Perspective

New insights into holonomic brain theory: implications for active consciousness

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Abstract

This pioneering research on how specific molecules deep inside our brains form a dynamic information holarchy in phase space, linking mind and consciousness, is not only provocative but also revolutionary. Holonomic is a dynamic encapsulation of the holonic view that originates from the word “holon” and designates a holarchical rather than a hierarchical, dynamic brain organization to encompass multiscale effects. The unitary nature of consciousness being interconnected stems from a multiscalar organization of the brain. We aim to give a holonomic modification of the thermodynamic approach to the problem of consciousness using spatiotemporal intermittency. Starting with quasiparticles as the minimalist material composition of the dynamical brain where interferences patterns between incoherent waves of quasiparticles and their quantum-thermal fluctuations constrain the kinetic internal energy of endogenous molecules through informational channels of the negentropically-derived quantum potential. This indicates that brains are not multifractal involving avalanches but are multiscalar, suggesting that unlike the hologram, where the functional interactions occur in the spectral domain, the spatiotemporal binding is multiscalar because of self-referential amplification occurring via long-range correlative information. The associated negentropic entanglement permeates the unification of the functional information architecture across multiple scales. As such, the holonomic brain theory is suitable for active consciousness, proving that consciousness is not fundamental. The holonomic model of the brain’s internal space is nonmetric and nonfractal. It contains a multiscalar informational structure decoded by intermittency spikes in the fluctuations of the negentropically-derived quantum potential. It is therefore, a more realistic approach than the platonic models in phase space.

Keywords*:* Fluctuations, uncertainty, free energy, kinetic internal energy, holonomic brain model, multiscalar effects, intrinsic information, active consciousness, statistical thermodynamics, intermittency, negentropic entanglement, functional entropy

1. Introduction

Karl Pribram's holonomic brain theory (Pribram, 1991) was developed to make sense of experimental evidence that memory is stored equipotential throughout the brain. Holonomic brain theory examines the scale beneath neurons where information is processed with quantum degrees of freedom, e.g., spin, and charge, allowing subjective functioning to be holonomic. This was the idea of Pribram (1991) in claiming that his holonomic brain theory was not analogous to quantum theory, but rather its formalism obeys the same rules as that of quantum mechanics. Holonomic brain theory is formally equivalent to computations in quantum mechanics and thus constitutes quantum neurodynamics. However, the processes at the neural level, such as the distribution of ionic charge, cannot be identified with those described in the quantum domain, such as delocalized electrons. Pribram's initial theory assumed Gabor's holography based on the idiom of information spread "everywhere" and "everywhen" in a hologram. The point is a hologram does not work spatio-temporally, as it operates in Fourier space. The formalism of the neural process was quantum-like based on Gabor's hologram as an analogy. Pribram's neural holonomy compares interference patterns observed in electron microscopy as a holograph of experiences in the brain. Accordingly, such localized holograms are in parts of neural networks that Pribram (1991) called “holonomy”.

Holonomy is spectral sensitive in a hologram, while in a holarchy, i.e., a hierarchy of holons, is distributed across scale in spacetime. Our definition of holonomic is in the context of a “holon,” defined differently from a hologram (see Koestler (1967)). As such, new insights into holonomic brain theory depend on the definition of holonomic. In a “hologram,” any part of the whole contains the whole in the frequency domain. In a “holon” simultaneously, a whole and a part of a larger whole are interconnected (but not integrated) in spacetime (see Mella (2009) and references therein). Holonomic has a broader viewpoint than the holonic one since it considers holons encapsulated in an operational environment that allows

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them to reveal themselves and produce the dynamic process for the entire holarchy. Note that a modular holarchy does not encapsulate the holons, so it is not the same as a holarchical modularity.

Bohm (1952) introduced quantum potential energy, defined and interpreted as a form of energy that cannot be localized in space. Gould (1995) could not form a unified interpretation of both David Bohm's ontological interpretation of quantum theory and Karl Pribram's holonomic brain theory because he assumed correctly that holonomic formalism was a non-quantum biophysical process. However, deriving the ontological theory based on quantum-thermal fluctuations makes unification possible. At any particular spatiotemporal scale, partial information is interconnected across scales within the whole organism in the context of non-integrated and compartmentalized modularity (Poznanski et al. (2022a)

How can holonomic brain theory decipher what consciousness is? Recent studies point to memory as multiscale (Fields & Levin, 2018), suggesting that a holograph is less applicable than a holon, where memory cannot be understood at any isolated scale. Such a holonomic approach encourages the understanding of relationships in their wholeness. This perception of 'wholeness' comes from active consciousness. It emphasizes the 'belonging' and the meaning of the systems and their coexistence. This tells us nothing without further delineating internal energy and what it all means in the consciousness process.

