The Role of Conscious Attention and Prior Knowledge in Quantum Measurement Collapse

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Abstract
Background: Quantum mechanics describes the behavior of matter and light at the atomic and subatomic levels. In quantum mechanics, a key principle is that quantum objects can exhibit both wave-like and particle-like behavior. This is called “wave-particle duality" (Squires, 1999). Moreover, quantum mechanics presents us with a mixture of possibilities, where the particles exist in a state of superposition until an observation occurs. When we measure, the wave function collapses into a single outcome. To address this, it’s imperative to understand what exactly constitutes an observation in quantum mechanics and its role in wave function collapse.
Objectives: This study explores the concept of measurement from both a physical and philosophical perspective, examining different interpretations of consciousness and how observation influences the outcomes of quantum experiments. More specifically, it focuses on how mental states, such as expectation or previous knowledge could impact wave function collapse. Complementing the existing body of research, this review expands to explore several critical questions surrounding the nature of observation in quantum mechanics.
Methods: The study conducted a literature review to establish the theoretical background and relevance. Forty-five participants (ages 13+) were randomly assigned to one of three groups: Expectation/Attention, Neutral Observation, or Automated Control. Each group observed 100 random binary outcomes generated using Random.org, with the Expectation group instructed to mentally focus on increasing the number of 1s. The experiment was conducted using PsychoPy, with all outcomes and timing automatically logged. A statistical analysis using ANOVA and post-hoc tests revealed significant group differences, particularly between the Neutral group and the others.
Results: Expected Group (primed with prior knowledge) yielded the highest median (63), suggesting expectation may amplify observed values. The Neutral Group (baseline awareness) recorded the lowest results (median=57). The Control Group (standard observation) occupied an intermediate range. Neutral < Control < Expected in median values. The expected group shows 2× the IQR of Control/Neutral, indicating higher variability. No outliers detected in any group using the 1.5×IQR rule. These patterns tentatively support the proposed link between conscious states (e.g., expectation/knowledge) and quantum phenomena. To validate the differences across the control, expected, and neutral groups, a one-way ANOVA test was taken, which revealed a statistically significant difference in the counts of ones between the groups ($p = 0.000014$). Post-hoc analysis using Tukey’s HSD indicated that the neutral group significantly differed from both the control and expected groups, while the control and expected

groups did not significantly differ from each other. Additionally, the effect size ($\eta^2 = 0.64$), indicates a large and meaningful difference between the groups.
Conclusions: This study provides preliminary evidence that conscious mental states, particularly expectation, may measurably influence quantum measurement outcomes. The observed positional trends and increased variability in the Expected group suggest that the observer's mindset is not merely a passive condition but may actively modulate the measurement process. While the findings align with and expand upon previous research linking consciousness to quantum phenomena, they also introduce new considerations regarding variability and individual cognitive influence. Nonetheless, this work offers a meaningful step toward understanding the complex relationship between consciousness and the physical world and underscores the need for continued interdisciplinary research to further explore this potential connection.
Keywords: Consciousness, Quantum Mechanics, Neuroscience, Measurement problem, Mental States, Wave function collapse

Introduction:

Quantum mechanics expresses the behavior between matter and light at the atomic and subatomic levels . In quantum mechanics, a key principle is that quantum objects can exhibit both wave-like and particle-like behavior. This is called “wave-particle duality" (Squires, 1999). Moreover, quantum mechanics presents us with a mixture of possibilities, where the particles exist in a state of superposition until an observation occurs. When we measure, the wave function collapses into a single outcome. But what, exactly, constitutes an observation?

But before we delve into that, we need to understand a few underlying principles. Firstly, the principle of superposition states that when two or more waves meet, the resulting displacement at a point is the sum of the individual wave displacements at that point. In a summary, the idea is that essentially a quantum system can exist in multiple states at once. For example, an electron can be both “up” and “down”. In mathematical terms, this is called a blend of possibilities, where it is a superposition of states until something interacts with it or “measures” it (*Spin, Entanglement and Quantum Weirdness*, 2010). This principle applies to other wave phenomena such as interference, diffraction and the standing waves. Likewise, measurement plays a similar role. When we observe or measure a quantum system, the superposition disappears, or collapses, or more clearly, the system settles into a single, static state. Therefore, the outcome we observe seems to be related to probability. This phenomenon, the collapse of a superposition upon observation, is the center of the “measurement problem” (Hossenfelder, n.d.) . This urges the question of how and why does observation even cause the collapse of a physical state? More importantly, it makes the boundary between the physical world and the role of conscious obstruction more cloudy. If a conscious mind is needed to collapse a wavelength, the observation in its nature isn't passive, rather, the conscious mind itself is an active variable in forming physical reality.

