Could a Fractal Theory of Consciousness provide the long sought Mechanism for Consciousness

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A *fractal theory of consciousness* is considered where consciousness occurs at or below the Planck scale on the holographic foundation or event horizon boundary of space-time in a sub-quantum substrate. Consciousness communicates, with perfect fidelity, up to the level of living minds, that are orders of magnitude larger, using fractals that exist only when minds are at a *critical point*. Consciousness, and perhaps even memory, operate external to the human mind, analogous to the resilience and redundancy benefits seen in modern information technology *cloud computing*. Analogies in modern physics and cosmology are provided in support of the model.

Renormalization as a link between consciousness and fundamental physics

Recent research has hinted at relationships between the tool used by physicists known as *renormalization.* Renormalization is a mathematical technique which raises analysis "up a level" to ignore infinities that prevent finding a quantitative solution [1]. Scientists have noticed that similarities exist between human perception and renormalization that support the theory of brains operating at a *critical point* - where every neuron has influence on the network as a whole [2]. Research in renormalization, as well as *deep learning* and biological learning, all point to a common theme of compression of information i.e., optimization of data processing [1]. Experiments by many scientists have created a description of the brain as balanced precariously at a critical point between periods of calm and avalanches of activity [3].

Science writer Natalie Wolchover described the work of Pankaj Mehta and David Schwab on artificial intelligence deep learning:

> "renormalization, which allows physicists to accurately describe systems without knowing the exact state of all their component parts, also enables the artificial neural networks to categorize data as, say, "a cat" regardless of its color, size or posture in a given video. Renormalization is a systematic way of going from a microscopic to a macroscopic picture of a physical system, latching onto the elements that affect its large-scale behavior and averaging over the rest… a suite of sophisticated approximation schemes is required to slide up the distance scales, dilating the relevant details and blurring out irrelevant ones along the way" [1, 4].

Notice how renormalization, as an approximation and methodology, is similar to Isaac Newton's use of the *limit* in Calculus as well as techniques created by Benoit Mandelbrot with fractal math. Benoit Mandelbrot's famous paper *How long is the coast of Britain?* shows how fractal mathematical techniques are similar to the renormalization concept of "rising up a level" (e.g., an observer viewing a fractal) thus averaging out the coarse items to find higher order relationships for optimization of speed (reduction of calculation time) or to get a holistic "view," and ultimately a solution, for what seemed to be a problem hidden in infinities - as seen in the example for the approximate answer to the length of the coast line of Britain [5].

Thus, perhaps the similarities between the techniques used to solve fractals and renormalization hint at a deeper connection in nature. Could it be that the nature of the smallest units of space-time, let us say a theoretical Planck-length space-time "pixel," as opposed to a fundamental particle like an electron, is actually not a square or circle, in terms of its shape or dimension, but is, rather, a fractal shape? Could a space-time pixel that is fractal in nature possibly provide a sink-like surface area where gravity dilutes and is, thus, so comparatively weak, compared to the other three fundamental forces in the Standard Model, as strong gravitational fields diffuse into the "cracks" of the fractal pixels of space-time?

Consciousness via fractals

Fractals are scale-invariant. [6]. When a system's properties remain unchanged when viewed at different scales, we say it is *scale invariant*. This is the key attribute of fractals where the same patterns

repeat themselves at smaller and smaller sizes. This feature of scale invariance or *self-similarity* is comparable to zooming in with a magnifying glass on an image to uncover finer, previously not visible, new structure or details. However, when done on fractals, no new detail appears and the image does not change. Instead, we see the same pattern repeating over and over [7, 8].

