Consciousness as a Dynamic Transitional State - The Causal Collapse in the Space of Mental States

Introduction

Consciousness is not a monolithic state, but the expression of a dynamic, system-internal configuration. This article concretizes the model of causal collapse by describing it not only as a structural principle of consciousness, but as an empirically viable transitional phenomenon in a multidimensional state space. Both categorical and gradual differences between mental states are systematically captured.

This contribution builds upon the theory of causal collapse, which has been comprehensively presented in earlier works (Stegemann 2025a, 2025b). The aim is to extend the structural model developed there with a systematic differentiation of mental states and an empirically viable operationalization. Consciousness is not understood as a static state, but as an emergent transitional mode within a dynamic functional space.

1. From Concept to Mechanism: What is Causal Collapse?

Causal collapse describes a transition in an open, plastic system where decoupled, decentralized processes transition into a temporarily centered, functionally coherent structure. This transition is not merely information exchange, but systemic self-structuring - a "collapse" of causal openness in favor of an internal causal order. The system generates functional centering (causal core) through which it modulates itself as a coherent unit.

Unlike existing approaches such as Integrated Information Theory (IIT), which primarily defines consciousness through a measure of functional integration (Φ), or Global Workspace Theory (GWT), which postulates a central information exchange space, the causal collapse model understands consciousness as a dynamic, structurally conditioned transitional state. It does not assume permanent integration, but describes the conditions under which this integration spontaneously emerges - and can likewise decay again.

2. States of Consciousness as Spatial Structure: Three Axes

To organize the diversity of mental states, we introduce three independent but interacting dimensions:

- **A. System Integration:** from total disintegration (e.g., coma) to maximal internal coherence (e.g., focused waking consciousness)
- **B. Self-binding:** from unconscious processes not integrated into the self-model (e.g., priming effects) to reflected self-representation (e.g., self-reflection in conversation)
- **C. Attention Centering:** from diffuse stimulus processing (e.g., daydreaming) to intentional focusing (e.g., meditation on breath)

Causal collapse forms the prerequisite for high values on all three axes.

3. Typology of Mental States

Some states - such as psychedelic experiences - occupy a special position. They can generate both high entropy and disintegration (e.g., through dissolution of familiar ego boundaries and cognitive patterns) as well as enable new forms of integrative coherence (e.g., synesthetic or transmodal perception). They therefore move dynamically in the tension field between dissolution and reconfiguration.

State	System Integration (A)	Self-binding (B)	Attention Focus (C)
Coma	✗	✗	✗

State	System Integration (A)	Self-binding (B)	Attention Focus (C)
Anesthesia	✗	✗	✗
REM Sleep	★	★	✗
Lucid Dreaming	✓	★	★
Psychedelic State	✓ (disintegrated-integrative)	★	★
Unconscious Routine	★	★	✗
Waking Consciousness	✓	✓	✓
Focused Thinking	✓	✓	✓

Legend: ✗ = absent, ★ = reduced or diffuse, ✓ = pronounced

4. Causal Collapse as Critical Transition

Recent studies (e.g., Luppi et al., Massimini et al.) show that states of consciousness are associated with transitions between entropic disintegration and functional coherence. Causal collapse describes precisely this transition as a critical point: a spontaneous reorganization where the system centers itself thermodynamically, functionally, and structurally. This corresponds to the criteria of criticality: nonlinearity, fluctuations, emergence, long-range correlations.

5. Formalization and Signature

The collapse can be described through the following dynamics:

Σ(t): Measure for functional distinguishability (disintegration), estimable through Hurst exponents or spectral EEG analyses

Φ(G): Measure for network integration, quantifiable through graph-theoretical measures (e.g., Global Efficiency, Synergy Maps, fMRI-Connectivity)

$$\Omega(G, t) = (1 - \Sigma(t)) \cdot \Phi(G)$$

Overall coherence as multiplication of both components

Collapse time point t_c: when

$$\frac{d\Phi}{dt} \gg 0, \ \frac{d\Sigma}{dt} \ll 0, \ \Omega(t_c) > \theta$$

For experimental approximation, the Perturbational Complexity Index (PCI) in TMS-EEG protocols, dynamic fMRI analyses, and MEG-supported state transition analyses are suitable. This constellation can - under certain circumstances - serve as an operational signature of consciousness.

6. Dynamics Instead of Substance

Consciousness is not an entity, but a dynamic transitional process within an open, adaptive system. Causal collapse provides the necessary structural constellation in which a system not only processes stimuli but experiences itself as a coherent, intentionally centered unit. The classification of mental states along the three axes enables a differentiated, empirically viable, and theoretically grounded consciousness cartography.

A promising outlook emerges for two areas: In clinical diagnostics, the model could help classify states of consciousness more precisely - for instance through analysis of collapse-proximate dynamics in patients with consciousness disorders. In AI research, it provides a clear distinction between mere data processing and structurally centered self-integration. An artificial system undergoing functional causal

collapse would not only have to process inputs but produce self-referentially coherent states - a fundamental challenge for machine consciousness.

