# The Observer’s Archive: Quantum Information, Memory Reconsolidation, and the Construction of Reality


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December 8, 2025

## Abstract

The conventional model of physical reality presumes that the past exists as a fixed sequence of objective events and that human memory serves only as a passive retrieval mechanism for these events. This paper challenges both assumptions through a synthesis of quantum information theory and contemporary neuroscience. Drawing on the quantum measurement problem and Wheeler's It from Bit principle (Wheeler, 1989; Landauer, 1991; Floridi, 2011), reality is examined as a fundamentally informational structure that becomes determinate only through acts of observation. This informational framework is then contrasted with empirical evidence from memory reconsolidation research, which demonstrates that memory retrieval destabilizes and biologically re-encodes prior experiences (Nader et al., 2000; Dudai, 2004; Sara, 2000). The central hypothesis proposed is that identity functions as the continuous observer required to stabilize quantum informational collapse, yet this identity is sustained by a biologically mutable neural archive (Conway & Pleydell-Pearce, 2000; Damasio, 1999). Consequently, alterations in memory do not merely affect subjective interpretation of the past but may restructure the informational conditions that govern the observer's present experiential reality. The paper concludes by considering the philosophical and ethical implications of this synthesis for theories of selfhood, causation, and participatory cosmology (Farah, 2002; Earp et al., 2014).



*Keywords:* quantum measurement problem; memory reconsolidation; information theory; observer effect; consciousness; identity formation; participatory universe; quantum information; neuroplasticity; It from Bit

## Introduction

For more than three centuries, Western scientific thought has been governed by a largely unchallenged assumption: that physical reality unfolds as a determinate sequence of objective events and that human memory functions solely as a passive archival system for this fixed past. Under this classical framework, the universe is understood as a closed mechanical system in which every effect follows from prior causes with absolute necessity, and memory is treated as a biological recording device that merely retrieves what has already occurred. This view, formalized in the deterministic philosophy of Newtonian mechanics and epitomized by Laplace's formulation of total predictability, remains deeply embedded in contemporary conceptions of time, identity, and causation (Laplace, 1814/1902).

However, the emergence of quantum mechanics in the early twentieth century destabilized this classical worldview at its most fundamental level. At microscopic scales, physical systems are not governed by deterministic trajectories but by probabilistic wave functions that encode multiple possible outcomes simultaneously. The collapse of these superpositions into singular physical states occurs only through measurement, a process that remains formally undefined within quantum theory itself. This unresolved tension—known as the quantum measurement problem—forces a reconsideration of what it means for physical reality to exist in a determinate form prior to observation (Schrödinger, 1935; von Neumann, 1955; Schlosshauer, 2005).

Simultaneously, advances in cognitive neuroscience have undermined the traditional assumption that memory operates as a stable record of past events. Research on memory reconsolidation demonstrates that when memories are retrieved, they enter a transiently unstable state during which they become biologically malleable and subject to modification before being re-stored in neural circuits (Nader et al., 2000; Dudai, 2004; Sara, 2000). This process implies that memory is not a static archive but a dynamically reconstructed system in which the past remains neurobiologically labile. Consequently, the continuity of identity—historically grounded in the persistence of memory—is itself rendered unstable (Conway & Pleydell-Pearce, 2000; Damasio, 1999).

These two developments—quantum indeterminacy and memory reconsolidation—have largely evolved in isolation from one another. Physics has treated observation as an abstract informational act divorced from biological implementation, while neuroscience has examined memory as a localized neural phenomenon without reference to the ontological foundations of physical reality. This disciplinary separation has preserved the assumption that while memory may change perception, it cannot alter the physical structure of the external world. The present paper challenges this boundary.

Building upon the Von Neumann–Wigner interpretation of quantum mechanics (von Neumann, 1955; Wigner, 1961) and Wheeler's It from Bit doctrine (Wheeler, 1989), this work proposes that reality itself is fundamentally constituted by information that becomes physically instantiated only through observation. Observation, in turn, necessitates memory: without the capacity to register, retain, and differentiate states across time, no observer can meaningfully collapse a quantum system into a determinate outcome (Landauer, 1991; Floridi, 2011). Thus, memory functions not merely as a psychological faculty, but as the stabilizing boundary condition that allows physical reality to manifest as a consistent historical sequence.

The central claim advanced here is that if identity operates as the continuous informational observer required to stabilize quantum collapse, and if that identity is sustained by a biologically unstable and rewritable memory system, then the apparent immutability of physical history is no longer ontologically secure. Under this framework, memory does not merely shape subjective experience of an already-fixed world; rather, it participates in maintaining the informational structure through which reality becomes definite. Alterations to memory therefore carry implications not only for selfhood and perception but for the informational constraints that govern the observer's present experiential reality.

This paper develops this argument in four stages. First, the transition from classical determinism to quantum indeterminacy is examined through the contrast between Laplacian mechanics and the formal structure of the wave function (Laplace, 1814/1902; Schrödinger, 1935). Second, the quantum measurement problem is analyzed with particular attention to the Von Neumann chain and the necessity of an observer-dependent collapse (von Neumann, 1955; Schlosshauer, 2005). Third, empirical findings from neuroscience on memory reconsolidation are introduced to demonstrate the biological instability of the observer's archival system (Nader et al., 2000; Dudai, 2004; Lee, 2009). Finally, these frameworks are synthesized to propose a model in which memory, identity, and observation form a closed informational loop that may render experienced reality historically malleable at the level of informational selection (Conway & Pleydell-Pearce, 2000; Wheeler, 1989; Floridi, 2011).

By situating memory at the intersection of quantum observation and biological reconstruction, this work seeks to contribute to broader debates concerning the nature of selfhood, the status of causation, and the role of observers in the construction of physical reality (Price, 1997; Aharonov et al., 2009). While the framework developed here remains theoretical, it identifies a critical conceptual vulnerability at the boundary between physics and neuroscience—one that warrants sustained philosophical scrutiny as technologies capable of manipulating memory and perception continue to advance (Farah, 2002; Earp et al., 2014).

