 100 million neurons firing between 10 and 100 Hz. The interpretation would be similar to Bohr's inference that "consciousness" and thinking involved quantum levels of energy. Presumably the two would share a particular value for geometry (space) that could be generated by different constructions of matter. He calculated that the magnitude of the quantum involved when one nucleus was removed from another. The relation was:

$$v_r = 1.32 \ \omega_o \sqrt{(m \cdot M^{-1})} \ ,$$

where m is the mass of the electron, M is the mass of a proton and $\omega_o = 6.2 \cdot 10^{15}$ Hz. The resulting wavelength is 1.54 μm. This value is within the range for several neuronal structures that mediate brain function including the width of a synapse [26] and nodes of Ranvier. The profound implications of this approach and measurements are that there is *no qualitative distinction* between body and mind or structure and "energetic" spirit. The apparent dichotomy is an illusion of quantitative differences and the inaccurate inference that mind and body and energy and matter are mutually exclusive and distinct entities.

Similarities of energy density in the universe and thresholds for consciousness

Although estimates vary depending upon the inclusion of dark matter and energy and various forms of the Open Cold Dark Matter (OCDM) model [69], the energy within the universe is about 10^{69} J. Assuming validity of the current estimate of length and shape, the volume is in the order of 10^{78} m^3. Consequently the average "energy density" would be ~10^{-9} J·m^{-3}[70]. Within the human cerebrum this would be equivalent to 10^{-12} J. Assuming there is minimal temporal heterogeneity we can assume about 10^{-12} J·s^{-1}. Applying the neuronal quantity of the action potential (10^{-20} J) this would be equivalent to 10^8 action potentials or 10^7 neurons firing at 10 Hz. This is the same order of magnitude as that associated with photon emissions from the cerebrum during cognitive generation of imagery and thinking [71].

In other words the average density of energy throughout the universe is equivalent to the energy associated with the activity of between a million to 10 million neurons discharging on average between 10 and 100 Hz. This "critical mass" of neurons is within the range discerned in functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) data for specific types of percepts and consciousness increments for different qualities of stimuli. This number is also associated with the critical mass of neurons inferred from studies involved with cases of "blind sight" where the patient does not exhibit "consciousness" (or more precisely "awareness") for visual objects (*i.e.,* is blind) yet negotiates complex routes within the environment [72,73].

The relationship between quantitative consciousness and universal energies

If consciousness is a property of the energies within the matter and space occupying the cerebral volume over its temporal extent, then one would predict convergence of quantities from different types of energy. The summed electromagnetic energy per second associated with average cerebral neuronal activity, assuming 10^{-20} J per action potential, is in the order of 10^{-9} J. This might be considered the potential for the cerebral volume. At any given moment only a subset (about 0.1%) would be displayed.

Gravitational energy potential can be described by E=G·kg^2 ·m^{-1}, where G is the Newtonian universal Gravitational Constant (6.67·10^{-11} m^3·kg^{-1}·s^{-2}), kg is the mass of a brain and m is the length. Assuming 1.35 kg for the mass and 1.2·10^{-1} m for the average occupancy of space, the energy is 10^{-9} J. This value converges with the energy associated with the organic sources from neuronal activity and suggests that an energy that permeates the universe and may be a fundamental force that interconnects matter superimposes the same level of energy as the neuronal activity associated with consciousness.

The test of any hypothesis is the experiment. As noted in the previous section, we have experimentally induced alterations in consciousness and the perception of the "right hemispheric" sensed presence by applying weak magnetic fields preferentially over the right hemisphere. The energy within the volume from an induced magnetic field (E=B^2·(2·4π·10^{-7} N·A^{-2})$^{-1}$·m^3) for the optimal intensities we employ (about 30 mG or 3 ·10^{-6} T) is about 10^{-9} J [12]. This may explain the efficacy, assuming the appropriate pattern and specific point duration are applied, of these fields for producing the altered forms of consciousness and their cerebral correlates as measured by neuroimaging.