Consequently, consciousness is intrinsic to affect but not cognition. From the perspective of the multiscalar brain, the dynamic brain organization is holarchical in that each scale is interconnected, not necessarily integrated, but modular. A modular structure does not imply dualism but gives intrinsic information the ability to noncontextually inform semantic information, which upon externalization becomes exogenous syntactic information, thereby losing its intrinsic character; it can no longer revert to being semantic information as per the central dogma of information (Cárdenas-García,2022).

Hameroff (2022) could not find consciousness in molecular systems configured by atoms with electrostatic interactions (London dispersion forces). Consciousness is about information activity; a nonclassical concept first applied in quantum mechanics by Bohm (1990). Recent work by Poznanski and colleagues (Poznanski et al., 2022b) suggests that intrinsic information comes about from the modularity of energy. It can be defined as the patterns associated with constrained internal energy processing (Pepperell, 2018). Still, it is not a form of energy or, from a classical perspective, a force constraining energy. In nonclassical terms, forces define the character of information, contributing fundamentally to information activity.

Subjective functioning requires for functional interactions as a biological counterpart to physical force to carry precognitive semantic informational structure, of physical feelings (non-felt feelings). It noncontextually allows brains to assign meaning (Poznanski et al., 2022a). Physical and nonlocal functional interactions must be represented by quantum chemical molecular systems configured by atoms with electrostatic interactions (London dispersion forces). Hence physical interactions depend on forces that can only operate when the medium is homogenous (local), and they concern only the structural organization without affecting its functional organization. In comparison, functional interactions depend on the activity of information in the brain where the medium is inhomogeneous (nonlocal functionality) (Poznanski et al., 2022b)

The holonomic model of the brain's internal space represents a manifold, a topological space that locally is Euclidean metric. Metric manifolds, i.e., locally Euclidean metric spaces, have been amongst the most studied objects in mathematical neuroscience (Brzychczy & Poznanski, 2014; Steel, 2021). Despite this, brain geometry is a nonmetric manifold (i.e., locally Euclidean topological spaces which do not carry a metric structure). A topological space is metrizable only when compact, i.e., closed and bounded. Recently biological closure in the form of dynamical "*biobranes*"may give insights into the problem (Signorelli & Meling, 2021).

Considering the holonomic structure of the internal space, we address the brain's internal energy, which is thermo-dynamic and not electromagnetic. Studies on the thermodynamics of the brain have been limited (see, e.g., Kirkaldy, 1965; Collell & Fauguet, 2015). The brain's internal energy is a thermodynamic state without effects due to electromagnetic fields that are impossible to quantify. Still, it is central to the problem of consciousness (Beshkar, 2018).

2. The material origins of consciousness

The nature of consciousness relies on an objective approach (Sperry, 1970). But the puzzle of consciousness is that subjectivity is substrate-dependent. More importantly, there cannot be a substrate of consciousness but only a substrate from which consciousness evolves. Otherwise, it would mean the existence of consciousness as a thing with pure spiritual consciousness. A good theory of consciousness must show the uniqueness of the material composition of the brain constituency. This suggests quasiparticles. The material origins of consciousness stem from quasiparticles and their interference patterns.

Eccles (1990) was the first to utilize quasiparticles in the brain as an entry point for mental causation in such a way

that "mental intention (volition) becomes neurally effective by momentarily increasing the probability of exocytosis" (Beck & Eccles 1992). However, this does not go deeper into the qualitative aspects, as is inherent in the brain's material composition or Sentiomics (Pereira & de Aguiar, 2022). We must further assume that quasi-polaritons as quasiparticles are archetypal quantum analogs of conscious experience that naturally depend on cognitive dynamics attributed to the arrangement of ions encasing the polaritonic wave. This is Eccles's "*psychons*" expressed in vibronic quasiparticles uniquely molded to the tune of the brain at different temporal scales and frequencies. Psychons are quantum analogs, and they are subjective because they encase the cognitive aspects of organisms uniquely.

A new theory of brain consciousness is needed where traditional quantum mechanics goes wrong. This new theory of brain consciousness where quantum mechanics goes wrong results in what we call quantum analogs (Tuszynski et al., 2022). Consciousness depends on the material composition of brains, where a particular quasiparticle interaction is uniquely mapped in the brain. We proposed that quasiparticles are the minimalist material origins of consciousness at the molecular scale (Tuszynski et al., 2022), which makes perfect sense as quasiparticles reflect on the intrinsic material composition of the brain. In other words, unlike fundamental particles like electrons, quasiparticles have intrinsic properties that depend on the material properties of the brain. Quasiparticles arise at the molecular scale throughout protein pathways via numerous protein-protein interactions across the cerebral cortices. We postulate that the consciousness process originates across proteinaceous pathways throughout the cortex. Transcription factors for gene expression of protein-protein interactions are limited in phyla apart from mammals. This approach suggests consciousness as a property of non-inert or 'active' matter, progressively expressed in specific neurobiological systems (Sperry, 1970; Popkin, 2016; Poznanski & Brändas, 2020; Funk, 2022).