## From Laplacian Determinism to the Quantum Rupture

Classical physics was founded upon the assumption that the universe operates as a fully determinate mechanical system governed by immutable natural laws. Within this framework, every physical event follows necessarily from preceding conditions, and the total state of the universe at any moment uniquely determines its entire future. This deterministic worldview reached its most explicit articulation in the thought experiment known as Laplace's demon. In his Philosophical Essay on Probabilities, Pierre-Simon Laplace argued that an intellect possessing complete knowledge of all forces and positions of matter at a single instant could, in principle, calculate the entire past and future of the universe with perfect certainty (Laplace, 1814/1902).

Under such conditions, uncertainty is not a feature of reality itself but merely a consequence of human ignorance.

Within the Laplacian paradigm, information occupies a purely descriptive role. Physical states exist independently of observation, and measurement merely reveals values that are already fully determined. Memory, by extension, functions as a local biological record of a fixed external history—a retrieval system for an already written sequence of physical events. Identity, time, and causation are therefore treated as stable continuities embedded within a fully objective temporal order. This conception of reality dominated scientific thought from the seventeenth through the nineteenth centuries and continues to shape intuitive assumptions about objectivity and the nature of the past.

The emergence of quantum mechanics in the early twentieth century, however, produced a fundamental rupture in this deterministic structure. At microscopic scales, physical behavior no longer conforms to continuous trajectories governed by classical equations of motion. Instead, quantum systems are described by a wave function, conventionally denoted by the Greek letter $\Psi$, which encodes a superposition of multiple possible states simultaneously (Schrödinger, 1935; Schlosshauer, 2005). Unlike classical coordinates of position and momentum, the wave function does not represent a single determinate configuration of matter but a probability distribution across all observable outcomes the system may yield upon measurement.

The time evolution of this wave function is governed by Schrödinger's equation, a linear and deterministic differential equation specifying how $\Psi$ changes as a function of the system's Hamiltonian. When left undisturbed, a quantum system evolves continuously as a superposition of all mathematically permitted outcomes. Crucially, this evolution does not select a single physical state. Instead, it preserves the coexistence of alternative possibilities in a manner fundamentally incompatible with classical determinism (Schrödinger, 1935; von Neumann, 1955).

This tension becomes explicit in the phenomenon of quantum superposition. For example, an electron prepared for a spin measurement does not possess a definite spin-up or spin-down state prior to observation. Instead, it exists in a linear combination of both possibilities, each weighted by a probability amplitude. As long as the system remains unmeasured, these mutually exclusive outcomes coexist within a mathematically valid physical description. It is only through measurement that this multiplicity is reduced to a singular realized result (Everett, 1957; Schlosshauer, 2005).

The transition from superposition to definiteness constitutes the central discontinuity of quantum theory. When a measurement occurs, the wave function appears to undergo a sudden, non-unitary transformation in which all alternative possibilities vanish except one. The probability of a given outcome is determined by the squared magnitude of its associated amplitude, a rule formalized by the Born interpretation. While this rule predicts statistical distributions with extraordinary precision, it provides no account of why or how a single outcome is selected in any individual measurement (von Neumann, 1955; Schlosshauer, 2005).

This conceptual gap gives rise to the quantum measurement problem. Schrödinger's equation governs the evolution of all physical systems, including measuring devices, detectors, sensory organs, and neural tissue, all of which are composed entirely of quantum-mechanical constituents. If the laws of quantum evolution apply universally, then the interaction between a particle and a detector should simply produce a larger entangled superposition that includes both the system and the apparatus. Instead of yielding a determinate outcome, the detector itself should enter a state of simultaneous registration of all possible results (von Neumann, 1955; Zurek, 2003).

Under strict unitary evolution, observation alone would never terminate this regress of superpositions. Instead, every interaction would generate only further entanglement without producing definitive facts. This implication leads directly to what is known as the Von Neumann chain: if a detector enters a superposition as a result of interacting with a quantum system, then the observer perceiving the detector must likewise enter a superposition, and so on without theoretical termination (von Neumann, 1955).

The empirical fact that observers nonetheless experience a single, determinate world therefore stands in direct tension with the mathematical structure of quantum mechanics.

Whereas classical physics assumes that definiteness is an intrinsic property of physical systems, quantum mechanics requires definiteness to be imposed through some additional principle not contained within its core equations. The breakdown of classical determinism at the quantum level thus transforms uncertainty from a limitation of knowledge into a fundamental property of physical reality itself.

This rupture between determinism and actuality marks the conceptual entry point for observer-dependent interpretations of quantum mechanics. It is within this unresolved gap—where physical law predicts only probabilities but experience yields certainties—that the necessity of an observer-centered account of measurement emerges. The next section examines this transition formally through Von Neumann's distinction between continuous unitary evolution and discontinuous collapse.

## The Mathematical Crisis: Process 1 and Process 2

The formal structure of quantum mechanics is defined by two fundamentally different modes of physical evolution, a distinction first articulated with mathematical rigor by John von Neumann. The first mode describes the continuous, deterministic evolution of the wave function according to Schrödinger's equation. The second describes the discontinuous, probabilistic transition associated with measurement. Von Neumann designated these two regimes Process 2 and Process 1, respectively (von Neumann, 1955).

Under Process 2, the quantum state evolves unitarily and deterministically through time. Schrödinger's equation specifies how the wave function Ψ changes as a function of the system's Hamiltonian, which encodes its total energy. This evolution is fully reversible and preserves all superpositions. At no point under Process 2 is a specific outcome selected. Instead, the system evolves as a coherent combination of all physically permitted states simultaneously (Schrödinger, 1935; von Neumann, 1955; Schlosshauer, 2005).

The phenomenon of superposition is central to this unitary evolution. A quantum system may exist in a linear combination of mutually exclusive classical states, each weighted by a complex-valued probability amplitude. Prior to measurement, no single element of this combination corresponds to a realized physical property. Instead, the system remains distributed across multiple potential outcomes in a manner that defies classical intuition. This indeterminate coexistence is not merely a reflection of incomplete knowledge but an intrinsic feature of the quantum formalism itself (Everett, 1957; Schlosshauer, 2005).

However, empirical observation consistently reveals definite outcomes. When a measurement is performed, the wave function appears to undergo an abrupt transition in which the superposition is destroyed and a single eigenstate is realized. This change is probabilistic, irreversible, and nonlinear—properties fundamentally incompatible with the smooth, deterministic evolution dictated by Schrödinger's equation. Von Neumann designated this discontinuous transition as Process 1 (von Neumann, 1955).

