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# Testing Human Free Will via a Delayed-Choice Quantum Eraser: A Proposal for an Experimental Protocol

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# Testing Human Free Will via a Delayed-Choice Quantum Eraser: A Proposal for an Experimental Protocol

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**Abstract**

The question of human free will has remained a central philosophical challenge for millennia. In physics, the issue of determinism versus indeterminism resurfaces in quantum mechanics, where measurement choices play a key role. In this work, we propose an experimental protocol inspired by delayed-choice quantum eraser experiments, in which the random switching of measurement settings is not performed by a quantum random number generator (QRNG), but instead by human participants making rapid spontaneous choices. If human choices are fundamentally unpredictable in a way that is not reducible to quantum mechanics or physical determinism, then the universal wave function could not have encoded them prior to the decision event. By introducing quantum memories to extend the decision window and ensuring strict separation and blindness of participants, this experiment could test whether interference patterns depend on genuinely free human choices or yield results identical to QRNG-based protocols.

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## 1. Introduction

The interplay between determinism, randomness, and free will has long fascinated both physicists and philosophers. In classical physics, determinism ruled, leaving no room for genuine unpredictability. In quantum mechanics, indeterminacy reemerges, yet the debate continues: is quantum indeterminism truly fundamental, or merely epistemic?

Delayed-choice experiments, first envisioned by Wheeler [1], test the counterintuitive nature of quantum measurement: a choice made after a particle's detection can seemingly influence whether it exhibited wave-like or particle-like behavior. The delayed-choice quantum eraser (DCQE) variant [2,3] extends this framework by allowing the erasure or preservation of which-path information, with interference recovered or lost accordingly. It has challenged our intuition about causality, suggesting that measurement choices can seemingly retroactively determine whether or not interference patterns emerge.

In all implementations to date, the "choice" of measurement basis has been performed by physical systems, such as beam splitters or QRNGs. From the perspective of deterministic or many-worlds interpretations, the outcomes of these physical choice mechanisms are already encoded in the universal wavefunction. A natural question arises: what if the choice mechanism is not reducible to physical determinism? If human free will exists in a strong sense—producing outcomes not predictable from prior physical states—then one can design an experiment to probe whether quantum predictions hold under such conditions.

Here, we propose a new variant of the DCQE experiment, in which the measurement choice is delegated to humans making spontaneous decisions within a short reaction window. *If* human free will exists in a form that escapes deterministic or quantum-mechanical prediction, then interference outcomes *should* differ from those obtained with physical random generators.

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## 2. Related Experiment

A large-scale project known as the BIG Bell Test [4] involved volunteers worldwide who provided random inputs to Bell inequality experiments via their keystrokes. While this addressed the "freedom-of-choice loophole" in nonlocality tests, the human inputs only replaced QRNGs in the selection of measurement bases for entangled particles. Our proposal differs fundamentally: it employs the *delayed-choice quantum eraser* architecture, where the measurement setting must be chosen *after* the signal photon has already been detected, and where quantum memory is required to extend the decision time window. To our knowledge, no experiment has yet tested whether genuinely human choices in this context yield results indistinguishable from quantum-random choices.

## 3. Proposed Experimental Setup

### *3.1. Overview*

Our setup is based on the canonical delayed-choice quantum eraser [3]. A signal photon is directed toward a detector screen $D_0$ after passing through a double-slit-like apparatus. Its idler twin photon is delayed and directed to a set of detectors that either erase or reveal which-path information.

In our variant, the decision of whether the idler photon encounters a "which-path revealing" or a "which-path erasing" configuration is determined not by a QRNG but by human participants.

### *3.2. Human Decision Protocol*

Participants are seated in front of a touchscreen interface. When the decision window opens, the screen displays four options (A, B, C, D). The participant make a rapid, spontaneous selection. Two options correspond to orienting a mirror (or optical switch) toward a path-erasing configuration; the other two correspond to a path-revealing configuration.

A large number of participants (e.g., 1000) would be required to ensure statistical significance. A parallel control experiment is performed using QRNGs for comparison.

### *3.3. Timing Constraints and Quantum Memory*

The central challenge is ensuring that the signal photon hits the detection screen *before* the human choice is registered, thereby preserving the delayed-choice condition. To achieve this, we propose using quantum memories to store the idler photon for several seconds.

State-of-the-art quantum memories [5,6] can achieve storage times approaching the second scale. Extending memory duration to several seconds would be ideal to provide participants with a comfortable decision-making time. Research into atomic ensemble memories and rare-earth-ion doped crystals provides a promising path.

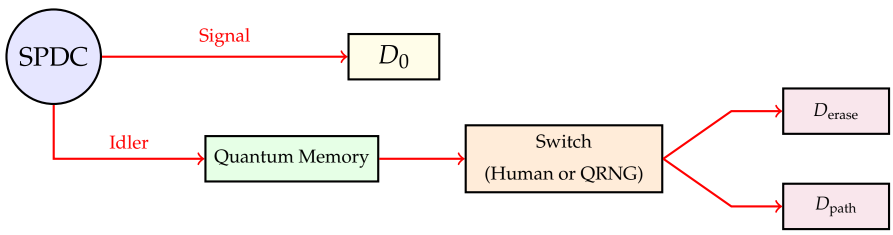


**Figure 1.** Schematic of the proposed delayed-choice quantum eraser with human (or QRNG) decision. The idler photon is stored in a quantum memory before the choice is made, ensuring the delayed-choice condition.

The timing of the events must satisfy the following inequality:

$$t_S < t_{\text{begin\_choice}} < t_H < t_I$$

where:

- $t_S$: detection of the signal photon on $D_0$.
- $t_{\text{begin\_choice}}$: display of options to participants.

- $t_H$: participant's choice (measured via touchscreen or EEG/EMG markers).
- $t_I$: arrival of the idler photon at the measurement stage.

### 3.4. Bias Control

Potential biases are controlled via:

- The form and meaning of the options are unknown to participants beforehand.
- The mapping between touchscreen options and measurement settings is randomized across runs.
- Instructions emphasize spontaneity and discourage premeditation.
- Communication between participants is forbidden to avoid coordination and premeditation.
- Blind post-processing to prevent data analysis bias.

## 4. Expected Outcomes

Two possibilities exist:

1. **Quantum mechanics holds:** Human choices yield results indistinguishable from QRNG-based choices. Interference appears only when which-path information is erased.
2. **Violation in favor of free will:** Human choice results deviate significantly from QRNG-based choices. Interference patterns appear even when which-path information is preserved.

## 5. Implications

If such an experiment is successfully performed, it would test whether human free will manifests in a manner irreducible to the quantum framework. Should the standard predictions hold, this would support the view that free will is ultimately grounded in quantum processes. Conversely, if deviations are observed, it would suggest that free will is not reducible to quantum physics and would have far-reaching consequences beyond physics, impacting neuroscience and philosophy.

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