Other earlier models depend on resonance recognition theories, where a coherent resonant frequency as resonant energy transfer remains in the frequency space or spectral domain (Cosic, 1987; Jaross, 2018). The resonant recognition models postulate certain periodicities within the distribution of energies of delocalized electrons along protein molecules arising from matching periodicities resulting in resonant recognition. Such constructive interferences have been applied to protein-protein interactions (Cosic, 1987), and neural networks (Grossberg, 2017) are inadequate because they do not explain the thermodynamics of consciousness.

Moreover, the electromagnetic resonance theory of consciousness is incomplete, as is any other resonance theory, such as resonance recognition in macromolecules (Cosic, 1987) or neural nets (Grossberg, 2017). For instance, intra-neuronal (changes in protein conformation, concentration, and synthesis) and extra-neuronal factors (electromagnetic resonance when a biophoton is exchanged in benzene rings of lipids and proteins) can have a profound effect on energy transduction mechanisms that create new information. Yet the constructive amplification of discrete periodicities as resonant energy transfer is not how information structure is decoded.

On the other hand, our approach is similar to the macroscopic quantum fluidic model of Nottale (2014) and Turner et al. (2020). They considered charge density and their Coulomb interactions creating a barrier to bonding, allowing greater freedom to interact with quantum-thermal fluctuations and their impact on internal energies of molecular assemblies in plant-like structures. Our approach differs in that the localized quantum potential energy is not discrete chains in a fractal spacetime that result in a change from microscopic to macroscopic by their interaction via linear summation of wave functions, but have explicitly incorporated the definition of the nonBohmian quantum potential energy in terms of both microscopic and macroscopic scales based on hydrodynamic quantum mechanics.

Hydrodynamic quantum mechanics allows the quantum fluid to be derived from classical mechanics based on the Brownian motion at the quantum realm with an action parameter or diffusion coefficient (Nelson, 1966). This theory has resulted in quantum potential (see Sbitnev, 2009, Turner et al., 2020) from various representations. Note: the reference to "*hydrodynamic*" does not connote fluid flow, for example, defined by purely classical hydrodynamic quantum analog (cf., "*droplet walkers*"), but rather 'quantum fluids' which invoke classical dynamics with quantum localizations as in quantum state diffusion. Our quantum analogs are holonomic, not "*droplet walkers*".

In the quantum analog approach, we consider replacing the wave function with a wave of quasiparticles where all quasiparticles in the quantum 'fluid' follow Brownian motion (Nelson, 1966). Quantum analog approximate quantum fluids with statistical-mechanical theories. Quantum statistical mechanics has a classical counterpart, namely statistical mechanics, but a distinguishing feature of quantum theory is that it does not have a classical counterpart. In this respect, our quantum analogs are based on quantum statistical mechanics and not quantum mechanics. This advances the quantum analog theories of consciousness as expressed in panexperiential materialism (Poznanski & Brändas, 2020) and subsequently espoused in Poznanski et al. (2022b) and Tuszynski et al. (2022).

A neuroscientific understanding of consciousness requires us to start thinking of the brain not as a connectome, i.e., assembly of neural networks, but as a hyper network of quasipolariton waves across protein pathways as the fundamental consciousness process (Tuszynski et al., 2022). Consciousness is built from a unique combination of quasi-

particles such as vibrons and polaritons. Since biophotons are a fundamental carrier of information at the submolecular scale, for higher-up consciousness quasiparticles are encapsulated by ions and water realization in cognition and perception, these molecules of which the resultant quasipolariton hyper network is a holonomic structure of information. The inner core encapsulates cognitive and perceptual states to bring about conscious experience. We must further assume that quasipolaritons surrounding the quasiparticles are an archetypal quantum analog of conscious experience that naturally depend on cognitive dynamics attributed to the arrangement of ions encapsulating the polaritonic wave (Tuszynski et al., 2022). Attempts at unifying quantum analog models of precognitive energy processing with cognitive processing of ions and water molecules that realize these higher-level behaviors have begun based on quasiparticles (see Tuszynski et al., 2022).