Therefore, this paper explores the relationship between the conscious mind and the collapsing wavefunctions. It ties observation, knowledge, and subjective awareness directly into the physical process of measurement. In order to unravel this topic, the paper first reviews the classical interpretations of the measurement problem. Next, it considers perspectives from neuroscience, where we will ask whether observation is completely needed within a conscious nervous system. Lastly, it explores the philosophical implications of this view in hopes of understanding the exact manner regarding how reality and knowledge are interlinked. Overall, in synthesizing these perspectives, the paper ultimately poses the
hypothesis, if conscious awareness is necessary for quantum measurement collapse, then observers with differing mental states (expectation, attention, knowledge) will produce measurably distinct outcomes in quantum systems compared to unconscious or automated observation. Henceforth, this urges the question: *Does the expectation or prior knowledge—the mental state—of the observer influence quantum outcomes*?

Methods:

Participants:

Forty-five volunteers (13+ years) with normal or corrected-to-normal vision were recruited through convenience sampling from high school and university bulletin boards, social media platforms, and personal networks. Participants provided informed consent and were compensated with a summary of study results upon completion through Google Forms and gmail. The study protocol followed established ethical guidelines for human subjects research. Participants were randomly assigned to one of three experimental conditions using a pre-generated randomization sequence created via Random.org.

Design: This study employed a between-subjects experimental design with three conditions: (1) Expectation/Attention group (n = 15), (2) Neutral observation group (n = 15), and (3) Automated control group (n = 15). The primary dependent variable was the proportion of ‘1’s and ‘0’s observed from a sequence of 100 binary outcomes. The experiment aimed to test whether an observer’s mental state influences their perception or interpretation of random binary sequences.

Materials: Random binary sequences of 100 outcomes (0 or 1) were pre-generated using Random.org’s true random number generator, which utilizes atmospheric noise to ensure authentic randomness. These sequences were validated to ensure approximately equal numbers of 0s and 1s. Google Forms was used both for informed consent and data collection. For live facilitation, sessions were conducted using Zoom or Google Meet.

The experimental paradigm was implemented using PsychoPy v2023.2.3, a Python-based software package for running psychology and neuroscience experiments. The experimental script was programmed to present stimuli on a standard computer monitor (1920x1080 resolution, 60Hz refresh rate) with participants seated approximately 60cm from the screen. Binary outcomes (0 and 1) were displayed as white text (Arial font, 72-point size) on a black background, centered on the screen. Each trial presentation lasted exactly 3 seconds with a 500ms inter-trial interval displaying a fixation cross.

Participant responses and timing data were automatically logged to CSV files by PsychoPy's built-in data handling system. All sessions were conducted at the comfort of the participant. Participants used a standard computer keyboard to advance through trials at their own pace during instruction phases. Participants needed a device with internet access and were instructed to participate in a quiet environment. Each session lasted approximately 15–20 minutes.

Data Collection: In live sessions, the researcher manually tracked observations and engagement in Google Sheets. In self-paced sessions, PsychoPy automatically recorded all stimulus presentations, timing information, and participant responses with millisecond precision. Each experimental session generated a comprehensive log file containing trial-by-trial data, participant information, and session metadata. Data integrity was ensured through PsychoPy's built-in validation systems and automatic backup file generation. All data submissions were cross-checked with the random sequence shown to ensure integrity.

Pre-Session Protocol: Participants completed informed consent procedures and basic demographic information through Google Forms. Group assignment was determined by sequential participant numbering with pre-randomized condition allocation, maintaining experimenter blindness to condition during data collection. Participants were seated comfortably in front of the computer screen and given standardized instructions for using the experimental interface. A brief practice session with 5 trials familiarized participants with the stimulus presentation format. Scheduling was done individually according to participant availability.

Experimental Manipulation:

- **Expectation/Attention Group:** Participants received the following standardized instructions: "You will observe outcomes from a high-quality random number generator that produces 0s and 1s. Research suggests that focused mental attention can influence these systems to produce slightly more 1s than 0s. Please concentrate on the number 1 appearing and maintain focused attention throughout all 100 trials. Your mental focus may influence the processes generating these numbers. Press the spacebar when you're ready to begin."