However the physical substrates for consciousness are not constant. They exhibit complex low amplitude temporal variations superimposed upon much greater steady state amplitude. For example the cerebrum's steady potentials or "d.c." fields between the rostral and caudal domain is in the order of 10 millivolts while the correlates of cognition (and QEEG) activity are in the order of microvolts, a difference of approximately 10^3. There is now evidence that even G, for example, is not constant but shows intrinsic variations.

Persinger and St-Pierre [74] quantitatively examined the results from the recent work by Quinn and his colleagues [75] and Vladimirsky *et al.* [76,77] from about twenty years ago. Both groups of researchers had found fluctuations in G that were in the range of 3·10^{-3} of the average value for G. We found moderate strength inverse correlations between the microvariations in G and global geomagnetic activity (or from perturbations in the solar wind) in both data bases. The reliability of the strength of the correlation suggested a shared source of variance. This interface would also occur within the range of cerebral cortical frequencies associated with consciousness according to the mathematical results of Minakov *et al.* [78]. They indicated that gravitational-to-electromagnetic conversion occurs within the earth-ionospheric (Schumann) resonator with peak power densities around 14 Hz.

This change of G when multiplied by the square of the mass for the average human cerebrum divided by its length results in ~3·10^{-14} J. The "magnetic" energy within a comparable volume of the human cerebrum due to the mean global geomagnetic variation of ~8 nT would be ~$3·10^{-14}$ J. Assuming the basic quantum of the action potential (10^{-20} J) is applicable, the energy from both variations would be equivalent to the activity of about a million neurons. If the unit of time were a second, the radiant flux density from the human cerebrum with a cross-section area of about 10^{-2} m^2 would be around 0.3·10^{-11}W·m^{-2}. This is precisely the range of photon emissions associated with consciousness and specific forms of thinking according to our experiments [63].

A strong correlate (or perhaps even an identity) between small fluctuations in G and electromagnetism, particularly light (the visible EM interval), has been theorized and inferred by measurement for decades [79]. In several settings with different subjects we have found an inverse relationship between the radiant power density of photon emissions from the right hemisphere while participants imagined "white light" and the ambient geomagnetic field intensity within 0.5 m of their skulls [80]. The decrease was about 5 to 7 nT during the increased photon emissions [71].

For one particular subject [81], Sean Harribance, conspicuous increases in photon flux densities were measured when he was imaging "a mystical source of white light". This specific cognition was also associated with marked alterations in QEEG-defined power densities over his right hemisphere (temporoparietooccipital interface) that were so specific and reliable they could be digitized and applied as a magnetic field pattern that affected growth rates in cell cultures. Digitized sequences from his normal brain activity did not affect cell growth rates [82].When the photon enhancement occurred during his "imaginative cognition" there was concomitant diminished intensity of the surrounding earth's magnetic field along the same (horizontal) plane as the emissions. The decreases at 1 cm, 25 cm, and 100 cm from his skull were 150 nT, 15 nT and 5 nT, respectively.

The changes began approximately the same time as the increases in radiant power density that peaked around 5·10^{-11} W ·m^{-2}. His output was more than about 10 times the level of the average person.

The calculated energies from the magnetic field decrease and photon increase were ~10^{-11} J, suggesting a shared source of variance. The energies were also congruent with the observed changes within the right hemisphere as measured directly by SPECT (Single Positron Emission Computerized Tomography) and his neuropsychological profile [83] (*Roll et al., 2002*).

Such interactions are an important condition for non-locality, as predicted by Umezawa's [84] mathematical Quantum Field Theory, which unifies electromagnetic, nuclear and gravitational fields. Non-locality which is a variant of Mach's principle that the behavior of any part of the cosmos is determined by all of its parts encouraged Di Base [85] to define *information* as "a intrinsic, irreducible and non-local property of the universe capable of generating order, self-organization and complexity. Similarly, Chalmers [17] defined consciousness as "an irreducible aspect of the universe, like space, time and mass". If virtual particles mediate non-locality and "real" particles (protons and electrons) mediate locality, then any process that promotes the transformation of virtual to real particles, such as applying an electromagnetic field to a changing boundary [32], could link these phenomena.