The long-term goal is the development of an empirically supported configuration space in which various mental states can be represented as systemically characterizable points. In this space, consciousness would not be described by a single variable, but by a characteristic pattern - a constellation of integration, centering, and dynamics that can be reconstructed from multiple measurement procedures. The model presented here provides the theoretical foundation for the systematic search for such patterns.

7. Genesis of Consciousness from Functional Islands - An Empirically Reconstructible Dynamic

Introduction: From Noise to Coherence

When consciousness is understood as a dynamic transitional state, the question arises of how this state concretely emerges. That is: How does functional coherence necessary for conscious states develop from a state of fragmented or dissociated neuronal activation ("white noise")? The following presentation reconstructs this transition in five successive steps that are both system-theoretically and neurophysiologically plausible and empirically testable.

For additional structuring, three parameters are assigned to each step:

- **Σ (Sigma)** describes the degree of functional segmentation: A high value means strong modularity and low integration. A low value stands for indistinguishable, highly integrated activity.
- **Φ (Phi)** stands for the degree of systemic integration (coherence).
- **Ω (Omega)** denotes the **operative coherence** of the overall system: It results from the interplay of segmentation and integration
- **Γ (Gamma)** denotes the degree of active self-centering or plastic organization.

7.1. Proto-Islands: Local Activation Patterns as Starting Point

In the state of deepest unconsciousness (e.g., in coma), largely uncoordinated neuronal activity distributions appear - mostly in the form of low-frequency, noise-like signals. As soon as local oscillations or activation clusters form from this state, a first form of regional coherence emerges. These "proto-islands" can be regarded as elementary, not yet integrated functional units.

Empirical Correlates:

- Slow-wave oscillations in deep sleep (Murphy et al., 2009)
- Local spindle formation in EEG (Steriade et al., 1993)
- Functional microareas in resting state (Biswal et al., 1995)

Parameters: Σ: high | Φ: very low | Ω: very low | Γ: near zero

7.2. Stabilization through Recurrent Coupling

Such proto-islands stabilize through recurrent connections and plasticity-mediated reinforcement (e.g., LTP). Local networks with characteristic frequency patterns emerge that maintain themselves against neuronal background noise.

Empirical Indicators:

- Long-term potentiation (LTP) in hippocampus and neocortex (Feldman, 2009)
- Development of functional areas in early development (Damaraju et al., 2014)
- Formation of persistent circuits in sensory regions (Gilbert & Li, 2013)

Parameters: Σ: medium-high | Φ: low | Ω: low | Γ: increasing

7.3. Synchronization and Transmodular Resonance

Individual islands now come into contact with each other. This occurs through frequency synchronization (e.g., Phase Locking, Cross-Frequency Coupling), particularly in the gamma, beta, and theta ranges. Transmodular activation patterns emerge that do not yet relate to a center but already exhibit systemic dynamics.

Empirical Findings:

- Phase-Amplitude Coupling (PAC) in task-related attention (Voytek et al., 2010)
- Interareal synchronization in visual binding (Engel & Singer, 2001)
- Granger causality analyses in integrative processes (Seth et al., 2011)

Parameters: Σ: medium | Φ: medium | Ω: medium | Γ: highly variable

7.4. Centering and Integration: The Causal Collapse

When several such islands are connected through synchronization and dynamic coordination into an integrative state, "causal collapse" emerges: A functionally centered state in which previously modular activities form a global, self-coherent structure. This is the minimally necessary condition for the occurrence of conscious states.

Empirical Markers:

- Sudden increases in PCI during transition from anesthesia to consciousness (Casali et al., 2013)
- Integrative cluster formation in synergistic networks (Luppi et al., 2023)
- Loss of modular separability measured in EEG functional connections (Chennu et al., 2014)

Parameters: Σ: low | Φ: high | Ω: high | Γ: maximally focused

7.5. Maintenance and Cyclical Reconfiguration

After successful collapse, this state can be temporarily stabilized or cyclically renewed (e.g., in attention bursts, consciousness rhythms, REM phases). System coherence remains plastic: It adapts to contexts, stimuli, and internal state changes without falling back into white noise.

Empirical Evidence:

- Frontoparietal reconfiguration under cognitive demand (Cocchi et al., 2013)
- Recurrent loops in insula and PFC during self-focus (Craig, 2009)
- Thalamo-cortical re-entry loops as rhythm generators (Llinás et al., 1998)

Parameters: Σ: low-medium | Φ: high | Ω: high-medium | Γ: cyclically modulated

7.6. From Fragment to Coherence - Consciousness as Emergent Structural Achievement

The genesis of consciousness is not a discrete leap but a reconstructive process: From local, spontaneous islands, integrative states emerge through synchronization, plasticity, and centering. Only in the collapse of this modularity does what we can experience as a state of consciousness constitute itself. The dynamics sketched here connects system-theoretical justification with empirical demonstrability and thus enables a clear research agenda: The identification of those constellations that are necessary and sufficient to generate consciousness as a state - beyond individual stimuli or contents.