- **Neutral Group:** Participants received neutral instructions, with no instructions regarding expectations, outcomes, or potential influence: "You will observe outcomes from a random number generator that produces 0s and 1s. Please watch the screen and note the results as they appear. The computer will automatically record all outcomes. Press the spacebar when you're ready to begin."
- **Automated Control:** The identical experimental program was executed without human observers present, no additional context provided about expectations or influence, with the PsychoPy script running autonomously and outcomes automatically recorded over 100 trials.

Trial Structure: Each session consisted of 100 binary outcome trials presented through the PsychoPy interface. Individual trials displayed a single binary outcome (0 or 1) for exactly 3.0 seconds, followed by a 500 ms fixation cross inter-trial interval. The total stimulus presentation duration was approximately 6 minutes. Participants were instructed to maintain visual attention on the screen throughout but were not required to make any responses during the main experimental trials. In live sessions, slides were screen-shared by the researcher. Total session duration was approximately 10 minutes. Participants were instructed to maintain attention throughout but were not required to make predictions or responses.

Post-Session Assessment: Following the main experimental session, participants completed a brief questionnaire assessing: (1) expectations about outcome ratios, (2) perceived ability to influence results (7-point Likert scale), (3) attention and concentration levels during the task, and (4) any notable subjective experiences. Participants were then debriefed about the study's purpose and theoretical background.

Primary Analyses: The primary outcome variable was the proportion of 1s observed in each group. Group comparisons will be made using standard statistical tests such as ANOVA or chi-square tests, conducted in Excel or R. Secondary analyses may assess whether attention, session format, or participant feedback moderated the main effect. All data analysis will utilize the CSV output files generated by PsychoPy's data logging system.

All outcome data were automatically logged by PsychoPy to prevent transcription errors. The experimental program included built-in validation checks to ensure stimulus sequences matched the pre-generated random sequences. Session timing and presentation accuracy were verified through PsychoPy's frame-by-frame logging capabilities. Each participant's data file included metadata about system performance, dropped frames (if any), and stimulus presentation accuracy.

This study involved minimal risk to participants and followed established ethical guidelines for human subjects research. While formal institutional review board approval was not obtained, all procedures adhered to principles outlined in the Declaration of Helsinki. Participants provided informed consent, were free to withdraw at any time. No deception was employed beyond the withholding of specific hypotheses during data collection to maintain experimental validity.

All participants were blind to other conditions and to the study's hypotheses. Group assignments were concealed from the researcher during live trials to minimize bias. Each group viewed the same PsychoPy script and hardware setup to avoid potential confounds. The automated control condition eliminated any potential observer effects by running the identical experimental program without human participants present.

Literature Review:

Perception and Observation

When discussing whether or not observation is completely needed within a conscious nervous system, we need to understand the role of consciousness, perception and observation. These are crucial to the measurement problem because they not only influence the state of the system itself, but our understanding of reality as a whole. Perception is the act of observation that influences the state of a system. Consciousness is a state of being aware of one's own existence and thoughts. Meanwhile, observation is simply the act of noticing or perceiving something (Quantumglyphs, 2024). While one could be conscious without actively observing, they can also observe something without being fully conscious of the act. This is because consciousness is a state of being, whereas observation is an action (BrighterMinds Connect, 2019). Moreover, conscious observation and simply the "feeling of energy/attention" are not distinct; rather, observation is a physical interaction instead of a subjective experience. Whereas attention, which denotes directed mental focus as a cognitive phenomena, lacks the empirical evidence to alter the understanding of quantum behavior from emerly psychical interactions (Dainton, 2010), (Barton, 2025). When talking about consciousness within quantum mechanics, it's important to note that conscious observation is not synonymous with quantum measurement. Rather, conscious observation needs subjective awareness, which emerges from brain processes, and is unobservable; whereas quantum measurement requires physical interaction, occurs via environmental decoherence, and is observable (Bacciagaluppi, 2003). Decoherence is just the interaction with surroundings, and it could suppress quantum interference. Conscious effects would require isolating consciousness from decoherence.