3. Aromatic residues of amino acids exhibit phonon polariton modes in van der Waals informational heterostructures

Jaross (2021) presented the central aspect, i.e., as not being the transfer of energy but the recognition and transmission of information employing electromagnetic frequency patterns. However, the case of "information transfer" is meaningless in a multiscalar brain. From a multiscale perspective, energy is constrained to a particular scale through boundary conditions, producing information (Kauffman, 2019). Therefore, integrated information undermines the importance of quasiparticles in multiscalar brains. It does not need to be transferred in different ways and scales because each scale has its localized information, not for the whole organism.

We postulated that the concrescence of holons as informational structures in phase space creates an “internal model” of intrinsic information that entails qualitative experience via energy transformations (Poznanski et al., 2022a), and this is done because the information is non-integrated in the brain. It is labile where information-based action (Poznanski et al., 2022b) actively constructs an "information structure" uniquely supplemented in memory. By assuming a formal analogy between Brownian motion and quantum potential energy (Nelson, 1966), we can express a quantum potential energy quantum in terms of interference patterns of quantum-thermal fluctuation (Poznanski et al., 2022b).

Using hydrodynamic quantum mechanics, Uzun (2022) showed interference patterns between incoherent waves of quasiparticles and their quantum-thermal fluctuations squeeze the kinetic internal energies to form a heterogenous informational structure. The informational structure constituting squeezed that are kinetic internal energies produces quantum-thermal correlations associated with functional interactions across the multiscalar brain. This physical description of the mechanism is attributable to dynamic correlations where quantum-thermal fluctuations are coordinated.

The holarchy of the brain’s kinetic internal energy governs its informational structure to encompass multiscale effects. The interactions between the interconnected collections of neurons or brain matter and its extracellular fluid constitute important additional information that must be included in the study of consciousness. For instance, Coppola et al. (2022) suggest that the dynamic reorganization of the functional information structure is a characteristic that emerges with awareness and has explanatory power beyond that of the complexity of dynamic functional connectivity. This is paramount in dismissing brain imaging through connectome studies as revealing the nature of consciousness.

The scale of the whole brain is large compared to molecules still, how interconnectedness via volume transmission, intermittent London forces and protein interactions manifest from holonomic brain geometry that provides opportunities for information-rich dynamic activity. To understand the role of inter-cerebral communication, we extended this assumption to the molecular-based quasi-polariton model (see Tuszynski et al. 2022). The vibration frequency alone cannot carry meaning as information in the informational structure. We proposed that molecular vibrations and photons propagating freely in water crystal lattices interact in van der Waals protein heterostructures across the cerebral cortices assembled from aromatic residues of amino acids and exhibit phonon polariton modes. It was proposed that Van der Waals protein heterostructures constrained molecular vibrations. These quasi-polaritons are informational signals and play a role in building information structures at the molecular level as an alternative to the metacognitive approach of neural networks sending information via neural transmitters and ions across membranes.

4. Quantum potential energy as a distinct informational channel

Without exception, all our conscious states are caused by lower-level neurobiological processes in the brain. And they are realized in the brain as higher-level or system features. In blindsight, physical perception exists without feelings, i.e., conscious sensations. Perceptual states influence how ions flow across the membrane and are not conscious; as proven in blindsight (Humphrey, 2006), there is visual input from the eyes. Still, the perception of the object in the visual field lacks conscious awareness. This proves that consciousness is separate from perception and has its separate channels. What are these separate channels that consciousness operates in?

These informational channels rely on internal energy exchange through quantum potential energy (Q) to postulate functional interactions of quasiparticles as evanescent meanings, arising as an infinitesimal energy source distributed in the brain. Hence, endogenously produced noncontextually semantic information, as a non-felt physical feeling, does not reflect on quantity such as the smallest unit of information, the "quanta of information" (Pribram,1991),

but for labile structures define minimum uncertainty in terms of the energy modularity.

Still, it is vital to realize Bohm's quantum potential is not Q since our approach does not use Bohmian mechanics. All archetypal molecular patterns of conscious experience are quantum analogs (Crick, 1994; Tuszynski et al., 2022). Therefore, pilot wave theory is not used, nor is the concept of 'active information'. Instead, we use Madelung quantum hydrodynamics to define a molecular system's 'intrinsic information' based on quantum potential chemistry (Boeyens,2000,2008).