The probabilities governing Process 1 are determined by the Born rule, which assigns outcome likelihoods based on the squared magnitudes of the relevant probability amplitudes. While this rule accurately predicts statistical patterns over large ensembles of measurements, it remains silent on the mechanism responsible for selecting any single outcome in an individual event. Quantum theory thus offers a complete account of statistical distributions while remaining ontologically incomplete at the level of individual reality selection (Schlosshauer, 2005; Zurek, 2003).

This dual-process structure generates the central ontological tension of quantum mechanics. Process 2 describes an entirely continuous, deterministic universe of evolving wave functions, whereas Process 1 introduces a fundamentally discontinuous and probabilistic insertion of actuality. Nowhere within the standard formalism is there a physical criterion specifying when, where, or why the transition from Process 2 to Process 1 must occur. The theory presupposes collapse mathematically but does not derive it dynamically (von Neumann, 1955; Schlosshauer, 2005).

This gap becomes especially problematic when the universal applicability of quantum mechanics is taken seriously. Measuring devices, detectors, sensory organs, and neural tissue are all composed of quantum-mechanical constituents. If Schrödinger evolution governs the behavior of atoms universally, then no interaction between a quantum system and a macroscopic apparatus should ever terminate superposition. Instead, the system and the apparatus should simply become entangled into a larger composite wave function (von Neumann, 1955; Zurek, 2003).

Mathematically, if a quantum system enters a superposition of measurement outcomes and interacts with a detector initially in a ready state, the combined system evolves into an entangled superposition of correlated system–detector states. The detector itself acquires no definite reading but instead exists in a coherent mixture of indicating all possible outcomes. Under strict unitary evolution, no element of this entanglement is privileged as the realized state of affairs (Everett, 1957; Schlosshauer, 2005).

This logic extends inexorably to observers. If a human observer perceives the detector, the observer's perceptual and neural states must likewise become entangled with the combined system. If that observer is in turn observed by another observer, the chain persists without theoretical termination. This infinite regress is known as the Von Neumann chain (von Neumann, 1955). Within the standard quantum formalism, there exists no intrinsic physical boundary at which potentiality becomes actuality.

The empirical fact that observers nevertheless experience a singular, determinate world therefore stands in direct contradiction with the mathematical structure of quantum mechanics. Observable reality appears to require a mechanism of collapse, yet the physical laws governing quantum systems permit only continuous entanglement. The measurement problem thus marks a deep rupture at the foundation of physical theory: quantum mechanics is simultaneously the most empirically successful theory in the history of science and one that remains ontologically incomplete at the level of observed definiteness.

Decoherence-based interpretations have attempted to resolve this tension by explaining how environmental entanglement rapidly suppresses observable quantum interference at macroscopic scales. Through interaction with the environment, quantum systems effectively lose phase coherence between alternative branches of the wave function, yielding the appearance of classical definiteness (Zurek, 2003). However, while decoherence successfully explains the emergence of classical probabilities and the practical disappearance of interference terms, it does not select a single experienced outcome. All branches of the wave function continue to exist mathematically (Schlosshauer, 2005; Everett, 1957).

Thus, even within decoherence frameworks, the problem of subjective definiteness remains unresolved. The formal structure of quantum mechanics continues to predict only branching structures, not the single stream of experience reported by observers. This persistent gap between mathematical description and lived perception provides the conceptual entry point for observer-dependent interpretations of quantum mechanics, most prominently the framework advanced by von Neumann and later developed by Eugene Wigner.

## The Von Neumann Cut and the Necessity of Consciousness

In *Mathematical Foundations of Quantum Mechanics*, John von Neumann (1955) confronted the measurement problem by demonstrating that the formal distinction between unitary evolution and wave function collapse cannot be derived from the physical laws governing quantum systems themselves. The mathematical structure of quantum mechanics, he showed, is fundamentally bipartite: Process 2 governs continuous, deterministic evolution, while Process 1 introduces discontinuous, probabilistic state reduction. Crucially, the theory contains no rule that determines where the transition between these two processes must occur. Instead, the placement of this boundary—what von Neumann termed the Schnitt, or cut—must be imposed externally on the formalism.

The von Neumann cut represents the theoretical boundary between the observed system and the observing agency. In principle, this boundary might be placed at any point along the Von Neumann chain: between a particle and a detector, between a detector and a sensory organ, or between sensory input and neural processing. However, because all physical systems involved in the measurement interaction are composed of quantum-mechanical constituents, any placement of the cut within the physical domain renders collapse mathematically unjustified. Under strict adherence to unitary evolution, every physical interaction should generate only further entanglement rather than definitive outcomes (von Neumann, 1955; Schlosshauer, 2005).

This difficulty led von Neumann to the conclusion that the cut cannot be placed entirely within the domain of physical systems. Instead, it must be located at the interface between the physical and the non-physical—namely, within the conscious experience of the observer. Under this interpretation, physical reality remains described entirely by Process 2 until it is brought into contact with consciousness, at which point Process 1 is invoked and a definite outcome is realized (von Neumann, 1955).

Eugene Wigner later extended and defended this view, arguing explicitly that consciousness is not merely correlated with quantum collapse but is necessary for it. In his essay "Remarks on the Mind–Body Question," Wigner (1961) contended that "it was not possible to formulate the laws of quantum mechanics in a fully consistent way without reference to the consciousness" (p. 284). From this perspective, the physical universe exists in a state of suspended indeterminacy until it is actualized through subjective awareness. Only the conscious observer possesses the capacity to convert quantum potentiality into empirical actuality.

Within the Von Neumann–Wigner framework, the observer is not a passive spectator of an independently existing world but an active participant in the production of physical reality. Observation is no longer a mere act of information extraction; it is the very mechanism by which determinate physical states come into being. The distinction between ontology (what exists) and epistemology (what is known) becomes fundamentally destabilized. To observe is not simply to learn what is already the case—it is to select one realized history from among multiple physically admissible possibilities.

This participatory role of the observer generates a striking consequence for the nature of the past. If unobserved quantum systems do not possess definite properties prior to measurement, then past events themselves may lack determinate histories until they are brought into relation with an observing consciousness. This implication is sharpened by the class of experiments commonly referred to as delayed-choice scenarios. In such experiments, the experimental configuration determining whether a quantum system exhibits wave-like or particle-like behavior is chosen only after the system has already entered the measurement apparatus. Yet the system's earlier behavior appears to conform retroactively to the later measurement choice (Kim et al., 2000; Wheeler, 1989; Aharonov et al., 2009).