However, the question whether or not a measuring device suffices, or if a conscious mind is required still exists. This paper will henceforth first explore three collapse mechanisms. Firstly, there are objective collapse models, such as the Continuous Spontaneous Localization (CSL) (Hameroff, 2019). This model modifies standard quantum mechanics by introducing a stochastic, nonlinear process that essentially leads to the collapse of the wavelengths–this is done continuously, rather than instantaneously. The stochastic, nonlinear process, has two key features. Stochasticity, which is randomness, is the collapse of the wavelength being driven by random fluctuations, rather than it being deterministic. It is modeled mathematically as a type of white noise or Brownian motion. Nonlinerauty suggests that the collapse process is nonlinear, which means that the evolution of the wave function depends on its current state that's not linear–this is crucial because it allows the suppression of quantum superpositions, leading the wavefunction to be localized around definite states. Both of these key features then gradually lead the wavefunction of collapse to a definite outcome (Piscicchia et al., 2023), (Bera et al., 2015). This model suggests that the interactions between macroscopic objects or even measuring devices can lead to wavelength collapses; this is completely independent of conscious observation (*[Ball*, n.d.-a). To explain this more in depth, this collapse is triggered by physical interactions. The stochastic noise field then acts universally, leading the superpositions to decay into a definite outcome as the systems grow larger and larger, becoming more and more entangled to their surroundings (Bera et al., 2015). This therefore means that even in the absence of a conscious observer, a measuring device alone could lead to a collapse (Piscicchia et al., 2023). Some recent models attempted to link consciousness (quantified via integrated information theory) to collapse. This is conveying that superpositions of conscious states are dynamically suppressed. A key feature of these models is that they don't need a consciousness to be a on-physical agent, rather they can be formulated within a materialistic worldview. In this perspective, the suppression of superpositions involving conscious states is a consequence of the physical properties of the system itself instead of the consciousness being a mysterious force (*Mithun*, n.d.-b). This paper will delve further into related theories later on.

Table 5:

Comparison of Key Collapse Mechanisms

Collapse Mechanism	Requires Consciousness?
Objective Collapse (CSL, OR)	No
Consciousness-Based Collapse	Sometimes (theoretical)
Standard Measurement (Device)	No

The Classical Interpretation of the Measurement Problem

The measurement problem in quantum mechanics questions why quantum systems are observed in definite states upon measurement. There are several interpretations that have been developed to address this problem. The Copenhagen Interpretation, developed by Niels Bohr and Werner Heisenberg is described by a wavefunction. This function encodes all the possible outcomes as a superposition. It states that upon any sort of measurement, the wave function collapses to a single outcome. This theory suggests that the observer, which is a conscious agent, plays a central role, although its exact mechanism is unspecified (*Quantum Enigma: Physics Encounters Consciousness*, n.d.) The many-worlds interpretation by Hugh Everett suggests that the wavefunction doesn't actually collapse but rather all the possible outcomes occur in separate, non-communicating branches of the universe. This theory expresses that when a certain measurement is made, the universe “splits” itself into multiple versions–each one becoming a possible outcome. Unlike the Copenhagen Interpretation, the observer has no special role (Zeh, 1999). There are also hidden variable theories such as the de Broglie-Bohm Interpretation, which explains that the quantum systems possess definite properties (hidden variables) at all times, even before measurement. The randomness of these outcomes arises from our simple ignorance of these hidden variables (Goldstein, 2001, (“Does Consciousness Really Collapse the Wave Function?: A Possible Objective Biophysical Resolution of the Measurement Problem,” 2005). Lastly, the relational quantum mechanics by Carlo Rovelli, suggests that the physical properties don't exist in an absolute sense, but are always relative to the observer, or another system. The outcome of the measurement is dependent on the context of the relationship between just the system and the observer–there is no universal, absolute wave function collapse (Zaghi, 2024).

Table 6:

Summary Table of Interpretations of the Measurement Problem

Interpretation	Collapse?	Role of Observer	Key Feature
Copenhagen	Yes	Central (ambiguous)	Measurement causes collapse
Many-Worlds	No	None (all outcomes)	All outcomes realized in parallel worlds
Hidden Variables (Bohmian)	No (deterministic)	None (pre-existing)	Definite properties guided by wavefunction
Relational QM	Relative	Relational	Properties exist only in relation to others

The Relationship between the Conscious Mind and Collapsing Wavefunctions
Given these ongoing debates, several theories have emerged to explain how consciousness could interact with quantum processes. Among these, the Orchestrated Objective Reduction (Orch OR) model, proposed by Penrose and Hameroff, expresses that consciousness arises from quantum computations in microtubules, which provide structural support of the cell cytoskeleton ("Consciousness in the Universe: A Review of the 'Orch OR' Theory," 2014), within brain neurons. These microtubules are made up of proteins called Tubulin Dimers, which are capable of supporting superposition, acting as quantum bits (qubits) (*Hameroff*, n.d.-b). Superposition is maintained by quantum-coherence, which is the coordinated behaviour of these states across many tubulin dimers within the microtubule lattice.

