Conscious and Unconscious Boundaries: A Mathematical Model of Consciousness Dynamics

Ariel Fuchs

Gaia College – Academy of Science & Technology

In memorial of

Dr. Erel Shalit, PhD

past president of the Israel Society

of Analytical Psychology Jungian psychoanalyst

1.   Abstract

This paper develops a formal model of consciousness dynamics grounded in Jungian psychology and recent scientific theories. We propose the *Fuchs Consciousness Equation*, $\partial C/\partial t = k(I \times E - \alpha C)$, linking conscious states to inner drives (I), environmental contexts (E), feedback (α), and coupling (k) (Fuchs et al., 2025). This paper emerges from Jung's exploration of ego–unconscious boundaries in the *Red Book* (Jung, 2009). We interpret the variables in Jungian terms—viewing I and E as inner archetypal and outer experiential forces and α and k as regulating constants. Mapping Jungian dynamics onto the equation, we show how conscious content arises from the interplay of ego, archetypal drives, and context, and how unconscious material gains expression through boundary negotiation. The framework reveals recursive feedback and spiral developmental patterns of consciousness (Beck et al., 2018), where each stage involves threshold crossings and bifurcations of inner and outer influences (Prentner, 2025). Archetypal symbols resonate as collective factors modulating individual awareness (Sun & Kim, 2024) and symbolic entropy is regulated by the balance of order and novelty (Carhart-Harris et al., 2014). Applications include new research hypotheses (e.g. measurable neural correlates of boundary dynamics),

integrative therapeutic techniques (combining dynamical systems with depth psychology), and AI models of self-organizing cognition. This interdisciplinary model unifies first-person phenomenology with quantitative modeling (Prentner, 2025; Carhart-Harris et al., 2014). It offers a systematic account of consciousness as an emergent, negotiated process (Fuchs, 2025), advancing theory and suggesting future lines of empirical and theoretical work.

2. Introduction

The nature of consciousness has long been framed by the boundary between the conscious mind and the unconscious. Carl Jung's *Red Book* (2009) vividly illustrates this dynamic boundary, as Jung's ego dialogued with unconscious figures like Philemon during his explorations of inner space. Contemporary theory likewise views consciousness not as a fixed internal object but as a process of ongoing boundary negotiation. For example, recent work of Fuchs (Fuchs, 2025; Fuchs et al., 2025; Fuchs & Fuchs, 2025) argues that "consciousness [is] a dynamic boundary negotiation process rather than a fixed entity". Similarly, philosophers of mind have noted that the limits of the conscious self are not rigidly fixed at the skull but are fluid, extending through recursive feedback with the world (Kirchhoff & Kiverstein, 2020). In this context, Fuchs et al. (2025) formalized these boundary dynamics mathematically.

This paper develops the Fuchs Consciousness Equation, $\partial C/\partial t = k(I \times E - \alpha C)$, as a simple differential model of the flux of consciousness. This equation is introduced in recent work as "the first mathematical framework" to unify diverse domains of experience (Fuchs et al., 2025). Our goal is to interpret and expand this model: we derive it from epistemological considerations, connect each term to psychological constructs, and show how it captures key phenomena described in depth psychology and consciousness science. In doing so, we bridge Jung's phenomenological insights with rigorous modeling, setting a foundation for testing and application. The introduction of this formal framework opens new avenues for understanding consciousness as an active, emergent, and negotiated process.

3. Literature Review

Jung famously posited a collective unconscious, a shared psychic substrate of archetypal images, underlying individual awareness. Archetypes are "ancient patterns and images that originate in the collective unconscious" and manifest as symbols in dreams, myths, and art (Sun & Kim, 2024). In Jung's view, the conscious ego is only one center of the psyche, which must integrate these unconscious archetypal forces through individuation. Jung described guides and phenomena (e.g. his inner mentor *Philemon*) as autonomous aspects of this psyche that influence consciousness. Depth psychologists have continued exploring these ideas; for instance, shamanic rituals show how archetype symbols (masks, totems, patterns) can induce profound shifts in consciousness by "connecting the individual to the collective unconscious" (*ibid*.). Such findings underscore that unconscious or symbolic contents can resonantly affect personal awareness, pointing to boundary permeability between personal and collective levels.