Extensive study of phase transitions have shown how scale invariant phenomena such as fractals and power laws emerged at the *critical point* between phases [9-17]. Woodrow L. Shew et al., noted in their research that "findings suggest that in the cortex, balanced excitation and inhibition establishes criticality, which maximizes the range of inputs that can be processed, and spontaneous activity and input processing are unified in the context of critical phenomena" [18]. John M. Beggs, in his book *The Cortex and the Critical Point,* notes:

> "One of the main consequences of being near a critical point is scale-free property. These are hypothesized to lead to optimal information transmission and also thought to optimize dynamic range, sensitivity to inputs, information storage, and computational power. Just being near the critical point will produce optimality over the scale of the brain" [19].

Brains are optimized at the critical point and consciousness fades as the brain drifts away from it, for example when a person is under anesthesia. Adam J. Eisen and his team:

> "found that propofol-induced unconsciousness is associated with destabilized neural dynamics. ... Propofol disrupts the balance between cortical excitation and inhibition. This balance is known to be critical for maintaining the stability of cortical dynamics. Combined with our findings, this paints a picture in which propofol tampers with this balance, causing widespread cortical instabilities and thereby disrupting the brain's capacity for information processing. Overall, our analysis suggests a mechanism for anesthesia that involves destabilizing brain activity to the point where the brain loses the ability to maintain conscious awareness" [20].

Is consciousness basically cloud computing?

Some of the principles that drove the creation of modern information technology *cloud computing* include its resiliency and redundancy. These traits are also common to life, or gene pools, focused on long-term survival. Thus, we might extend the cloud computing analogy to brain criticality.

At the critical point, brain signaling is *scale invariant* (a fractal pattern going down to the smallest scale). Thus, might it be the case that life has found a "location" or mechanism for optimal information processing?

Might it be the case that human consciousness does not actually lie inside our physical brain but, rather, lies in the space-time boundary as described in the Holographic Principle? According to the Holographic Principle, information encoding everything taking place in our three-dimensional world is encoded on the boundary of that region as a kind of hologram [21-29]. Perhaps the reason for brain criticality is that, by reaching a state of scale invariance, actual thought and intelligence, occurring at the microscopic boundary, is thus able to be communicated up (and sensory inputs down) a "fractal ladder" to the scale of neurons in our macro world.

The brain, at its critical point, where self-similar fractals occur and each smaller fractal scale or level is exactly in-sync (has the perfectly identical pattern) with the top level (by definition), thus becomes a "vertical" human data network channel. Life as experienced in the living minds of organisms, in order to *read* and *write* data with perfect fidelity on a space-time substrate (the universe's boundary or event horizon), utilizes fractals in minds at a critical point. Only a fractal pattern can maintain perfect fidelity up and down such a scaling distance. It is this idea that explains why consciousness occurs at a critical point which is the only state where fractal self-similar and scale invariant structure can occur.

The brain at its critical point, where all scales are identical fractals (i.e., synchronized), becomes synonymous with the definition of a "vertical" human data network telecommunications channel. According to the formal definition of a telecom channel, when a continuous stream of fixed-length frames are sent, a synchronized receiver can in principle identify frame boundaries forever, and receivers can usually maintain synchronization despite transmission errors [30, 31].

If all particles and forces that create our reality can, in theory, be encoded in a boundary, then why not consciousness as well? Colloquially this might imply that every consciousness is part of a single consciousness (the singular boundary of our universe) and perhaps even add some merit to metaphysics as one's conscious *self* may already, and inherently, exist external to our physical world.

Consciousness as a tool for life

We may consider life less as an "inventor," and more of an entity that commandeers, almost always, out of necessity. We can envision life, with an ecosystem on planet earth that becomes increasingly large, diverse, complex, and intelligent, using whatever "tools" it can find for any competitive advantage e.g., neurons, memory, categorization and labelling, planning, learning, language, etc. Then we can imagine life seeking improvements on each of these including long-term memory, modeling, written language, and possibly even fractal messaging and holographic memory as fast, resilient, and perhaps abundant critical information processing resources.