The issue of temporal permanence

Although the order of magnitude of the global intracerebral magnetic fields (about 3 nT) associated with cerebral activity appears to be small, it's effects on the induced magnetic moment by changing the angular velocity of an electron are revealing. The fact that the electron with a charge q orbits within a closed circle indicates that a magnetic field is generated. The classic equation for the change in angular velocity is:

$$\Delta m = -[q^2 \cdot r^2] \cdot [4m_e]^{-1} \cdot B,$$

where q is the unit charge, r is the radius (assuming the Bohr radius or magneton), m_e is the mass of an electron and B is the applied magnetic field.

If the applied field to every electron is the "averaged" cerebral magnetic field of ~3 pT [53], the change in magnetic moment is in the order of 10^{-41} A·m^2. This aggregate is the same as Joules per Tesla. The matter of the human brain like all matter within the planet and solar system are immersed with galactic magnetic fields with intensities in the order of 10^{-11} T [86]. When this value is multiplied by 10^{-41} J·T^{-1} the increment of energy is 10^{-52} J. Even if one assumes the 10^{-10} T strength magnetic fields [87], measured at 1.3 mm during an impulse in the (frog) sciatic nerve, its immersion within the lower limits (~10^{-13} T) of intergalactic fields [88], would result in values within the same order of magnitude.

This quantity is significant for two reasons. First as c^2 approaches 1, this means that the mass would be ~10^{-52} kg [79]. This is the predicted value, for which there is strong empirical evidence, for the upper limit of the rest mass of a photon [68]. This boundary has been considered a significant support for complex ideas that describe the mechanics by which all space becomes interconnected.

The second significance occurs when 10^{-52} J is divided into the most fundamental constant of modern energy (quantum) theory, Planck's constant of 6.626·10^{-34} J·s. The duration of the change would be within the order of 10^{18} s, which is considered the final duration or final epoch of our present conceptual life time for the universe. In other words, the physical bases of consciousness expressed as induced magnetic moment from a change in angular velocity would exhibit a temporal permanence equal to that of the universe. This would not necessarily imply that the manifestation of individual human consciousness, controlled by the constraints of individual experiences and synaptic patterns within the approximately 1,350 cubic centimeters (mL) of space occupied by the cerebrum, would also show this persistence.

Implications for the physical bases of consciousness

The information and quantifications from this perspective for the physical bases for consciousness could be sufficient to initiate a critical mass of thinking amongst Neuroscientists that will encourage design of experiments that employ tools which researchers have not employed traditionally. A shift to a paradigm that is profoundly more integrative and interdisciplinary is necessary. There are at least five conceptual possibilities that might help reveal the hidden variance associated with the verifiable and measurement-driven properties of "consciousness" assuming the caveats from the introduction are accommodated.

First, the time required for a photon with a velocity c to traverse the plasma cell membrane of a neuron (10^{-8} m) is 10^{-16} s. This is remarkably similar to the time required for one orbit of an electron around a proton. The mass-energy equivalence of an electron for this duration is effectively the value of Planck's constant which is the centroid for quantum calculations and the transformation of frequency into energy. In addition the convergence suggests the possibility that information contained within the neuronal membrane could be coded onto photons being emitted from the neuron. More importantly information coded within photons (from theoretically anywhere in the universe) could affect the local dynamics of the neuronal membrane.

Secondly, the conditions of non-locality become more than mathematical possibilities. Mach's principle of the immanence of the universe states that the inertia of any component of the universe is affected by all of the other components of the universe. Gravitational forces between the potassium ions that are presumed to control the resting membrane potential are in the order of 10^{-45} N and considered negligible. However, if they were applied across the distance of the universe the energy would be within the range of 10^{-20} J. There are several authors such as Hu and Wu [89,90] and Pitkanin [91] who have developed quantitatively testable theories for non-locality and the excess correlation or entanglement of cerebral processes over potentially universal distances.

There is compelling experimental evidence that excess correlation or entanglement [92] can be produced between two cerebral processes separated by none-traditional distances if both share the same type of circular magnetic fields rotating with changing angular velocities [62]. Similar excess correlations when two spaces share the same electromagnetic configurations have been shown repeatedly for photon emissions [63] and alterations in local pH within specific volumes of water displaying physiological constituents [93]. This physical feature of consciousness articulated from a quantum perspective and employing known physical forces offers alternative explanations for an entire domain of previously pejorative phenomena that involve putative exchanges of information over extraordinary distances by mechanisms not known to date [94-96].