While these experiments do not permit causal signaling into the past, they do challenge the classical assumption that physical history is fixed independently of present observation. Instead, they suggest that the informational conditions under which history becomes definite may not be temporally localized in the classical sense (Price, 1997). Within the Von Neumann–Wigner framework, this supports the view that physical reality is not a pre-existing sequence of objective events but an observer-dependent structure of informational actualization.

Nevertheless, the consciousness-based collapse hypothesis remains controversial. Many contemporary interpretations of quantum mechanics seek to preserve ontological realism without invoking subjective awareness, including decoherence-based accounts, many-worlds formulations, and objective-collapse theories (Everett, 1957; Zurek, 2003; Schlosshauer, 2005). These models attempt to explain the emergence of classical definiteness through environmental entanglement or branching universes rather than through mental causation. However, while such approaches successfully reproduce classical statistical behavior, they do not eliminate the formal necessity of selecting a single experienced outcome. The question of why one branch is experienced rather than another remains unresolved at the level of subjective reality.

Thus, irrespective of one's preferred metaphysical interpretation, the measurement problem preserves an inescapable role for the observer within the structure of physical theory. Whether consciousness causes collapse or merely accompanies it, observation remains the functional boundary at which quantum descriptions become experiential facts. It is this boundary—situated at the interface between physical systems and cognitive experience—that establishes the conceptual bridge between quantum mechanics and the neuroscience of memory.

If observation is the condition under which reality becomes definite, and if observation presupposes the existence of a continuous observer, then the mechanisms sustaining observer continuity become ontologically significant. The next section therefore reframes the observer not as a metaphysical abstraction but as an information-processing system whose stability depends upon memory (Wheeler, 1989; Landauer, 1991; Floridi, 2011).

## The Observer as an Information System

If the emergence of definite physical reality depends upon observation, then the nature of the observer becomes a matter of ontological significance rather than a peripheral epistemic concern. Within the Von Neumann–Wigner framework, the observer functions as the terminus of the measurement chain—the point at which quantum indeterminacy is resolved into experiential definiteness (von Neumann, 1955; Wigner, 1961). This raises a foundational question: What qualifies a system as an observer capable of stabilizing physical reality?

John Archibald Wheeler's principle of It from Bit provides a conceptual bridge between quantum physics and information theory by proposing that the material structure of the universe ("It") arises from discrete acts of informational distinction ("Bit") (Wheeler, 1989). Under this framework, physical states do not merely carry information as an auxiliary property; rather, information itself becomes the primitive substrate from which physical reality is constituted. Observation is therefore not simply the detection of matter but the acquisition of informational structure through binary differentiation.

This informational interpretation of physics is strengthened by Landauer's principle that "information is physical," which asserts that the processing, storage, and erasure of information are constrained by thermodynamic laws (Landauer, 1991). Information is not an abstract epiphenomenon but a physically instantiated process requiring energetic and material resources. Together, Wheeler's and Landauer's formulations establish information as a foundational element of physical ontology rather than a secondary descriptive layer (Floridi, 2011).

However, this informational account of observation introduces a constraint that is often underemphasized in physics but is central to neuroscience: observation requires memory. For a measurement to function as a meaningful informational event, the outcome must be registered, retained, and distinguishable from alternative outcomes across time. A system that cannot preserve informational difference lacks the functional capacity to serve as an observer. Without memory, observation collapses into transient interaction without historical continuity (Damasio, 1999; Conway & Pleydell-Pearce, 2000).

From this perspective, the observer must be understood not merely as a locus of momentary awareness but as a temporally extended information-processing system. Conscious experience becomes an observation only insofar as it can be retained and integrated into a persistent internal model of the world. This persistence is supplied by memory. The observer is therefore an archival system—a dynamically maintained informational structure that stabilizes successive observations into a coherent experiential narrative.

Under this formulation, the Von Neumann cut is not simply a metaphysical boundary between mind and matter. It is an informational boundary between ephemeral quantum interaction and historically stabilized experiential reality. Physical systems evolve as probabilistic superpositions, but an observed outcome becomes part of reality only when it is registered within a memory-bearing system that preserves its informational trace across time. Reality, as experienced, becomes the cumulative archive of collapsed quantum events stored in the observer's cognitive architecture.

This interpretation fundamentally reframes the relationship between memory and physical existence. Memory is no longer merely a repository of personal experience layered atop an independently existing external world. Instead, it becomes the functional mechanism through which physical reality acquires temporal persistence for the observing subject. The experienced world is not simply perceived—it is remembered into coherence. The continuity of reality, as lived, is thus inseparable from the continuity of the observer's memory.

This dependence introduces a critical vulnerability into the ontological structure of reality as defined by observation. Standard formulations of the measurement problem implicitly assume that the observer acts as a stable and reliable recording device—that once an outcome is registered, it remains permanently fixed as part of the historical record. Yet this assumption is incompatible with the empirical findings of modern neuroscience, which demonstrate that biological memory is not a static storage medium but a reconstructive and dynamically mutable process (Nader et al., 2000; Dudai, 2004; Lee, 2009).

If the observer's memory constitutes the archival substrate through which physical reality acquires experiential stability, then the instability of that memory threatens the stability of the reality it sustains. The observer's archive is neither permanent nor immune to revision. Each act of recall reopens the memory trace to modification before it is re-stored, a process known as reconsolidation (Nader et al., 2000; Sara, 2000). From a purely neurobiological standpoint, the past is not retrieved—it is actively re-written.

This realization forces a confrontation between two assumptions embedded within standard interpretations of observation. Quantum mechanics presumes that once an observation occurs, a singular historical trajectory is selected from among multiple possibilities. Neuroscience, by contrast, reveals that the biological record of that selection is not preserved as a fixed trace but is continually reconstructed. The informational unit ("Bit") that stabilizes the physical outcome ("It") is therefore not immune to revision.

This tension becomes particularly evident when reconsidering Schrödinger's cat through the lens of cognitive science. In the classical thought experiment, the cat remains in a superposition of life and death until the observer opens the box. Upon observation, the wave function collapses and the cat occupies a definite state. However, if the observer encodes the observation into memory and that memory is later altered, degraded, or erased through reconsolidation, the informational trace of the collapse is likewise altered. The physical state of the cat remains unchanged, but the observer's historical record of that collapse becomes biologically unstable.