We can speculate that it is the fractal structure that allows life to utilize yet another advanced data processing mechanism and to access a microscopic space-time substrate. We can imagine life using fractal structures for not only optimal memory storage but, perhaps, also to access an ultimate memory or ultimate "library of libraries," akin to Carl Jung's *collective unconscious* [32-35]. There is an obvious analogy here between the self-similar and infinite regression of a fractal, and the recursive nature of consciousness where a mind can ask or ponder i.e., why it asks why it asks why.

But is there any evidence that the universe is fractal at a fundamental microscopic scale? Modern theoretical research does support this claim [36-43]. Oliver Lauscher et al., note that:

> "spacetime is a fractal in general, with a fractal dimension of 2 on sub-Planckian length scales. … The scale-free relation suggests that at distances below the Planck length… is a special kind of fractal with a self-similar structure. …This phenomenon is familiar from fractal geometry"[36].

Mary Alexandria Kelly et al., who proposed the idea of human brains using holographic reduced representations (HRRs) or associative memory, note that:

> "The mathematics of holography has long been suggested as the principle underlying the neural basis of memory… holographic associative memories have also been used to model how humans understand analogies and the meaning of words, how humans encode strings of characters, and to model how humans perform simple memory and problem-solving tasks" [42].

German physicist Asterid Eichhorn stated in a 2026 interview with Charlie Woods in *Quanta Magazine*:

> "Or you can say that fields and particles persist; space-time persists; and the new thing is that space-time takes on a structure that is, broadly speaking, like a fractal: The intensity of the forces, including gravity, stops changing, and you start seeing the same picture, the same rules for how particles talk to each other, over and over. That's the idea I'm pursuing, asymptotic safety. If this self-similar realm exists, then the fluctuations of space-time, and of the other fields, would become stable enough for us to make predictions using good old-fashioned quantum field theory" [43].

In a 2026 article in *New Scientist* discussing the strong nuclear force, that binds quarks inside protons and neutrons, and the mathematical techniques of Martin Hairer, Michael Brooks wrote:

> "Hairer agrees. "Dimension four is really special for these kinds of theories, especially Yang-Mills, that's because the 4D Yang-Mills equations are "scale-invariant", meaning they look essentially the same no matter how closely you zoom in or out. Hairer's method relies on teasing apart behavior at different scales before surgically stitching them back together. But if every scale behaves identically, that strategy loses its leverage" (pg. 33) [44].

Another example of research that supports the idea of a deeper reality with the capability of memory involves theoretical work in the field of fundamental physics regarding *quasiparticles*. Institute of Theoretical Physics professor Leon Balents states that "unlike other particles we know of, these quasiparticles (Abelian anyons) can, in effect, remember how they have been manipulated… your electrons, photons, and quarks - may themselves emerge from something deeper" [45].

Analogies in modern physics and cosmology

If consciousness does exist on a foundational boundary of our universe, equivalent to an *event horizon* from physics and cosmology, then we encounter some startling direct analogies in these fields to the proposed model of consciousness. Our model may not only describe a mechanism for consciousness in the brain, it may also help provide a solution to *the measurement problem* in quantum mechanics. The Measurement Problem, in short, seeks to answer how, in a probabilistic world of superpositions described by quantum wave functions, when an observer measures a particle, they obtain a distinct result as experienced in our classical physics macroscopic reality. In short, how does this process of *decoherence* of a quantum wave function into a single particle at a specific location occur?

Cosmology has determined that the boundary of a black hole is synonymous with the boundary of our universe [46]. University of California Berkeley professor Yasunori Nomura in 2017 noted in *Scientific American* that "any description of the quantum state of the universe should include only the region within (and on) the horizon - in particular, there can be no infinite space in any single, consistent description of the cosmos (pg. 35)" [46].

Lyndie Chiou noted in the February 2025 edition of *Quanta Magazine*:

> "…regions of space-time can also become disconnected, or decoupled, in the presence of strong gravitational fields, such as those found in and around a black hole. These fields slow down the flow of time so much that interaction becomes impossible. …strong gravitational fields can cause space to decouple… as you get close to a singularity, the strong gravity causes every point in space to decouple from every other one. This means that each tiny part of space behaves on its own terms" (pg. 6) [47].

