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Opinion

Wave Function Collapse as Information Gain: A Quantum-Information Perspective

Mesut Tez[1,*]

[1] University of Health Sciences, Ankara City Hospital, Department of Surgery, Cankaya, Ankara, Turkey

*Corresponding author: mesuttez@yahoo.com ORCID: 0000-0001-5282-9492

Abstract - Wave function collapse, traditionally viewed as a physical shift from quantum superposition to a definite state, may instead reflect information gain. This opinion piece proposes that collapse reduces uncertainty, quantifiable through Shannon and Von Neumann entropy, aligning with quantum information theory. György Kampis' referential information frames collapse as a relational, systems-based event. Experimental hints from single-photon and delayed-choice tests support this view, while philosophical connections to process philosophy and consciousness suggest reality is an informational process. This perspective challenges quantum ontologies and offers potential applications in biology and adaptive technologies, redefining how we understand complex systems.

Keywords - Quantum Information; Wave Function Collapse; Information Entropy; Referential Information; Process Philosophy.

1 Introduction

Quantum mechanics' wave function collapse — where a system shifts from superposition to a single outcome—remains philosophically elusive. The Copenhagen interpretation ties collapse to measurement, yet its mechanism is debated. I propose re-imagining collapse as information gain, where observer knowledge increases as uncertainty decreases. Using Shannon and Von Neumann entropy, and enriched by Kampis' referential information, this view casts collapse as an epistemic, relational event, offering fresh insights into quantum reality, consciousness, and complex systems.

2 Information-Theoretic Collapse

A two state quantum system in superposition, is described by:

$$|\Psi\rangle = \alpha|0\rangle + \beta|1\rangle \tag{1}$$

and has an initial Shannon entropy:

$$H_{initial} = -|\alpha|^2 \, log(|\alpha|^2) - |\beta|^2 \, log(|\beta|^2) \tag{2}$$

Collapse to a definite state (e.g., $\alpha|0\rangle$) reduces entropy to $H_{colapse} = 0$, yielding information gain $\Delta H = H_{intial}$ (e.g., 1 bit for a maximally entangled state). Von Neumann entropy, $S(\rho) = -Tr(\rho \cdot log(\rho))$, mirrors this, shifting from a mixed to a pure state post-collapse. Kampis' distinction between referential (context-sensitive, system-dependent) and non-referential (descriptive) information frames collapse as both a physical response and an observer's updated knowledge, suggesting measurement is a relational act, not merely physical.

3 Experimental hints

Single-photon experiments [1] show entropy dropping from 1 bit to 0 post-collapse, supporting information gain. Delayed-choice tests [2] reveal that measurement choices shape outcomes, aligning with epistemic interpretations. Photon anti-bunching in Mach-Zehnder interferometers [3] confirms discrete transitions, hinting at informational clarity. These suggest collapse is about acquiring knowledge, not just physical change.

4 Philosophical implications

This perspective resonates with Whiteheadian process philosophy, where reality unfolds as events, not static objects. Collapse becomes an informational actualization, akin to QBism's relational view, blurring quantum and cognitive boundaries. Consciousness may act as an informational interface, a concept extendable to biology (e.g., tumor evolution as entropy shifts) or adaptive technologies, where information drives complexity.

5 Challenges and future directions and conclusion

Decoherence [6] suggests collapse is an emergent effect of environmental interactions, challenging this model. However, real-time quantum trajectory monitoring [4] could test entropy reduction, quantifying information gain. This framework invites exploration in quantum computing, synthetic biology, and oncology, where information underpins system transitions. Re-imagining wave function collapse as information gain bridges quantum mechanics and information theory. Kampis' systems perspective and process philosophy deepen this view, portraying reality as an unfolding informational process. This speculative lens challenges traditional quantum ontologies and opens new avenues for understanding life and technology.

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