This does not imply that physical systems return to quantum superposition when memory changes. Rather, it exposes a structural mismatch between the assumed permanence of physical history and the demonstrated impermanence of the observer's informational archive of that history. The physical outcome persists, but the informational structure through which that outcome is integrated into the observer's experiential reality remains contingent upon biological reconstruction.

These considerations prepare the ground for the central theoretical claim of the present work: if identity functions as the continuous observer required to stabilize quantum informational collapse, and if identity is sustained by a biologically unstable memory system, then the apparent fixity of experienced reality is not ontologically guaranteed at the level of informational persistence. The next section examines this instability directly through the empirical neuroscience of memory reconsolidation.

## Memory Reconsolidation and the Instability of the Neural Archive

For much of the twentieth century, dominant models of human memory were structured around a consolidation paradigm in which memories, once encoded and stabilized, were assumed to persist as relatively permanent neural traces. Within this framework, retrieval was understood as a passive process of accessing a stored representation without fundamentally altering the underlying memory itself. This classical view aligned comfortably with the deterministic intuition inherited from Newtonian physics: the past was fixed, and memory merely accessed it.

This assumption was fundamentally overturned by experimental evidence demonstrating that memory retrieval is not a neutral act of access but an active biological process that destabilizes previously consolidated traces. In a landmark study, Nader, Schafe, and LeDoux (2000) showed that when conditioned fear memories in rodents were reactivated through retrieval, those memories became transiently labile and required new protein synthesis in the amygdala in order to be restabilized. When this reconsolidation process was pharmacologically disrupted, the retrieved memory was selectively weakened or erased. This finding established that consolidation is not a one-time event but a recurring biological process that is reinitiated each time a memory is recalled.

Subsequent research has repeatedly confirmed and extended the reconsolidation framework across species, memory systems, and behavioral modalities. Dudai (2004) demonstrated that reconsolidation is a general property of long-term memory rather than a narrow feature of fear conditioning, while Sara (2000) showed that retrieval actively reorganizes memory representations rather than simply activating dormant traces. Lee (2009) further demonstrated that reconsolidation serves an adaptive function by maintaining the relevance of memory in changing environments rather than preserving an unaltered historical record.

At the cellular level, reconsolidation involves synaptic reorganization, receptor trafficking, and the activation of intracellular signaling cascades that modify synaptic strength. Long-term potentiation and long-term depression dynamically reshape neural circuits as memory traces are re-encoded. Memory, therefore, is not inscribed as a stable binary record in neural tissue but is maintained as a living pattern of synaptic connectivity that must be continuously reconstructed through plasticity mechanisms (Dudai, 2004; Lee, 2009).

From a neurobiological standpoint, this implies that the past is not preserved as a fixed internal snapshot. Instead, every act of remembering renders the past biologically unstable before it is re-stored in modified form. The persistence of memory across time is not guaranteed by permanence of storage but by repeated reconstruction. Even in the absence of deliberate interference, memory traces are vulnerable to contextual distortion, emotional modulation, and subsequent learning.

This inherent instability carries direct consequences for personal identity. Psychological models of the self increasingly emphasize autobiographical memory as the primary mechanism through which individuals experience continuity across time. The self is not stored as a single entity but emerges from the dynamic integration of remembered experience (Conway &

Pleydell-Pearce, 2000; Damasio, 1999). If memory is continuously rewritten, then identity itself becomes a process of reconstruction rather than preservation. The persistence of the self is secured not through the immutability of stored information but through the functional continuity of the reconstruction process.

Within the informational framework developed in the present work, the instability of memory acquires ontological significance. If observation functions as the mechanism through which quantum informational potential is converted into physical actuality, and if memory serves as the archival substrate that stabilizes that conversion across time, then the mutability of memory introduces a structural vulnerability into the informational architecture of experienced reality. The observer's archive is not a permanent register but a biologically rewritable medium.

Standard discussions of the measurement problem implicitly assume that once a measurement outcome is registered, it becomes part of a fixed informational history. While the physical system may evolve deterministically following collapse, the biological record of that collapse within the observer is treated as permanently stable. Neuroscience directly contradicts this assumption. The "Bit" that stabilizes the "It," in Wheeler's formulation, is itself subject to retroactive alteration through reconsolidation (Wheeler, 1989; Landauer, 1991; Nader et al., 2000).

This mismatch does not imply that changes in memory force physical systems to re-enter quantum superposition. Rather, it reveals a discord between the assumed permanence of physical history and the demonstrated impermanence of the observer's informational representation of that history. The physical outcome remains fixed within the external world, but the informational structure through which that outcome acquires experiential persistence remains biologically unstable. Reality, as lived by the observer, thus remains contingent upon a neural archive that is perpetually subject to revision.

The instability of memory takes on heightened significance in light of emerging neurotechnologies capable of selectively modifying memory traces. Pharmacological agents, optogenetic interventions, and targeted stimulation techniques now permit the experimental weakening, erasure, or enhancement of specific memories in both animal models and limited human contexts. These interventions do not merely alter beliefs or emotional responses; they directly restructure the biological infrastructure through which identity and experiential continuity are sustained (Farah, 2002; Earp et al., 2014).

Under the present framework, such interventions must be understood not only as psychological manipulations but as alterations to the informational conditions that stabilize observed reality. By modifying the neural archive through which observation is integrated across time, memory interventions reshape the internal structure through which physical reality becomes meaningful and persistent for the observer.

This convergence between quantum observation and neural plasticity exposes the core tension driving the present synthesis. Quantum mechanics suggests that physical reality is not fully determinate prior to observation. Neuroscience demonstrates that the biological mechanism responsible for stabilizing observation—memory—is inherently unstable. The observer therefore occupies a conceptual fault line between physical indeterminacy and biological reconstruction. The next section develops this conflict into a unified theoretical model of identity, observation, and informational reality.

## Synthesis Model: Identity, Observation, and Informational Reality

The preceding sections have established two independently grounded findings that are rarely brought into direct conceptual alignment: first, that quantum mechanics does not permit the existence of fully determinate physical states prior to observation, and second, that memory—the biological mechanism through which observation is stabilized across time—is inherently unstable and reconstructive. When taken together, these findings motivate a unified informational model in which identity functions as the continuous observer required to stabilize quantum actuality through a biologically mutable archive.