In parallel, scientific theories of consciousness have embraced quantitative modeling. Integrated Information Theory (IIT) is one prominent example: it formally defines consciousness in terms of how integrated a system's informational structure is (Kleiner & Tull, 2021). Kleiner and Tull (2021) provide an axiomatic formulation of IIT, highlighting the importance of integration and

causal structure. Other approaches focus on brain dynamics: the *entropic brain hypothesis* posits that different conscious states correspond to different levels of neural entropy (Carhart-Harris et al., 2014). Carhart-Harris et al. (2014) argue that high-entropy "primary states" (such as psychedelic or dreaming states) contrast with the more ordered structure of normal waking consciousness; in this view, the brain normally suppresses entropy to maintain stable awareness. Threshold and bifurcation dynamics have also been observe (Sergent et al., 2021): EEG studies find that, for a given stimulus, neural responses can bifurcate into either sustained activity or near-silence, predicting whether the stimulus reaches awareness. This suggests an all-or-none threshold at which unconscious processing becomes conscious. Altogether, these models treat consciousness as a dynamic process (integration, criticality, bifurcation) rather than a static state, resonating with the Jungian view of evolving boundaries.

Philosophical work emphasizes that consciousness' boundary is negotiable. Kirchhoff and Kiverstein (2019) note that positing a strict skin-skull boundary is unwarranted; instead, conscious processes arise from complex networks of feedforward and feedback interactions. This perspective is echoed in embodied and extended mind theories, which allow the environment and tools to become part of cognitive "boundaries." In summary, the literature converges on two insights: (1) consciousness involves interplay between internal and external influences (archetypal drives, sensory context, cognitive frameworks); and (2) this interplay often has nonlinear, emergent characteristics (integration vs. fragmentation, thresholds, entropy regulation). However, a unifying formalism bridging Jungian phenomenology and dynamical systems has been lacking. The Fuchs Consciousness Equation aims to fill that gap by explicitly linking psychology and mathematics.

4. Methodological Framework

Our approach is interdisciplinary, combining phenomenological, Jungian, and dynamical perspectives. Epistemologically, we treat consciousness as an activity rather than a substance. We adopt a mathematical formalism analogous to models of biological or cognitive growth, where *rate of change* of consciousness ($\partial C/\partial t$) depends on input factors and intrinsic dissipation. This choice reflects a process-oriented view (in line with process philosophy and neurophenomenology). Conceptually, we posit that consciousness increases when inner and outer factors align and exceeds a damping effect from habituation. The equation $\partial C/\partial t = k(I \times E - \alpha C)$ was proposed in prior work (Fuchs et al., 2025); here we derive it heuristically by balancing two terms. The first term, $k\,I\,E$, represents a *generative drive* proportional to both internal intent (I) and external affordances (E). The second term, $k\alpha C$, represents a *dissipative feedback* scaling with existing conscious content. The constant k sets overall coupling strength, while α governs how quickly consciousness decays absent new inputs. This form is analogous to logistic or Lotka-Volterra dynamics, capturing feedback loops. In sum, our model is grounded in a cybernetic epistemology: we model the ego-field C as a dynamic variable fed by driving forces and moderated by feedback.

Mathematically, we treat I, E, and C as time-dependent scalar measures of psychic energy or information. This is admittedly a simplification, but it allows us to draw conceptual parallels. Our framework thus inherits the interpretive flexibility of phenomenological description, now cast into a differential form as Prentner (2025) advocates for mathematizing first-person phenomena. By formalizing phenomenological primitives (intentional drive, situational field, and ongoing awareness) in one equation, we aim to make Jungian insights amenable to empirical inquiry. Importantly, the model remains at the level of "proto-physics" of the psyche, not tying itself to

specific neurobiological substrates. This reflects the phenomenological ambition to describe conscious structures directly, rather than only their neural correlates. The resulting equation provides a quantitative scaffold on which we can map Jung's terms and predict how consciousness evolves under various scenarios.

