Title: Reframing Wheeler's Delayed-Choice Paradox Through Observer-Lag in Neural Decision Timing

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Abstract Wheeler's delayed-choice experiment appears to challenge classical causality by implying that present choices affect past photon behavior. We propose a reinterpretation grounded in neuroscience and relativity. Drawing on Libet's findings on neural decision lag and the timeless nature of photon propagation under special relativity, we argue that the illusion of retrocausality arises from a lag between unconscious decision-making (Neural Agent) and conscious awareness (Phenomenal Observer). When this observer lag is accounted for, the paradox dissolves: photon behavior reflects physical conditions shaped by unconscious processes prior to conscious awareness. This model preserves causality without invoking exotic physics.

1. Introduction Wheeler's delayed-choice experiment challenges classical causality by implying that present measurements determine a photon's past behavior. Instead of invoking many-worlds or backward-in-time effects, we argue that the perceived retrocausality is a result of misinterpreting the timing of human decision-making. When the delay between unconscious action and conscious awareness is considered, the paradox vanishes.

2. Key Concepts 2.1 Wheeler's Delayed-Choice Setup In Wheeler's Mach-Zehnder interferometer, a photon first encounters a beamsplitter, entering a superposition of paths. A second beamsplitter may or may not be inserted before detection. Inserting it yields interference (wave behavior); omitting it provides which-path information (particle behavior). The paradox arises because this choice is made after the photon has passed the first splitter.

2.2 Neural Decision Delay Libet's experiments revealed that neural activity linked to a decision precedes conscious awareness by 300 to 500 milliseconds. The decision-maker is not the conscious mind but the unconscious brain. This lag means the moment of choice and the awareness of that choice are separated in time.

2.3 Photon Timelessness According to special relativity, photons travel at the speed of light and experience no time between emission and absorption. From the photon's perspective, its entire journey from source to detector is a single, timeless event. This everything-at-once nature is critical. The photon can be seen as encountering a configuration already shaped by decisions made outside our conscious awareness.

1. Observer-Lag Model 3.1 Two Selves

2. Neural Agent: The unconscious agent initiating decisions.

3. Phenomenal Observer: The conscious narrative that emerges several hundred milliseconds later.

3.2 Timing Resolves the Paradox When considering the photon's timeless experience, it becomes evident that it never needed to retroactively adjust its state. Instead, it encountered an apparatus shaped by the Neural Agent's unconscious decision, one made before the photon reached the relevant interaction point. The apparent retrocausality arises because the Phenomenal Observer perceives the decision after the fact, even though the photon's state was determined earlier.

3.3 Retrocausality as Illusion The delayed-choice paradox emerges only when we incorrectly assume the Phenomenal Observer is the central causal agent. In fact, the photon's state is determined by the Neural Agent's unconscious decisions, made prior to the photon's interaction with the apparatus. The lag between unconscious action and conscious awareness creates the illusion of retroactive change, but in reality, the decision has already shaped the photon's state.

3.4 Measurement Is Not Observation Detectors respond to the physical setup shaped by the Neural Agent's unconscious decisions, not by the Phenomenal Observer's later conscious awareness. The photon's state change is a result of the Neural Agent's unconscious action, and the Phenomenal Observer's role is purely retrospective.

3.5 Clarifying the Role of Consciousness Standard quantum mechanics does not require consciousness to collapse the wave function. Observer-Lag does not claim otherwise. Rather, it proposes that the physical setup influencing the photon's behavior is often attributed to a conscious decision, when in fact that configuration was already shaped by unconscious processes.

1. Proposed Experimental Approaches

2. EEG + Photon Delay: Extend photon transit time beyond 500ms while capturing neural precursors. If behavior matches the unconscious timestamp rather than conscious awareness, the model is supported.

3. Passive Delay (No EEG): Use long fiber optic paths or mirrors to delay detection. Late awareness should not alter photon behavior if shaped earlier by unconscious intent.
4. Cosmic Variant (Gedankenexperiment): Illustrates the irrelevance of delayed choices when viewed from the photon's null proper time.

4.4 Threshold Considerations The observer lag becomes relevant only when the photon's travel time exceeds the minimum neural delay observed in decision-making. Below 300 milliseconds, the Neural Agent and Phenomenal Observer effectively coincide, making any divergence undetectable. Neuroscience studies (e.g., Libet et al., 1983) report delays ranging from 300 to 500 milliseconds, with 500 ms representing the upper bound of reliably measured neural lag between unconscious action and conscious awareness. To isolate the Neural Agent's influence, photon transit times should exceed this threshold.

4.5 Engineering Challenges Achieving 500 milliseconds of photon delay requires approximately 150,000 kilometers of effective travel. While possible with fiber optics or multi-path reflection, photon decoherence is a major challenge. Engineering around this is non-trivial.

4.6 Cryogenic Solutions Cryogenic setups may allow photons to persist coherently longer. Superconducting delay lines or optical cavity traps could help preserve wave integrity while providing delay.

1. Implications 5.1 Consciousness Is Narrative The Phenomenal Observer narrates events after the fact. Awareness is not causal but retrospective.

5.2 Causality Remains Intact Quantum behavior conforms to real-time configuration. Once the neural lag is accounted for, there is no need to invoke retrocausality.

5.3 Fit Within Quantum Frameworks The model aligns with Copenhagen and does not conflict with decoherence or relational quantum mechanics. It adds a cognitive layer without disrupting physical theory.

1. Conclusion Observer-Lag reframes the delayed-choice paradox by combining special relativity and neuroscience. It explains the illusion of retrocausality without resorting to exotic physics. Photons interact with configurations shaped by unconscious choices, not by when we become aware. Time, for the photon, does not flow. For us, awareness follows action.

References

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