Let us make a profound conclusion from the language in these above sentences. We take our universe's foundational boundary to be equivalent to an event horizon. If event horizons are associated with strong gravitational fields and if strong gravitational fields can decouple or separate space-time into every unique point as noted, then how is this any different from quantum mechanical wave function decoherence i.e., the answer to *the measurement problem*?

If our brain is quantum entangled with the event horizon foundational boundary of our universe, and if we assume consciousness exists in this event horizon or substrate boundary, then perhaps consciousness is equivalent to "processing," dynamics, or changes occurring from strong gravitational fields! The results of this "processing" at the extreme distance (cosmologically and microscopically far away) is then communicated and enlarged into our macroscopic world, without loss, via fractal patterns formed in brains at critical points. Minds are envisioned in the model as utilizing foundational aspects of reality including quantum entanglement, fractal patterns, and strong gravitational field dynamics.

But any processing, change, or dynamics requires time i.e., a clock? Zack Savitsky wrote in the January 31 edition of *New Scientist* how scientist Paola Verrucchi "thinks she has stumbled upon nature's supreme clock" (pg. 30) [48]. Verrucchi describes an existential "clock" as comprised of:

> "…enough energy to track the evolving systems; isolation, so its evolution wouldn't be scrambled by outside noise; and the ability to become entangled with whatever it is keeping time for. …something in nature ticks all three boxes: black holes. These energetic objects have gravitational fields around them that are so strong that not even light can escape their event horizon, making them essentially non-interacting. Yet…they can still become entangled with the outside world. A pair of quantum particles might form at the black hole's horizon, with on falling in and the other escaping as radiation. In this way, the inside of the black hole becomes linked to the outside - perhaps just enough to act as a timekeeper. "It's a perfect clock… you cannot interact with it, but at the same time, you can be

> entangled with it"… The arrow of time might simply be a record of what has been measured"" (pg. 31) [48].

Here again let us compare the language in the referenced research to our model. We can imagine *strong gravitational fields* versus "enough energy," the boundary *event horizon,* by definition, as fulfilling the requirement of "isolation," and atoms to comprise our physical brains as entities able to be entangled with a "time keeping" event horizon at the boundary of our universe. Black holes may literally be the boundary of our universe simply "protruding" into our local region of space. One might argue that black holes alone then should be able to collapse wave functions, if not contain consciousness. But recent research has already shown the former [49]. Thomas Lewton described the research of Robert M. Wald and his team in *Quanta Magazine* in 2023:

> "The mere presence of a black hole, they've found, is enough to turn a particle's hazy "superposition" - the state of being in multiple potential states - into a well-defined reality. "It evokes the idea that these black hole horizons are watching" … "What we have found might be a quantum mechanical realization of [the participatory universe], but where space-time itself plays the role of the observer," …Theorists are now debating what to read into these watchful black holes. "This seems to be telling us something deep about the way gravity influences measurement in quantum mechanics" (pg.1) [49].

Conclusion

If consciousness is fractal and exists with memories on a holographic boundary or event horizon, then many questions still remain. Has a microscopic consciousness, or even a collective subconscious, always existed? What is the exact process or protocol by which memories are stored and fractal messages sent? What is the minimum size in bits of a fractal message or duration in time? Can we observe, prove, or even change fractal messages or memories in a brain or in the holographic boundary event horizon? If we understand the mechanisms deeper, can a machine be built that has consciousness? Does this model imply that a consciousness could exist after the death of a physical body or brain? Is there a maximum limit to the amount of memory in an event horizon or holographic boundary of a universe? Could an increase in the amount of memory stored in a boundary be in any way part of the observed Dark Energy driven expansion of the size of our Universe?

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