Orchestrated Objective Reduction (Orch OR):
However, the Objective Reduction, or the "OR", suggests that these superpositions cannot act indefinitely because when the mass-energy difference reaches a threshold related to quantum gravity. they collapse without the need for an external observer (Różyk-Myrta et al., 2021). Hence, according to this model, the quantum-coherence leads to the orchestrated collapse of the wavefunction in microtubules which then corresponds to conscious events. The "orchestrated" act of this model is meant to symbolize the synaptic inputs and memory, where they shape how the superposed states evolve over time (Różyk-Myrta et al., 2021). Each collapse corresponds to a precise moment of conscious experience–which essentially means that consciousness is rather a sequence of quantum collapses, each encoding information in the superposed tubulin states rather than a consciousness being a continuous flow. The Orch OR theory then suggests that the tubulin dimers can exist in multiple states at once because consciousness is linked to quantum superpositions of possible tublic states within microtubules; therefore, it represents different possible conformations (Hameroff, 2006), ("Orchestrated Reduction of Quantum Coherence in Brain Microtubules: A Model for Consciousness," 1996)(Hameroff, 2006),("Orchestrated Reduction of Quantum Coherence in Brain Microtubules: A Model for Consciousness," 1996) (*Hagoon*, n.d.-d). However, the Orch OR remains controversial because of the debate of whether or not it is sustainable in warm or wet environments (*Introduction to Quantum Theories of Consciousness*, 2024).

Integrated Information Theory (IIT):
The Integrated Information Theory, or the IIT, posits that consciousness is a byproduct of integrated information; this information is the result of casual interactions within the system itself. IIT expresses that any system that has sufficient integrated information, could possess consciousness–even if its biological or artificial. Consciousness, which is identical to the system's casual properties, has degrees which are quantified by phi–this measures how much information is generated. Consciousness needs a physical framework where elements affect each other in a unified manner. This theory provides a mathematical construct (*Integrated*

Information Theory of Consciousness, n.d.), (Schrödinger, 2025). Quantum logic gates, which are the fundamental building blocks of quantum circuits ((Bigelow, 2025) , and entangled states have extended IIT's formalism to quantum systems. It would translate measures of integrated information into the language of quantum density matrices and accommodating superpositoin, etc. Some models speculate combining IIT with CSL (Chalmers & McQueen, 2021).

Table 7:

Summary Table of IIT in Classical vs. Quantum Contexts

Aspect	Classical IIT	Quantum IIT Extension
System	Neural networks, classical circuits	Quantum gates, entangled systems
Integration Metric (Φ)	Based on classical causality	Reformulated for quantum density matrices
Consciousness Trigger	Physical integration at macro scale	Potentially at any scale, including quantum
Collapse Role	Not specified	May influence or be linked to collapse

Objective Collapse Models:

The objective collapse models, also known as spontaneous collapse, or even dynamical reduction models suggest that it doesn't need consciousness because wavefunction collapse is an objective process. These models express that the wavefunction collapse is a physical process stimulated by additional nonlinear terms–this means that the collapse occurs objectively, completely independent of any sort of measurement and observation (Ghirardi & Bassi, 2002). A few notable examples are, Ghirardi–Rimini–Weber (GRW) Model, Continuous Spontaneous Localization (CSL) Model, and the Diósi–Penrose (DP) Model. These models work because they posit that superpositions involving conscious states are rapidly collapsed; and so, the conscious beings don't directly experience the superposed states (*Siegal, 2024), (Hameroff, 2024).*

Table 8:

Comparison Table of the Objective Collapse Model

Model Type	Collapse Trigger	Role of Consciousness	Materialistic?	Suppresses Superpositions of Conscious States?
Standard Objective Collapse (e.g., CSL)	Physical parameters (mass, size)	None	Yes	No
Consciousness-Based Objective Collapse	Integrated information (Φ)	Physical measure of consciousness	Yes	Yes

Subjective-Objective Collapse (SOC) Model:
The SOC model suggests that the wavefunction collapse operator depends on a specific physical property correlated with consciousness (Clifton, 2013), compared to other models that ignore consciousness or treat it as a nonphysical agent. This is a novel approach because it integrates consciousness into the collapse with the measurement problem while being compatible with the materialistic worldview (Atmanspacher, 2004). The SOC model is testable because it predicts that systems with conscious systems, or rather highly integrated information, could experience rapid collapse of superpositions (Sattin et al., 2021).