This quantum potential is an analog of the Bohmian quantum potential and depends on temperature. Like the Bohmian quantum potential, it is carrier of information. We have redefined Q based on the hydrodynamic model of quantum mechanics (Poznanski et al., 2022b):

$$Q = -\frac{\gamma^2}{8mT^2k_B^2}(\nabla f)^2 + \frac{\gamma^2}{4mTk_B}\nabla^2 f \qquad (1)$$

where T is the temperature in Kelvin, $k_B$is Boltzmann's constant in units of [energy]/Kelvin, f is the fluctuations in units of [energy], γ is a spread function parameter in units of [energy][time], t is time [time], m is the effective mass of protons in units of [mass], ∇ is the gradient in units of [length]$^{-1}$, and ∇^2 is the Laplacian in units of [length]$^{-2}$. The analysis of this equation leads to a kinetic interpretation of temperature: Temperature measures the average kinetic energy of atomic and molecular motions.

Equation (1) shows a gradual reorganization of the internal energy with temperature, suggesting that the quantum potential is not limited to absolute zero temperature as is assumed by Schrödinger's equation. However, the recent work of Uzun (2022) and Poznanski et al. (2022b) have expressed Q in terms of temperature (macroscopic) and quantum-thermal fluctuations (microscopic/mesoscopic), which means it is multiscalar. This is needed to gauge if the multiscalar effects of a modular holarchy can replace the unproven fractal-like geometry based on self-organized criticality (SOC).

The internal energy has been directly associated with the quantum potential energy (Dennis et al., 2015). However, deriving the brain's internal energy in terms of temperature introduces the multiscale effect needed to explain quantum chemistry via biology. As we can see from quantum potential chemistry (Boeyens, 2000), the quantum potential exists as a wave at temperatures greater than absolute zero. It plays a pivotal role in biological consciousness as an informational channel where information redistributes the internal energy between the kinetic and potential parts.

5. Negentropic entanglement: re-organization of the brain's internal energy

Organismic life entails, among others, the compartmentalization of internal energy possible only in a modular structure, for example, animate matter. At the same time, consciousness is a ramification of this containment through the thermodynamic formulation of life. Living systems where entropy production (2nd law of thermodynamics) matches the negentropic gain in achieving the minimum possible entropy. This modularity purports two-stage hybrid thermodynamic conditions. The first stage of the entropic exchange between scales is 'closed.' Thus, the thermodynamic transfer operates as an "isolated" system. During the second stage, the entropic exchange between scales is "quasi-closed," Thus, the thermodynamic transfer operates an 'open' dissipative system far from equilibrium (Del Castillo & Vero-Cruz, 2011). Such a two-stage hybrid thermodynamic system enables negentropy to have physical meaning.

Furthermore, from the physical perspective, there must be a correspondence between the modularity of energy and the associated negentropic process. When the informational structure constituting squeezed kinetic internal energy produces quantum-thermal correlations (Uzun, 2022), the fabric of non-inert matter organizes interferences between regions for the extra quality of energy-negentropy exchange, providing the transformation of information that creates the information-based action as the origin of intrinsic information encoding.

The principle which produces spatiotemporal binding across the brain has been proposed as the 'unity of consciousness' (Germine, 1991). Some have speculated that synchronicity of neural spiking produces a spatiotemporal binding (Germine, 1991, Crick & Koch, 2003). Historically, synchronicity refers to a single state generated throughout the brain, coined by Jung (1960) as a principle by which action-at-a-distance might result in a synchronous connection of mental and physical events. Germine (1991) considered Jung's principle of synchronicity to be amplified quantum differences and assumes resonance as the mechanism of consciousness emergence (cf., Cosic, 1987; Grossberg, 2017).

We define negentropic entanglement as the restructuring of the redundancies across scales, which amounts to reorganizing internal energy and functional entropy lowering as a consequence of such a re-organization is what we define as the 'binding' of intrinsic information necessary for consciousness (Poznanski et al., 2019). The neologism negentropic entanglement (negentropic = relating to information gain; entanglement=binding) should not be confused with quantum entanglement as the binding of quantum states between particles. The difference is that the former is fundamentally intrinsic, and the latter is not, but exists in the connection between the particles across the Universe.

The functional entropy is delayed and eliminated by the environment resulting in a negentropic gain in the brain. Constrained internal energy where functional entropy production matches the negentropic gain in achieving the minimum possible entropy suggests a negentropic action that naturally liberates semantic information in terms of minimum uncertainty. The medium that stores information gives it unique properties. The information must be embodied in a physical system. Human-made information is not labile,

whereas information content of nature is always labile. The meaning essential for understanding 'uncertainty' as a definition of consciousness falls into the category of semantic information in the central dogma of information (Cárdenas-García, 2022).