5.   Results and Theoretical Integration

Mapping Equation Variables to Jungian Concepts

In our model, $\partial C/\partial t$ represents the current state of conscious awareness or ego-conscious content. It can be thought of as the "light of consciousness" illuminating certain psychic material. *I* denotes internal drive or intention – the inner archetypal energy or libidinal charge pushing for manifestation. Jung's notion of libido as psychic energy is apt here: intense emotional or archetypal forces heighten I. *E* denotes the external or environmental context – the objective stimuli, cultural symbols, and situational fields receptive to meaning. Together, the product I×E captures the idea that consciousness grows most when a strong internal impulse meets a conducive external frame (for example, an archetypal symbol in a meaningful context). The term αC models *feedback damping*: once a content is conscious, it loses novelty and further growth is curtailed unless new inputs arise. Jung described the ego as habituating to patterns over time, which parallels how α suppresses growth. Finally, *k* is a coupling constant reflecting boundary permeability or overall sensitivity – higher k means the psyche more readily incorporates new material.

Using these identifications, the equation reproduces key Jungian dynamics. When I and E are large (e.g. intense inner charge in a rich context), the term kI E drives $\partial C/\partial t$ upward: the ego rapidly brings unconscious material into awareness (as in a visionary experience). As C grows, the −kαC term slows the growth, modeling saturation and the need for a "reset" (perhaps a symbolic transformation) before further development. If I×E falls below αC, then $\partial C/\partial t$ becomes negative and conscious content fades back into the unconscious reservoir – analogous to forgetting or repression. In this way, the equation captures the boundary negotiation between conscious and unconscious contents. Importantly, this mapping is not merely metaphorical: it explains why large archetypal factors can ignite consciousness, and why consciousness self-stabilizes.

Consistency with Established Theories

This integration aligns with several theoretical results. For instance, Kleiner and Tull (2021) emphasize that conscious experience depends on the integration of information within a system; our term I×E can be seen as a measure of integrated internal and external information. Likewise, the entropic brain hypothesis suggests normal consciousness suppresses entropy through organized patterns (Carhart-Harris et al., 2014); in our model, the −αC term enforces order, preventing runaway complexity. The existence of thresholds also emerges: setting $\partial C/\partial t = 0$ yields a balance point kI E = kαC, so that consciousness can only increase if I×E > αC. This reproduces an all-or-none condition reminiscent of experimental findings that neural activity must reach a critical threshold (around ~250 ms) to achieve reportable awareness (Sergent et al., 2021). In summary, each variable in the Fuchs Equation finds a natural counterpart in Jung's framework: I (inner aim), E (environment/sense-data), C (ego-conscious field), α (dissipation), and k (boundary openness).

6.   Additional Contributions

Recursive Feedback and Spiral Development

The equation intrinsically allows *recursive feedback*: as C rises, it feeds back into future dynamics. Iterative application of the equation can produce spiral-like development of consciousness, echoing Jung's and later thinkers' notions that each stage of awareness is built upon the last. This is reminiscent of the *Spiral Dynamics* model (Beck & Cowan, 1996), which posits that human development progresses through emergent stages. In our terms, when C grows, it may alter I and E in subsequent cycles, leading to new emergent I×E conditions in a higher 'spiral' stage. Recent analyses of symbolic cognition support this idea: for example, studies of altered states find that symbolic content often recurses over itself – participants "become language" or experience metaphor loops – suggesting that consciousness can re-enter earlier themes at a higher level (Saqr, 2025). In therapeutic or developmental contexts, this implies that the ego revisits unconscious material repeatedly, each time at a deeper or expanded level, much like climbing a spiral staircase. Our model provides a formal mechanism: recursive terms (C feeding back into I or α) could be added to represent how past conscious growth alters future drive or damping, yielding self-sustaining spiral trajectories of individuation.