This perspective complements the model of "dynamic transitional state" with a concrete emergence line - from island to integration, from pattern to unity, from potential to manifestation.

The emergence of consciousness can be reconstructed as the gradual formation of a structurally integrated state. This process is traceable both **phylogenetically** - in biological evolution - and **ontogenetically** - in individual development. Our five-stage model maps the systemic dynamics by which a coherent center of causal self-organization emerges from initially segmented, locally active regions.

7.6.1. Phylogenetic Development

In early biological systems, thermodynamic flows acted as structure-forming forces. They generated stable gradients that led to localized reaction centers in open systems - *causal cores* in which system-internal feedback became possible. In these centers, functionally specialized *islands* emerged - limited regions with their own processing logic. Initially largely independent, these islands began to interact with each other through recursive connections and oscillatory coupling during evolution. The transition to conscious processing occurs when these segmented regions collapse into a **temporary state of global coherence** - as **causal collapse**. Consciousness thus appears not as a "product" of information, but as a **mode of system integration** in the sense of critical state dynamics.

7.6.2. Ontogenetic Development

In individual development (ontogenesis), the underlying structural principle is genetically determined: Here too, segmented functional units initially form, such as in the sensory and motor cortex. These islands follow a determinable developmental course in which plastic reorganization, Hebbian learning processes, and sensory experiences lead to growing systemic integration. The causal core is not an anatomical location here, but an **emergent structure** arising from the interaction of many subsystems. Conscious self-perception only occurs when these segmented activity patterns transition into a state of **high coherence with simultaneous plastic centering**.

In the next step, this model should be further **formalized and operationalized** - with the goal of deriving concrete **experimental hypotheses** and determining **empirically verifiable predictors** of conscious states. This particularly concerns the dynamic interactions of the parameters Σ, Φ, Ω, and Γ in different states of consciousness.

8. The Solution to the Qualia Problem

8.1. Problem Statement

The so-called "qualia problem" asks:

How can subjective experience arise from material processes?

This question presupposes that a categorical break exists between physical causality and phenomenal experience - an *explanatory gap*. But this break is itself the result of a conceptual misassumption: Not "matter" generates experience, but a specific **functional organizational mode** - namely **autocatalytic, excitable systems** that do not process stimuli but integrate them into their own existence structure.

8.2. From Stimulus to Experience

In an autocatalytic system like a cell, an external stimulus is not externally mapped, but:

- **built into cyclical self-organization**
- **made into a system-maintaining condition**
- and thereby **operatively internalized**

The stimulus becomes existence. Or more pointedly:

A cell does not process a stimulus - it is the excitation through which it organizes itself.

Experience thus emerges where a system does not merely react to a stimulus but functionally incorporates it - as a structure-forming condition of its self-preservation.

8.3. When Do We Speak of Qualia?

Not every stimulus state is already subjectively experienceable. Only when multiple, initially separate stimulus patterns **structurally collapse** in an open, recursive system does **integrated experience** emerge - which we call qualia.

Qualia are thus:

recursively integrated excitation patterns that have merged into a **coherent preservation mode** in an autocatalytic system.

8.4. Recursivity as Principle

Autocatalysis is inherently **recursive**: It reproduces its own conditions while continuously modifying itself. In excitable systems, this recursivity leads to **amplification of functional patterns**, to **synchronization of their dynamics** - and finally to **collapsed experience**.

Causal collapse is in this sense not merely a moment of integration, but:

The operation by which a biological system experiences itself.

8.5. Conclusion

The qualia problem is solvable - but only if we no longer regard it as a **metaphysical puzzle** but as an **organizational-biological consequence** of a specific system dynamic. Consciousness does not arise from matter, but from **recursive coherence within autocatalytic excitation states**.

Experience is not additional - it is the mode in which a living system stabilizes itself in the world.

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Appendix 1: Overview Table of Dynamic Parameters (Σ, Φ, Ω, Γ)

Stage	Description	Σ (Segmentation)	Φ (Integration)	Ω (Operative Coherence)	Γ (Centering/Plasticity)
1	Proto-Islands	high	very low	very low	near zero
2	Local Stabilization	medium-high	low	low	increasing
3	Synchronization	medium	moderate	medium	high
4	Collapse/Integration	low	high	high	maximum

Stage	Description	Σ (Segmentation)	Φ (Integration)	Ω (Operative Coherence)	Γ (Centering/Plasticity)
5	Reconfiguration	fluctuating	high-fluctuating	high-medium	selectively variable

Appendix 2: Parameter Table

Symbol	Designation	Type	Function in Model	Empirical Approximation
Σ	Segmentation	Input value (structural)	Measure for separability of functional subsystems	Hurst exponents, decorrelation, EEG coherence
Φ	Integration	Input value (structural)	Measure for global functional coupling	Synergy degrees, PCI, fMRI integration
Ω	Operative Coherence	Derived value (formal)	Structural overall coordination of a system	Network synergy, PCI, PCIst
Γ	Dynamic Self-coherence	Qualitative control value	Ability for centering, maintenance of self-modulation	Re-entry loops, attention, recursive activation