The act of understanding uncertainty is consciousness. It does not need to make sense for "understanding" to take place. As the term "understanding" in the above definition of consciousness is precognitive, i.e., consciousness is intrinsic to affect but not to cognition. Cognition suppresses surprise or uncertainty. The consciousness process involves internal energy exchanges that encapsulate the cessation of consciousness and the beginning of memory (Solms, 2014). However, there is no conscious experience without recognition, so conscious recall arises instead of memory, and only in the presence of 'uncertainty' is memory reconsolidated (Solms,2017). Thus, memory must be a way of compensating for partial information or non-integrated information. This compensatory mechanism is defined as "uncertainty" (Solms, 2017).

Experimental findings from acknowledged work on savants indicate that the disintegration of spatiotemporal patterns of neuronal activity can bring about lower-level recall of vast raw sensory less-processed information at the expense of cognitive functions, such as conceptual thinking (Snyder, 2009). We are saying that consciousness is similar to a savant-like process except that instead of raw sensory information, it is the endogenously produced semantic information expressed by physical feelings (Poznanski et al., 2022a).

6. The effects of modularity on multiscalar intermittency

Our main novelty in defining an informational structure is that it is labile and non-integrated. Since integrator ≠ integrated, interference patterns between fluctuations enable the binding of internal energy, acting as an 'integrator' of non-integrated intrinsic information where entropy production matches the negentropic gain in achieving the minimum possible entropy, suggesting a 'negentropic force' ($f_{S_Q} = -\nabla Q$). This is not a force since entropic changes at a small scale can remove it. The energy gain of the molecular system driven by the negentropic force is seen as a negentropic gain and is closely intertwined with the environment's entropic state. However, entropy production is not always matching the negentropic gain uniformly, and this increase in the Boltzmann thermal entropy over multiscalar distance is the consciousness code. The consciousness code is an informational pattern caused by negentropic force during information-based action. There is almost an infinite unique variation of these patterns due to the non-integrated and compartmentalized modularity. Therefore, the negentropic force is an effect of multiscalar phenomena.

The consciousness code is a structure of physical feelings that assigns novel meanings through functional interactions. This points to the importance of functional operations in defining what David Chalmer's refuted as impossible, namely "subjective functioning". This is not a functionalist state via panpsychism but takes place in the organism and depends solely on functional biology and the central dogma of information. Subjectivity is within the organism, and the semantic information it uses through consciousness is not syntactical that can be consolidated in memory but occurs before memory formation. As per the central dogma of information, semantic information interactions with syntactical information is when conscious recall arises instead of memory, and only in the presence of 'uncertainty' is memory reconsolidated (Solms,2017).

Consciousness does not have an electrical component and is, therefore, not within the electro-ionic brain of the two-brains hypothesis but resides in the electromagnetic brain (Bercovich et al., 2017). Here, ions are not flowing as currents; the thermodynamic state creates the brain's internal energy, which includes covalent energy between molecular bonds and dispersion energy due to van der Waals bonds. Consciousness is a process that carries an integrative function, arising when the brain's internal energy is dynamically transformed (i.e., changes) by van der Waals bonds.

The mechanism of such an integrative function relies on information channels, including functional entropy, which measures randomness in energy distribution, and negentropy, which results from the accumulation of information within the living organism by transforming energy into a new form of energy with higher thermodynamic value. For example, this is from quantum potential energy to "squeezed" kinetic internal energy (Uzun, 2022). The reference to "squeezed" can be referred to as constraining energy flow, and "accumulation" can be an increase of information associated with molecular complexity and functional dynamical activity. Therefore, negentropy contains a lot of uncertainties or surprises.

To quantify expected surprise (uncertainty) from a statistical mechanics point of view, a new term called variational "*free energy*" is used. It is not thermodynamic free energy (Gibbs free energy) but represents a bound on the uncertainty inherent in any exchange with the environment. Surprisal is an information-theoretic concept. The surprisal analysis is a way to identify and characterize systems that deviate from the state of maximum entropy due to physical constraints that prevent a situation of balancing equilibrium. Quantifying the probability of a particular event in relation to its prior probability, it is easy to identify surprisal with the lowering of entropy and negentropic gain (Brändas & Poznanski, 2020).

Solms & Friston (2018) claim free energy has a role in consciousness. Decreasing free energy means a decrease in surprise or uncertainty. Increasing free energy means increasing uncertainty and, therefore, negentropic action.

Encoding uncertainty in a multiscalar brain where modularity is common and where each scale is encapsulated within the other within a holarchical organization to form an Leibnizian informational structure is pivotal in understanding how non-integrated information holistically concresce.