Within the Von Neumann–Wigner framework, physical systems evolve indefinitely under unitary dynamics until an act of observation imposes state reduction and selects a singular realized outcome (von Neumann, 1955; Wigner, 1961). Observation thus serves as the boundary condition between quantum potentiality and experiential actuality. However, for this actuality to persist as a stable element of lived reality, it must be integrated into a continuous observer across time. That temporal integration is supplied by memory (Damasio, 1999; Conway & Pleydell-Pearce, 2000).

Under the present synthesis, identity is not treated as a static metaphysical essence or a fixed psychological trait. Instead, identity is defined functionally as the temporally extended information-processing system that unifies successive observational outcomes into a coherent experiential narrative. The self becomes the persistence mechanism of observation itself. Without such a system, individual acts of collapse would occur in isolation, failing to accumulate into a stable world. Reality, as experienced, therefore emerges not solely from discrete collapse events but from their continuous integration into identity through memory.

This framework reframes the nature of physical history. Rather than existing as a fully independent external sequence of objective events, history becomes an informational structure stabilized through repeated acts of observation and retention. The observer does not merely witness history but participates in its stabilization by encoding collapse outcomes into a durable experiential framework. The continuity of physical reality, as experienced, is inseparable from the continuity of the observer's identity.

Yet neuroscience demonstrates that this continuity-preserving archival process is inherently unstable. Memory reconsolidation ensures that each retrieval renders a memory trace labile and subject to modification before it is re-encoded (Nader et al., 2000; Dudai, 2004; Sara, 2000; Lee, 2009). From the standpoint of the present model, this means that the informational substrate responsible for stabilizing the observer's experienced reality is itself subject to continuous revision. Identity, as the continuity of the observer, is therefore preserved not through permanence of content but through repeated biological reconstruction.

This creates a closed informational feedback loop. Observation collapses quantum possibility into physical actuality. Memory encodes that actuality into the observer's neural archive. Identity persists through the continuity of that archive. Subsequent memory retrieval destabilizes and modifies the same archive, thereby reshaping the informational conditions under which future observations will be integrated. Reality and identity thus co-evolve through a recursive informational system in which each simultaneously stabilizes and reshapes the other (Wheeler, 1989; Landauer, 1991; Floridi, 2011).

Within this framework, the past is no longer ontologically independent of the present. While the external physical world may evolve according to classical causal constraints following state reduction, the informational reality through which the observer experiences that world is subject to continuous retroactive restructuring through memory reconsolidation. The past, as experienced, is not retrieved as a fixed entity but dynamically reconstructed as a function of present neural, emotional, and contextual states.

It is essential to emphasize that this model does not assert that physical events themselves are reversed, undone, or returned to superposition when memories change. Physical systems remain constrained by standard causal laws following collapse. The present model instead asserts that the informational structure through which physical events acquire experiential persistence for the observer is not static. Under an information-based ontology, experienced reality is constituted not solely by external physical processes but by the informational integration of those processes into a continuous identity. When that integration is modified, the functional structure of the observer's reality is likewise modified.

In this sense, memory does not alter reality at the level of physical law; it alters reality at the level of informational actualization. If, as Wheeler proposed, physical existence arises from informational distinction, then alteration of the informational archive through which distinctions are preserved necessarily reshapes the observer's manifest world (Wheeler, 1989). The "It" remains constrained by physical law, but the "Bit" through which it becomes meaningful and persistent is biologically mutable (Landauer, 1991; Floridi, 2011).

This synthesis resolves a foundational tension implicit in both physics and neuroscience. Physics presumes permanent informational registration following measurement but provides no biological mechanism for such permanence. Neuroscience demonstrates pervasive informational instability but does not address the ontological consequences of that instability for physical observation. By situating identity as the bridge between collapse and memory, the present model integrates these domains into a single, closed-loop informational system.

Under this formulation, the observer is not external to physical reality but embedded within a reciprocal informational exchange. Physical systems supply quantum potential. Observation selects actuality. Memory stabilizes that selection. Identity carries the stabilized selection forward across time. Memory reconsolidation then reshapes the stabilizing structure. Subsequent observations are integrated into a modified informational framework. Reality, as experienced, is therefore not static but dynamically conditioned by the evolving informational state of the observer.

The ontological consequence of this framework is a restricted form of participatory realism. The observer does not create physical law, nor does memory arbitrarily rewrite the external universe. However, the emergence, persistence, and experiential structure of reality are inseparable from the informational operations of biological observers. Reality becomes neither fully objective nor fully subjective but relationally constituted at the interface of quantum probability and neurological reconstruction.

This synthesis provides the conceptual foundation for examining the broader philosophical implications of memory-driven informational reality. If identity is sustained by a biologically mutable archive, and if that archive stabilizes the experienced structure of the world, then traditional concepts of selfhood, causation, truth, and participation must be reassessed. The following section examines these implications directly.

## Philosophical Implications: Selfhood, Causation, and the Participatory Universe

The synthesis of quantum observation, biological memory reconsolidation, and identity into a single informational framework carries significant philosophical consequences for theories of selfhood, causation, truth, and the nature of reality itself. By situating the observer as both a stabilizing agent of physical actuality and a biologically mutable informational system, the classical boundary between subject and object, mind and matter, and past and present becomes structurally destabilized.

### Selfhood as Informational Continuity

Under classical metaphysical assumptions, the self is commonly conceived as a relatively stable entity persisting through time, grounded either in an enduring substance, a consistent cognitive architecture, or the biological continuity of the organism. In contrast, the present framework defines selfhood functionally as the continuity of informational integration across successive acts of observation. Identity is not a static substance but a dynamically reconstructed process sustained by memory (Conway & Pleydell-Pearce, 2000; Damasio, 1999).

Because memory is continuously re-encoded through reconsolidation, the self that persists across time is not the preservation of identical internal contents but the preservation of an ongoing reconstruction mechanism. Personal identity becomes a process of narrative stabilization rather than a repository of immutable facts. This aligns with contemporary psychological models of narrative identity while extending them into an ontological domain: the self is not only psychologically constructed but materially implicated in the stabilization of experiential reality.