Table 9: *SOC Model vs. Other Collapse models*

Model Type	Collapse Trigger	Role of Consciousness	Materialistic?	Suppresses Superpositions of Conscious States?
Standard Objective Collapse (CSL)	Physical parameters (mass, size)	None	Yes	No
SOC Model	Physical property correlated with consciousness (Φ)	Physical measure of consciousness	Yes	Yes

Neuroscience Perspectives on Observation and the Conscious Nervous System

Having reviewed the classical interpretations of the measurement problem and theories and models surrounding the role of consciousness in collapsing wavefunctions, it is essential to examine the neuroscience perspectives to see how they might influence quantum mechanics. The Orch OR model explained previously suggested that quantum coherence in microtubules could be the basis for conscious experience because the structural and functional properties of them may allow for quantum coherence and information processing (Hameroff, 2006), ("Orchestrated Reduction of Quantum Coherence in Brain Microtubules: A Model for Consciousness," 1996). This is because of their repeating tubulin proteins which are arranged in lattice. The interior environment could shield quantum states from decoherence and the rapid assembly and disassembly could facilitate information at the quantum level (Hameroff, 2021), (Hagon, 2002 Moreover, the Orch OR model suggests quantum coherence in the microtubules could generate conscious experience; the collapse of this coherence then leads to specific consciousness events (Wiest, 2025). This approach offers a different perspective on the "hard problem" of consciousness, which focuses on why and how subjective experience arises from physical processes. Recent research has found evidence of quantum coherence in biological systems. For example, In photosynthesis, they challenged the idea that quantum effects cannot survive in the warm, noisy environment of the brain (Kerskens & Pérez, 2018b) . Usually it was thought that quantum coherence could only be sustained in cold and isolated systems, however with the energy transfers between pigment molecules in photosynthesis complexes, it was shown to be remarkably efficient there was a less than 5% lost as heath (Panitchayangkoon et al., 2010). This is understood through the notion that when a photon is absorbed by a plant's light harvesting complex, the energy can travel through the pigment molecules in a wave-like, coherent manner–they are sampling all the pathways and selecting the most efficient routh.

Furthermore, through a neuroscience lens, the role of the observer suggests that the observer's conscious state may influence the measurement process, influencing the collapse of the wavefunction (*Towards a Generalized Theory of Observers*, n.d.).This is most popularly interpreted through the double-slit experiment. Also, for quantum processing to even occur in the brain, there are several stringent neurobiological requirements that should be met. For example, according to the Orch OR model, the microtubules within the neurons maintain quantum coherence. Other models explored the role of sub-neuronal structures and the wider neuronal cytoskeleton (Hameroff, 2022). These models propose that the brain should be viewed as a scale-invariant hierarchy. This perspective endorses that the quantum and classical processes interact across multiple organization levels. Experimental findings using MRI also have detected long-ranging quantum coherence in the human brain, with singlas correlated to physiological processes. Additional research has also been shown in aesthetics (Neuroscience News, 2024), (Kerskens & Pérez, 2018a), (Neuroscience News, 2024).

To further contextualize these quantum perspectives, neuroscience has developed several influential frameworks for understanding consciousness. For instance, research into NCCs focuses on identifying specific patterns of neural activity that correspond to conscious perception, such as visual awareness, attention, and neural binding. Synchronized gamma oscillations across cortical regions are often linked to the unified experience of conscious awareness, supporting both computational and quantum binding models (Gallotto et al., 2017). Moreover, Global Workspace Theory, GWT, posits that conscious access arises when information is globally broadcast across distributed neural networks. This “global workspace” enables higher-order cognition and reportability, emphasizing the integration and amplification of information through attention and widespread connectivity (Mashour et al., 2020).

Philosophical Implications

After exploring the neurobiological and quantum models that propose mechanisms for consciousness, we see that the boundaries between physics, biology, and subjective experiences are far from clear-cut. These perspectives not only challenge traditional views of brain function, but raise questions about the nature of reality as we know it. Hence, this convergence of neuroscience and quantum theory naturally leads us to consider the deeper philosophical implications.