Boundary Negotiation Dynamics

The model highlights active *negotiation* of boundaries. Consciousness increases only insofar as inputs exceed resistance. Philosophers note that viewing the self as enclosed by the skull is unwarranted (Kirchhoff & Kiverstein, 2020); similarly, our model shows the "edge" of consciousness (controlled by k and α) continually adjusts. In practice, this could mean that intense experiences (high I or E) temporarily expand the boundary (effectively increasing k), allowing otherwise unconscious material into awareness. Conversely, strong damping (high α) can contract boundaries, closing off consciousness to extraneous stimuli. This dynamic resonates with clinical observations: for example, during trauma or ritual, boundaries can temporarily dissolve, enabling unconscious content to erupt; afterward, boundaries re-form. Our framework suggests these shifts are the result of changing parameter values, and could be modeled as bifurcations in (I, E, k, α) space. In short, the Fuchs Equation formalizes boundary negotiation as a feedback-regulated process, moving beyond fixed-boundary assumptions.

Archetypal Resonance as Collective Influence

Archetypes function in our model as sources of collective influence that modulate I and E. Jung argued that archetypes manifest through universal symbols tapping into the collective unconscious (Sun & Kim, 2024). In equation form, encountering an archetypal symbol in the environment (E) can multiply any inner intention (I), giving rise to outsized $\partial C/\partial t$. Likewise, internal archetypal complexes can raise I even when personal preference is low, priming consciousness for particular thematic content. Empirical work on ritual symbolism supports this: archetypal symbols in shamanic context induced a "conscious dissolution of the self," carrying participants to peak experiences (*ibid.*). In our terms, this is an extreme case of I×E dominance driving C. Moreover, archetypes create *resonance* across individuals: when a symbol (collective content) is present in E, many people experience a similar effect, reflecting a shared unconscious pattern. The equation implies that group-level "E" (culture, narrative) can collectively pump I across a population, a

point relevant to fields like sociology of religion or mass psychology. Thus, the Fuchs model accommodates collective unconscious effects by treating archetypal factors as strong modulators of the boundary dynamics.

Symbolic Entropy Regulation

Our model naturally engages with ideas of entropy and order. The term $-\alpha C$ acts to reduce "noise" by damping ongoing consciousness, akin to maintaining ordered cognitive function. This mirrors the *entropic brain* view that normal consciousness operates with suppressed entropy (Carhart-Harris et al., 2014). Symbolically, αC could correspond to memory consolidation and reality-testing that prevent runaway free-association. If α is too low, our equation predicts entropy-like explosion (C grows uncontrollably), analogous to psychotic or psychedelic states. Conversely, if α is too high, consciousness becomes rigid and low-entropy (risking numbing or depression). Thus, adjusting α might correspond to symbolic regulation: therapeutic interventions (like grounding or narrative integration) might effectively raise α to restore order. In summary, the Fuchs Equation embeds a quantitative mechanism for symbolic entropy regulation, with α tuning the trade-off between novelty and coherence.

Threshold and Bifurcation Dynamics

As noted, the balance point $kI E = k\alpha C$ defines a threshold for conscious change. This predicts bifurcation behavior: small changes in I or E around this threshold lead to qualitative shifts in $\partial C/\partial t$. Empirical neuroscience corroborates such bifurcations. Sergent et al. (2021) found that identical stimuli produced either a late sustained EEG response or none, a clear "all-or-none" bifurcation linked to conscious perception. Their finding that conscious report coincides with an abrupt neural transition (around 250–300 ms) is a neural analog of our model's threshold crossing. In the Fuchs framework, this corresponds to moving from a subthreshold (unconscious) regime to a superthreshold (conscious) regime. These insights imply that consciousness emerges via critical transitions, not smooth gradations, consistent with our differential equation's nonlinear character. Future work might classify these transitions (e.g. saddle-node or Hopf bifurcations) in terms of psychological phenomena like epiphanies or insights.