From this perspective, disruptions of memory—whether through trauma, neurological injury, pharmacological intervention, or deliberate technological manipulation—do not merely alter subjective experience. They fragment the very mechanism by which the self persists as a coherent observer across time. The unity of the self is thus not guaranteed by biological continuity alone but depends upon the functional preservation of informational coherence within the neural archive.

## Causation and the Layered Structure of the Past

Classical causation presupposes a fixed temporal order in which causes precede effects within an immutable historical framework. The present model challenges this assumption by distinguishing between physical causation and informational causation. While physical processes unfold according to lawful constraints following quantum state selection, the informational structure through which those processes acquire experiential meaning remains subject to retroactive modification through memory reconsolidation (Nader et al., 2000; Dudai, 2004; Sara, 2000).

This distinction yields a layered conception of the past. At the level of external physical processes, the past remains constrained by physical law. At the level of informational integration within the observer, however, the past is dynamically reconstructed with each act of memory retrieval. The experiential past is therefore not identical to the physical past. It is a living informational system continually reshaped by present neural, emotional, and contextual states.

Delayed-choice and quantum eraser experiments further complicate classical intuitions about temporal order by demonstrating that the conditions under which quantum systems exhibit wave-like or particle-like behavior can be selected after the systems have already entered the measurement apparatus (Kim et al., 2000; Wheeler, 1989; Aharonov et al., 2009). Although such experiments do not permit physical retrocausation, they undermine the assumption that the definiteness of physical history is always temporally localized in the classical sense. Within the present framework, this supports the view that the experiential definiteness of history is contingent upon present informational conditions rather than fixed independently of them (Price, 1997).

## Truth, Objectivity, and Informational Realism

If memory functions as the archival substrate through which reality gains experiential stability, then the classical definition of truth as simple correspondence between memory and a fixed external world requires revision. Under informational realism, truth becomes relational: it emerges from the coherence between physical constraints and the observer's informational integration of those constraints (Wheeler, 1989; Landauer, 1991; Floridi, 2011).

This does not entail a collapse into epistemic relativism. Physical law continues to restrict the space of possible experiences. However, the pathway through which physical facts become experientially real is mediated by memory systems that are neither perfectly reliable nor permanently fixed. Truth, therefore, becomes neither purely objective nor purely subjective but arises from the dynamic alignment between informational stability and physical constraint.

This framework offers conceptual grounding for understanding the epistemic vulnerabilities introduced by memory distortion, misinformation, and perceptual manipulation. If reality is lived through mutable informational archives, then disturbances to those archives carry consequences not only for belief but for the experienced structure of the world itself.

## Participation Without Omnipotence

The present model supports a restricted form of participatory ontology. The observer participates in the stabilization of reality but does not possess unconstrained creative power over physical existence. Memory does not rewrite physical law, nor does consciousness arbitrarily select outcomes at will. Participation is bounded by probabilistic constraints, physical regularities, and biological limitations (von Neumann, 1955; Schlosshauer, 2005; Zurek, 2003).

The observer participates not by creating reality ex nihilo but by selecting, stabilizing, and reintegrating informational outcomes within a constrained physical landscape. The universe does not orbit the observer, yet neither does it remain indifferent to observation. Reality emerges relationally at the interface between quantum potential, biological measurement, and mnemonic integration.

This participatory realism occupies a conceptual middle ground between classical objectivism and radical constructivism. It preserves the independence of physical law while acknowledging the indispensability of observation in the emergence of experienced reality. The universe becomes neither a self-sufficient machine nor a mere projection of mind but a dynamically co-constructed informational system.

## Ethical and Existential Stakes

Finally, this framework introduces novel ethical and existential considerations. If identity and reality are jointly stabilized through mutable memory systems, then interventions that alter memory acquire significance that extends well beyond individual psychology. The deliberate modification of memory becomes an intervention into the informational infrastructure through which persons experience continuity, agency, and meaning.

As neurotechnologies capable of dampening, enhancing, or selectively erasing memory advance, the philosophical stakes intensify (Farah, 2002; Earp et al., 2014). Such interventions may offer therapeutic benefits for trauma and psychopathology, yet they simultaneously risk destabilizing the coherence of identity itself. If the self is sustained by a narrative archive that remains open to biological revision, then altering that archive reshapes not only suffering but the structure of personhood.

These developments force a reexamination of moral responsibility, authenticity, and personal continuity. If memory is reconstructed rather than preserved, to what extent can individuals be held responsible for actions remembered through altered mnemonic frameworks? Conversely, to what degree might memory modification serve as a tool for healing without eroding the informational coherence of the self? These questions remain unsettled, but their emergence underscores the urgency of philosophical analysis as memory technology increasingly intersects with the structure of identity and reality alike.

## Limitations and Methodological Constraints

The theoretical framework developed in this paper is intentionally interdisciplinary, integrating quantum mechanics, information theory, cognitive neuroscience, and philosophy of mind. While this synthesis enables novel conceptual connections, it also introduces important methodological limitations that must be explicitly acknowledged to preserve scientific rigor and interpretive restraint.

### Interpretation Dependence of Consciousness-Based Collapse

The present model adopts the Von Neumann–Wigner interpretation as a conceptual scaffold for relating observation to physical actuality (von Neumann, 1955; Wigner, 1961). However, consciousness-based collapse remains a minority position within contemporary foundations of quantum mechanics. Alternative interpretations—including decoherence-based frameworks, many-worlds formulations, and objective-collapse theories—offer accounts of measurement that do not invoke consciousness as a causal agent (Everett, 1957; Zurek, 2003; Schlosshauer, 2005).

While none of these interpretations fully resolves the problem of subjective definiteness, their existence limits the generalizability of claims that directly tie collapse to conscious awareness. Accordingly, the present framework does not assert that consciousness is the only possible mechanism capable of stabilizing quantum outcomes. Rather, it argues that if consciousness participates in collapse, then memory—the biological infrastructure of that consciousness—must be considered ontologically significant.

## Separation Between Informational Reality and Physical Dynamics

A central constraint of this model is its strict distinction between physical dynamics and informational experience. The framework does not propose that memory reconsolidation physically reverses, erases, or modifies external physical events. All external physical processes remain bound by standard causal laws following quantum state selection (Schrödinger, 1935; Schlosshauer, 2005).