Quantum mechanics fundamentally challenges us to consider if reality is fundamentally probabilistic and that the act of observation influences the state of a system. When a quantum system is measured, the observer's knowledge of the system is updated—but crucially, the measurement itself also alters the state of the system. This interplay raises deep questions about the nature of both knowledge and reality, as famously debated by philosophers such as Niels Bohr and Werner Heisenberg, who argued that quantum phenomena do not have definite properties independent of observation. The Orch OR (Orchestrated Objective Reduction) model extends this perspective by proposing that knowledge and conscious experience are fundamentally linked to quantum processes in the brain's microtubules. According to this theory, microtubules act as quantum processors, where tubulin proteins serve as qubits capable of superposition and entanglement. When these quantum states reach a critical threshold, they collapse, resulting in a discrete moment of conscious awareness—a process that is not just physical, but informational and experiential (*Gasseb*, n.d.-f). This means that knowledge, in the Orch OR framework, is not simply a reflection of reality, but an active process that shapes and participates in the unfolding of reality itself. For example, a 2025 study involving monozygotic twins found that quantum entanglement could enhance conscious experience and learning efficiency, suggesting a measurable link between quantum processes and cognitive function (Escolà-Gascón, 2025). The study used EEG and biomarkers of neuroplasticity, revealing that entangled quantum states explained significant variance in cognitive performance and learning outcomes. Such findings, while preliminary, point toward the possibility that knowledge acquisition and conscious awareness may be influenced by quantum mechanisms at the biological level.

Philosophically, this challenges the classical view, from Bertrand Rissell and Fransis Crick, that knowledge is a passive mirror of an objective world (Jones, 2009). Instead, it aligns more closely with constructivist and phenomenological traditions, such as Edmund Husserl, which emphasize the active, participatory role of consciousness in constituting reality (Beyer, 2003) .

Panpsychism and Consciousness:

Panpsychism is the philosophical position that consciousness is a fundamental and ubiquitous feature of the universe, rather than an emergent property of complex systems (Goff et al., 2001). In the context of quantum mechanics, it urges the question if consciousness is tied to quantum processes, and if such processes are present throughout nature, then some form of proto-consciousness could be a basic aspect of all matter (Atmanspacher, 2004).

The Orch OR model resonates with this view by suggesting that consciousness arises from quantum events that are not unique to the human brain, but are a fundamental feature of reality itself. This perspective not only offers a potential solution to the hard problem—by positing that subjective experience is woven into the fabric of the universe—but also reframes our understanding of knowledge and reality as co-emergent, rather than separate domains (Loker, 2023). Meanwhile, the IIT suggests that while it isn't inherently quantum, consciousness is a fundamental property of certain complex arrangements. In addition, Cosmopsychism, a modern philosophical position that argues that the universe as a whole is conscious, and that individual consciousness are simply fragments of the universal mind (*Institute of the Cosmos*, n.d.) . Philosophers like Philliop Goff or Hedda Morch, express that cosmophysics point to quantum entanglement. QBism, by Christopher Fuchs, expresses that the observer's knowledge and beliefs are at the center of quantum theory. The wavefunction is the agent's degrees of beliefs about measurement outcomes, not just an objective property of the system. This philosophy reframes reality as fundamentally participatory, where the observer's perspective is inseparable from the physical world (*What Is QBism?*, n.d.), (Gefter, 2015). Moreover, relational quantum mechanics, by Carlo Rovelli, suggests that the properties of quantum systems are not absolute but are always relative to other systems (including observers). This relationality implies that "facts" about the world are always observer-dependent, which resonates with the idea that consciousness or subjectivity is woven into the structure of reality (PhD, 2025) . On the other hand, Neutral monism, advocated by philosophers like Bertrand Russell and William James, posits that both mind and matter are manifestations of a more fundamental "neutral" substance. Recent interpretations have suggested that quantum events could be the neutral base from which both physical and mental properties emerge (Stubenberg, 2005)**.**

Philosophies Related to Consciousness and Wavefunction Collapse

While early quantum theorists like von Neumann and Wigner speculated that consciousness might play a direct role in measurement, subsequent developments have produced a range of nuanced models.To understand how these perspectives shape our current view of reality, it is essential to examine the major philosophical approaches that address the interplay between mind and measurement. The following section explores these diverse philosophies, from consciousness-based collapse models to objective and process-oriented interpretations, and situates them within the broader context of quantum theory and the enduring mysteries of conscious experience (Harold, 2024).