Autonomous Archetypal Guidance (Philemon Principle)

Finally, the model can accommodate Jung's notion of autonomous guidance from the unconscious. Figures like Philemon in Jung's vision exemplify how the psyche can organize itself; symbolically, this is an act of *self-regulation* of the Fuchs parameters. One can view Philemon's guidance as an embodied increase in I or re-tuning of k: an internal mentor raising awareness of neglected content. In practice, this suggests that under some conditions, archetypal knowledge (collective wisdom) becomes an independent driver of consciousness dynamics, without being reducible to personal intention. We term this the *Philemon Principle*: the idea that archetypal forces can autonomously steer ego development. While philosophical, this aligns with Jung's reports and underscores that our model is open to agents beyond the personal self: the unconscious can be modeled as a separate subsystem influencing I and C in the same equation. In therapeutic or creative contexts, acknowledging this principle means treating archetypal figures as real "participants" in one's consciousness dynamics.

7.   Practical Applications

The Fuchs Equation suggests several applications. In research, it proposes concrete variables (I, E, α, k) to measure. For example, experimental paradigms could manipulate I (motivation) and E (contextual richness) to test predicted changes in conscious reportability or neural markers (EEG or fMRI dynamics). The threshold condition (I×E ≈ αC) could be experimentally verified by gradually varying stimuli intensity until a bifurcation of response occurs. In therapy, the model offers a framework to integrate psychodynamic and cognitive techniques. Therapists might assess how clients' boundaries (k, α) are too rigid or too loose and intervene accordingly (e.g. grounding techniques to raise α, or imagination exercises to enhance kI×E). Jungian-active imagination and dream analysis can be seen as methods to modulate I and E in safe ways. For artificial intelligence and cognitive modeling, this equation can inspire architectures in which an agent's "awareness" variable adapts dynamically to internal drives and environmental input. For instance, unified consciousness simulators might implement similar feedback laws to balance exploration (entropy) and stability. In all cases, this model encourages bridging subjective and objective methods: questionnaires or EEG could quantify C; measures of arousal or expectancy could index I; and environmental complexity metrics serve as E.

8.   Meta-Theoretical Discussion

Our integration exemplifies a *mathematized phenomenology* approach (Prentner, 2025). Instead of reducing consciousness to neural mechanisms, we encode phenomenological features directly into formal variables. This aligns with Prentner's call to construct mathematical representations of first-person structures (*ibid.*). We see the Fuchs Equation as part of a larger trend to synthesize phenomenology and science: it remains agnostic about whether I, E, and C are brain processes, field states, or emergent qualities. What matters is their relational dynamics. By providing a minimal topology of consciousness (intentional drive ↔ world ↔ awareness) in equation form, we create a common language for psychologists, philosophers, and neuroscientists. This addresses a key gap in consciousness studies: the "explanatory gap" between subjective experience and mathematical description. Our work does not claim to solve the hard problem, but it does offer a bridge: it encodes phenomenological distinctions (ego vs. archetype, inside vs. outside) in a dynamical systems framework. In future meta-theoretical development, one could combine this equation with richer mathematical structures (e.g. network models of brain regions or symbolic geometry) to expand the model.

9.   Conclusion

This paper has proposed and elaborated a quantitative model of consciousness dynamics inspired by Jungian psychology. By grounding the Fuchs Consciousness Equation in both depth-psychological concepts and recent consciousness science, we have shown that key features of conscious experience – boundary fluidity, archetypal influence, threshold transitions, and iterative development – can be formally represented. Our theoretical integration suggests new testable hypotheses and unites disparate literatures. Limitations include the model's simplicity and current lack of empirical parameter estimation. Future work should empirically validate the model (e.g. relating equation terms to neural measures) and explore extensions (multidimensional I, E; networked versions of C). Overall, this interdisciplinary exploration suggests that treating

consciousness as a dynamic, negotiable boundary phenomenon can yield fertile insights, potentially guiding research in psychology, neuroscience, and artificial intelligence.

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