The "absoluteness" of spacetime is not considered with the Leibnizian approach to space, which is relational in contrast to Newton's substantivalism, and space is an amenity in its own right, existing independently of things. Therefore, the brain is not essentially a Riemannian space-time manifold (Le Bihan, 2020) but rather a system of epistemic relations between intrinsic information harnessing a multiscalar informational structure reflecting a grossly nonmetrical and nonfractal geometry that is dynamic holarchy (Bandyopadhyay, 2020). The problem is that multi-fractality does not **exist** across the full scale of the brain, from subatomic particles to large neuronal systems. Self-similarity along a few scales differs from the brain's complete fractal geometry (Bandyopadhyay, *personal communication*).

With relationalism, self-referential amplification can exist and function only as relational entities. Without relations, the microscopic entities would not amplify, such as Q. The associated negentropic entanglement permeates functional organization at multiple scales through a self-referential amplification via long-range correlative information, ODLCI (Brändas, 2021).

The fluctuation theorem (Wang et al., 2002), which originated from statistical mechanics, allows for violations of the second law of thermodynamics in dissipative, non-equilibrium systems. The brain is a dissipative system which is an open system operating far from equilibrium. It deals with the relative probability that the entropy of a system currently away from thermodynamic equilibrium (i.e., maximum entropy) will increase or decrease over a given amount of time. Accordingly, in any nonmodular system, where fluctuations are absent, the nonnegativity of the functional entropy production applies, but in multiscalar systems where the holarchical organization of brain functionality treats parts of a whole to be interconnected within the whole in the context of modularity. The modularity across scales contains fluctuations at the juncture of each scale of organization, suggesting a perpetual motion machine of the second law of thermodynamics through the negentropic force. The negentropic force between quantum-thermal correlations must be continuous from the micro to the macro level and is referred to as negentropic entanglement (see **Fig. 1**).

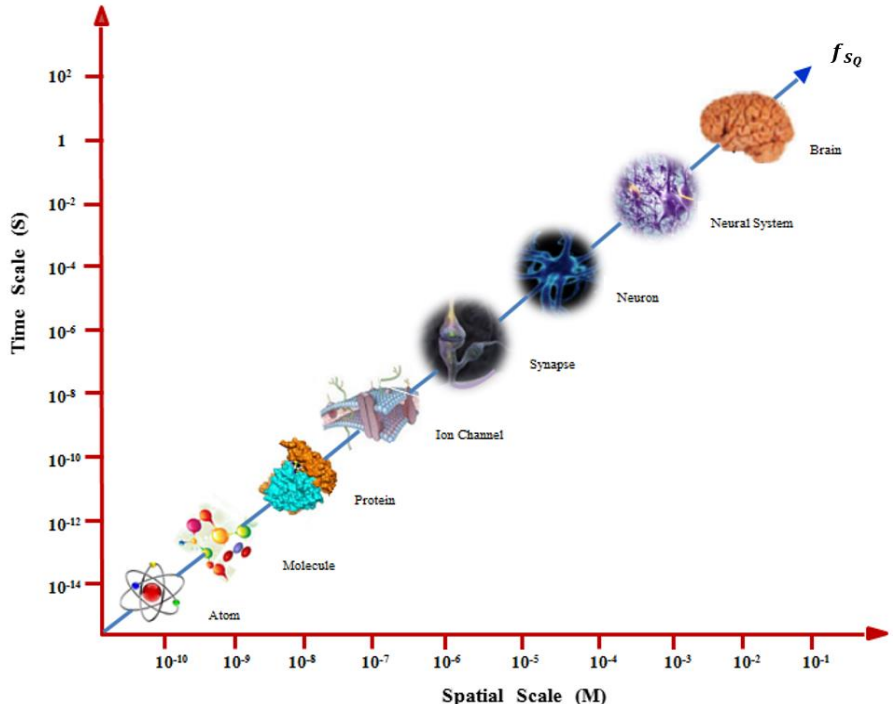

Figure 1 *Coordinated change is required for the fluctuations to operate across the brain as the dimension of consciousness. Negentropic entanglement of periodicities of discrete internal energies through a negentropic force (f_{s_Q}). This schematic diagram shows how internal energy in multiscalar brains originates at the sub-atomic level and manifests to the system level in spacetime. For illustrative purposes, only a linear slope is shown instead of a chaotic waveform with high intermittency prevailing due to the 2nd and 3rd-order derivates of the fluctuations. Dynamic correlations can be bestowed through higher intermittent fluctuations concentrating on small and isolated regions or time intervals surrounded by larger, smoother correlations.*

The spatiotemporal binding occurs by self-referential amplification via long-range correlative information. To prove spatiotemporal binding, one can use intermittency. What is an intermittent phenomenon? Intermittency is defined as localized bursts of high-frequency activity. This means that intermittent phenomena are localized in both physical and spectral spaces, and thus a suitable basis for representing intermittency should reflect this dual localization. Intermittency is an indicator of fractal properties in fractal media, but it can also be an indicator of multiscalar effects in holarchies or modularities (Grahovac et al., 2022).

