Recursive Dynamics of Quantum Duality and Neurophysiological Signaling

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Abstract

This paper applies the recursive epistemic dynamics framework to two traditionally distinct phenomena: quantum particle-wave duality and neurophysiological signaling. Both domains involve phase-sensitive, context-dependent state transitions that have resisted unification under linear causal models. Here, the recursive formulation provides a common logic: signal propagation and apparent state shifts arise not from inherent ambiguity, but from recursive phase-state negotiations with embedded contextual memory fields. We demonstrate that apparent quantum indeterminacy and neuronal firing behaviors are both emergent phenomena of recursive harmonization.

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1. Quantum Duality as Recursive Phase Collapse

1.1 Traditional Model

Quantum mechanics describes wave-particle duality as intrinsic: particles behave as waves under certain experimental conditions (e.g., interference patterns in double-slit experiments), but collapse into localized states upon observation.

1.2 Recursive Model Application

The recursive dynamic framework models a quantum object (photon, electron) as a contextual spiral state, not as a discrete particle or wave:

S\_{n+1} = C(R(S\_n, δ), C) + ε

Where:

S\_n: current recursion-level phase pattern

δ: perturbation due to slit geometry, energy density, or observation

R: phase-state transformation function

C: experiment field/contextual boundary

ε: stochastic fluctuation from energetic uncertainty

1.3 Interpretation

Wave-like behavior arises when recursive signal states remain unresolved across recursive iterations (i.e., harmonic superposition persists). Collapse into particle-like localization occurs when contextual recursion constraints enforce convergence.

This resolves the observer paradox by making the 'collapse' a result of recursive harmonic resolution rather than a measurement-induced quantum discontinuity.

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2. Recursive Modeling of Neurophysiological Signals

2.1 Traditional Neural Model

Neuronal signaling is typically described through electrochemical propagation of action potentials governed by membrane potential thresholds. The system is modeled linearly with state thresholds.

2.2 Recursive Signal Model

Neuronal firing is reframed as recursive convergence within contextual energetic memory fields. Each firing event is:

Ψ(x) = ∇φ(Σᵍₙ(x, ΔE)) + ℛ(x) ⊕ ΔΣ(ᵍ')

Where:

x: node (neuron or region)

Σᵍₙ: recursive firing potential across previous cycles

ΔE: local perturbation (input signal, neurotransmitter release)

∇φ: emergent resonance gradient (signal lock-in threshold)

ℛ(x): harmonization function (dendritic integration)

⊕: constructive merge or contradiction reconciliation

2.3 Interpretation

A neuron does not fire due to a strict voltage threshold, but when recursive summation of incoming phase-locked energies creates sufficient resonance alignment. Failures to fire represent local contradictions in recursive harmonics, not just sub-threshold voltages.

This explains:

Stochastic firing in noise conditions

Resonance-based memory encoding

Phase-locked firing patterns in cognition and trauma imprinting

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3. Unified Implications

Phenomenon Traditional Explanation Recursive Explanation

Quantum Collapse Observation-induced Harmonic resolution

Neuron Firing Threshold voltage Recursive phase convergence

Indeterminacy Fundamental Context-dependent perturbation noise

Memory Encoding Synaptic weight Recursive field harmonics

Both quantum state behavior and neural signal propagation emerge as recursive harmonics within context-sensitive energy structures. The recursive model provides a unified language for both domains.

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Conclusion

The recursive epistemic dynamic framework reinterprets the foundations of quantum duality and neurophysiological signaling. It removes paradoxes around observation and collapse, replacing them with predictable harmonization dynamics. Neurons and particles alike are no longer binary actors but recursive spiral nodes negotiating phase-state outcomes. This opens a path toward a unified language of consciousness, biology, and fundamental physics.

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