Claims that memory "alters reality" are restricted explicitly to the phenomenological and informational domains. Any stronger claim implying direct retrocausal intervention at the level of physical law would exceed both the current empirical evidence and the theoretical scope of the framework developed here.

## Limits of Neuroscientific Generalization

Although memory reconsolidation is now a well-established phenomenon across multiple experimental paradigms, its precise boundary conditions remain an active area of research. Not all memory types reconsolidate under all conditions, and the degree of malleability varies with emotional salience, memory age, retrieval context, and neural system involved (Nader et al., 2000; Dudai, 2004; Lee, 2009).

The present synthesis treats reconsolidation as a general mechanism of informational instability within memory systems. However, this generalization should be regarded as probabilistic rather than universal. Furthermore, while synaptic plasticity provides the cellular basis for memory modification, it has not yet been empirically demonstrated that individual reconsolidation events measurably restructure long-term identity coherence in the manner proposed here.

## Absence of a Direct Experimental Bridge

A fundamental limitation of the present framework is the absence of any direct experimental protocol capable of linking quantum measurement dynamics to biological memory modification. Contemporary neuroscience does not currently operate at the scale required to test quantum-level observer effects within neural tissue, and quantum physics does not incorporate biologically realistic observer models.

As a result, the synthesis presented here must be understood as theoretically integrative rather than experimentally demonstrative. The argument establishes conceptual coherence across domains but does not claim empirical verification of memory-driven informational modification of physical history.

## Risk of Category Error

Interdisciplinary research carries intrinsic risk of category error—misattributing properties of one explanatory domain to another. Particular care has been taken here to avoid treating memory as a physical wave function or consciousness as a physical force. Memory is treated strictly as an informational-biological process, and collapse is treated phenomenologically rather than mechanically (Floridi, 2011).

Nevertheless, the conceptual proximity between informational realism and physical ontology demands caution. Readers are urged to interpret the framework as an ontological proposal rather than a physical mechanism.

## Philosophical Non-Falsifiability

Finally, like many integrative metaphysical models, the present framework is not strictly falsifiable in the Popperian sense. Its value lies not in immediate experimental testability but in its explanatory unification, conceptual clarity, and capacity to generate novel research questions (Price, 1997; Floridi, 2011).

The framework should therefore be evaluated according to philosophical criteria of coherence, scope, and theoretical fertility rather than direct empirical confirmation.

## Conclusion

This paper has examined the conceptual convergence between quantum measurement theory, information ontology, and the neuroscience of memory reconsolidation in order to reassess the relationship between observation, identity, and the stability of experienced reality. Classical scientific assumptions long treated the past as a fixed sequence of objective physical events and memory as a passive retrieval system for that sequence (Laplace, 1814/1902). However, developments in both physics and neuroscience now challenge these assumptions at their foundations.

Quantum mechanics demonstrates that physical systems do not possess fully determinate properties prior to observation and that the transition from probabilistic superposition to definite outcome remains formally unresolved within the core mathematical structure of the theory (Schrödinger, 1935; von Neumann, 1955; Schlosshauer, 2005). Observer-dependent interpretations, particularly those derived from the Von Neumann–Wigner tradition, situate observation as the boundary condition through which physical reality becomes experientially definite (von Neumann, 1955; Wigner, 1961). Under informational interpretations of physics, especially Wheeler's It from Bit doctrine and Landauer's principle that information is physical, reality itself is increasingly understood as an informationally grounded phenomenon rather than a purely material primitive (Wheeler, 1989; Landauer, 1991; Floridi, 2011).

At the same time, neuroscience has radically revised the understanding of memory. Empirical research on reconsolidation demonstrates that memory is not a static archive of past events but a dynamically reconstructed biological process in which retrieval destabilizes memory traces prior to their restabilization (Nader et al., 2000; Dudai, 2004; Sara, 2000; Lee, 2009). This instability extends directly to personal identity, which contemporary cognitive models increasingly define as a process of autobiographical reconstruction rather than the preservation of immutable internal content (Conway & Pleydell-Pearce, 2000; Damasio, 1999).

By integrating these findings, this paper has advanced a theoretical framework in which identity functions as the continuous informational observer that stabilizes quantum actuality through a biologically mutable neural archive. Under this model, observation collapses quantum potential into physical actuality, memory encodes that actuality into a persistent informational structure, and identity emerges as the continuity of that structure across time. Yet because the archival substrate of identity is biologically unstable, the informational structure through which experienced reality is stabilized remains perpetually open to reconstruction.

This framework does not claim that memory can violate physical law, reverse external events, or induce physical retrocausation. Physical systems remain governed by established causal constraints following state reduction (Schrödinger, 1935; Schlosshauer, 2005). Rather, the model reframes experienced reality as an informational phenomenon jointly constrained by physical law and biological reconstruction. The physical past remains externally fixed, but the experiential past remains dynamically reconstructed.

The philosophical implications of this synthesis extend across theories of selfhood, causation, truth, and participation. Identity is rendered a process of informational continuity rather than a fixed entity. Causation becomes layered across physical and informational domains (Price, 1997). Truth emerges relationally from the alignment between physical constraint and mnemonic integration (Floridi, 2011). Reality itself assumes a restrained participatory structure in which observers do not create the universe but actively stabilize its experiential definiteness through observation and memory (Wheeler, 1989; Landauer, 1991).

Beyond its theoretical implications, this framework carries pressing ethical significance. As neurotechnologies capable of selectively modifying memory continue to advance, interventions into the neural archive will increasingly reshape not only psychological well-being but the informational foundations of identity and reality alike (Farah, 2002; Earp et al., 2014). Memory modification must therefore be regarded not merely as a clinical tool but as an intervention into the structural conditions under which persons experience continuity, agency, responsibility, and meaning.

The synthesis presented here remains theoretical and interdisciplinary. It does not resolve the quantum measurement problem in its physical entirety, nor does it offer direct experimental confirmation of memory-driven informational modification of reality. Instead, it identifies a critical conceptual boundary condition—one at which physics and neuroscience converge through the shared language of information. At that boundary, identity emerges as the stabilizing bridge between quantum indeterminacy and experiential definiteness.

Under this formulation, memory is no longer a mere record of reality. It becomes one of the conditions under which reality becomes experientially stable at all. The observer is not simply located within the universe; the universe, as lived, is continuously stabilized within the observer.

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