Third, the electromagnetic bases of consciousness encourages a re-evaluation of the labile increment of approximately 30 min following stimulation by patterns of stimuli during which time dendritic spines are synthesized and memory is represented. If the correspondence between matter and energy occur as well, then there could be representation of the *information* extra-cerebrally, that is, beyond the

cerebral volume which would still be continuous with all other space. The definition of information according to Di Biase and Rocha [85] is "an intrinsic, irreducible and non-local property of the universe, capable of generating order, self-organization and complexity". In many respects this description can be considered the most prominent feature of human consciousness and its physical substrates.

Persinger [51] has suggested that the information during this labile phase could be represented within the space occupied by the earth's magnetic field and the Schumann Resonance waveguide. It may not be spurious. The analogous situation would be the continuity of DNA over millions of generations. The DNA information is present although the recipient does not experience the memories of the antecedents over phylogenetic history. Although one's personal memories and consciousness may be dissipated with the dissolution of synaptic patterns, the information [97] might still be retained within this Hilbert-like space [98]. If this information is retained then it would have the capacity to be totally or partially reconstituted within a cerebral space whose microstructure is compatible.

Fifth, for physical descriptions of consciousness the role of quantum phenomena in the more accurate definition of the properties that neuroscientists describe as "consciousness" becomes prominent. The recoil energy of a photon with the Bohr frequency wavelength (which is the median value of the width of synapse (~1.5 μm)) is equivalent to the action potential (10^{-20} J). In other words the recoil frequency when one nucleus is removed from another is equal to the fundamental quantity of energy involved with cognitive processes [28].

The recoil energy for one photon with the current estimates of the upper limits of rest mass has also been calculated for cerebral spaces. This value is in the order of $4 \cdot 10^{-9}$ J which is the energy estimated to be associated with action potentials coupled to the approximately 20 billion cerebral cortical neurons in the average human brain each discharging around 10 Hz. Stated alternatively, the recoil energy from *one* photon moving from it rest mass would be sufficient to *simulate* the energy generated within the entire cerebral cortical manifold during consciousness due to neuronal activity.

Conclusion

The pursuit of the cause of consciousness, with all of its denotative and connotative embellishments, has been a central theme in the history of thought and deliberation. It embodies the fundamental dichotomy or diametric opposition for "physical" and "not physical" categorization that has shifted from mind and body to energy and matter. Although the predilection is to focus upon "logical" and philosophical methodologies which are largely dependent upon "nominal scales" (language), the History of Science has shown that *convergence of quantifications of measurement* employing ratio scales for any putative phenomenon with respect to basic physical parameters is more revealing. The accuracy of this approach has been confirmed by the precision of the predictions.

The physical bases for the class of experiences described as "consciousness" do not reduce or trivialize this category of phenomenon. Instead the approach shows that the temporal, spatial, and electromagnetic parameters and values from which brain activity is generated within the cellular level are evident within experiential domains. The basic energy unit or quantum that mediates the dynamic process, in the order of 10^{-20} J, is evident within the conditions that define the resting membrane potential, its chemical interactions, and its similarity to pervasive energies within the known universe. This same quantum of energy converges with many other models regarding the physicochemical bases to consciousness.

Recent numerical convergence between the quantities of energy from emissions of photons from the cerebrum during cognitive processes, the estimated numbers of axon potentials associate with consciousness-cognition, and intrinsic cerebral dynamics strongly suggests that very weak (picoTesla) magnetic fields may be the cause or strongest correlate of the human forms of consciousness. The persistence of changes in magnetic moment from this order of magnitude of magnetic field immersed within field strengths manifested over extensive spaces indicates a component of "permanence". A central role of photons in the experience of consciousness, such as Bokkon's photon field within cerebral space, may require a shift in paradigm that will alter the experiments that Neuroscientists perform and the models we develop to study this problem.

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