The quantum potential depends on the first and second derivatives of the quantum-thermal fluctuations, which can exhibit higher intermittent fluctuations that tend to concentrate into small and isolated regions or time intervals surrounded by smoother larger fluctuations. The informational structure constructed through informational channels of Q and decoded by intermittency spikes.

We can harness quantum ontology into the mesoscopic realm of brain holonomy through Q. Holonomic dynamics expressed in the holonomic brain dynamics occur via intermittency of the quantum-thermal fluctuations bestowed by Q, which depends on the first and second derivatives of the quantum-thermal fluctuations, which can exhibit higher intermittent fluctuations that tend to concentrate into small and isolated regions or time intervals surrounded by smoother larger fluctuations as is indicated in **Fig. 2**.

Unlike free energy, the stored energy is the transfer of internal energy in nested spacetime compartments. The work of molecules by such action involves negentropically - derived Q. Free energy entails the work done by the transfer of internal energy that does not involve any notion of time. However, Q is the stored energy that, is an internal energy that does vary in time but only through its intermittent spikes (see **Fig. 2**), which suggests that Q is stored, mobilizable energy that is kinetic internal energy.

Multiscalar intermittency is not SOC. The problem with SOC in the brain is the failure to consider multiscalar effects. First, the brain's capacity for information processing is not an indicator of consciousness. The information processed by neural spike activity rests in cognition, and spatiotemporal binding is a molecular-level activity outside neural spiking that involves the activity of information (Poznanski et al., 2022b). Second, SOC is a scale-invariant.

However, in neuronal avalanches, the scale is interpreted as the distance between electrodes (Beggs & Plenz, 2003) or protein molecules (Phillips,2014). The problem here is that that is no fractal relationship that ties together both space and time in the dynamic holarchy that is modular. Third, the critical brain hypothesis that the control parameter leading to the critical point is hypothesized to be the balance between excitation and inhibition does not happen in modular neural networks (Meunier et al.,2009).

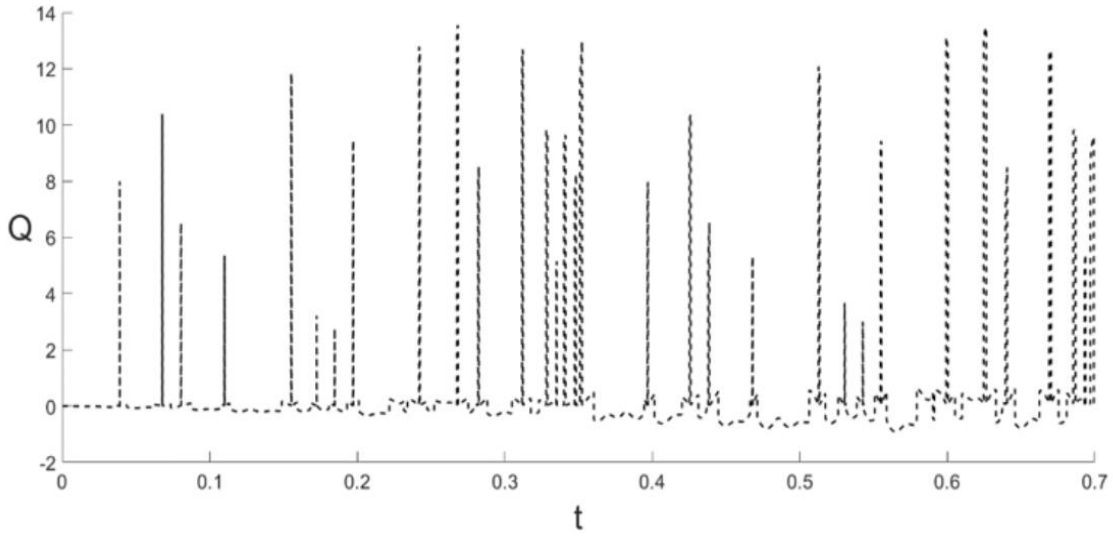

Figure 2. *Computation of equation (1) showing waveform with intermittency spikes. Dynamic holarchy can be bestowed through higher intermittent fluctuations that tend to concentrate into small and isolated regions or time intervals surrounded by larger, smoother correlations.*

7. Conclusion

In conclusion, a new notion of intermittency spikes was used to decipher the role of multiscale effects in understanding consciousness as an active process without the need to assume SOC based on fractality. The combination problem (Chalmers, 2017) can be resolved along functional pathways through negentropic entanglement.

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