There is a discussion between Emergence and Reduction. While Reductionism expresses that systems are simply just the sum of their parts, Emergence suggests that there are complex systems that exhibit novel properties that just aren't predictable from their parts. THese two theories have drastic consciousness viewpoints. For example, Reductionism states that consciousness is reducible to neural computations, while Emergence states that consciousness emerges from neural complexity (*Reductionism*, n.d.), (Maloney, 2020). Reductionists face challenges explaining subjective unity from discrete neurons, while emergentists struggle to define how consciousness "arises" without invoking dualism (Wagemans et al., 2012).

A central distinction in the philosophy of consciousness is between epistemic and ontic interpretations. Epistemic information concerns how a subject knows and experiences conscious states, emphasizing the immediacy and directness of first-person awareness, such as introspection (Newman, 1997). In contrast, ontic information refers to the objective reality underlying these experiences—such as the neural patterns, microtubule states, or quantum coherence that may constitute the physical basis of consciousness (“Consciousness in the Universe: A Review of the ‘Orch OR’ Theory,” 2014). Cognition serves as a bridge between these realms: changes in subjective experience (epistemic) are mirrored by measurable changes in neural or quantum substrates (ontic). This duality is reflected in quantum mechanics itself, where the act of observation (epistemic) is thought to collapse the wave function (ontic), linking knowledge and reality in a fundamental way.

The binding problem further illustrates the complexity of conscious experience by asking how the brain unifies diverse sensory inputs, like color, shape, and motion, into a single, coherent percept. Neurobiological mechanisms such as neural synchronization, particularly gamma-wave coherence, are thought to temporally bind distributed neural activities (Lee, n.d.) . Quantum models, including Orch OR, propose that microtubule quantum coherence may serve as a biological substrate for this binding, orchestrating unified conscious moments. The philosophical significance of the binding problem lies in its illumination of the "unity of consciousness", where our seamless, integrated experience of the world can become fragmented in certain neurological conditions.

When we synthesize these perspectives, it becomes apparent that consciousness resists reduction to purely physical or emergent properties. Panpsychism, for example, posits consciousness as a fundamental aspect of reality, thereby closing Chalmers’ explanatory gap by making subjectivity intrinsic rather than emergent ((Goff et al., 2001) . The unity of experience, as explained by binding mechanisms, demonstrates how ontic processes (like quantum collapses) can manifest as seamless awareness (epistemic)(Caticha, 2025) . Critiques of reductionism and emergence highlight the limitations of explaining consciousness solely through lower-level physical processes, thus supporting models that treat consciousness as a foundational feature of the universe—potentially mediated by quantum phenomena that bridge subjective and objective realities.

Previous Mentioned Theories and their Philosophical Implications:
The Orch OR Model bridges quantum physics and philosophy because it implies proto-consciousness is inherent with microtubules (Yue, 2024), (“Consciousness in the Universe: A Review of the ‘Orch OR’ Theory,” 2014). It also draws from Gofel’s incompleteness

thermom to argue that consciousness transcends simple computation, requiring quantum level processing.

IIT bridges panpsychism and materialism, where it implies that proto-consciousness in all systems with non-zero Φ, resonating with Alfred North Whitehead's process philosophy where experience is fundamental to reality. It also positions consciousness as an intrinsic property of information integration, bypassing dualism while explaining subjective experience emergence (Weber & Weekes, 2009)

The Consciousness-Based Quantum Objective Collapse model ties collapse dynamics to integrated information (Φ). Systems with higher Φ experience faster suppression of conscious-state superpositions, making consciousness a physical parameter in collapse equations. Unlike dualist interpretations, this model embeds consciousness within physicalism—Φ is a measurable property, not a non-physical entity (Okon & Sebastián, 2018). Collapse becomes an objective process where conscious systems naturally resolve superpositions, avoiding arbitrary observer boundaries.

The SOC model formalizes consciousness-collapse interaction within physicalism. Consciousness and its physical correlation are two aspects of a unified reality, resolving mind-body duality. Moreover, it updates Wigner's consciousness-collapse hypothesis by replacing mental substances with physical correlates.

The Relational Quantum Dynamics (RQD):
The relational Quantum Dynamics (RDQ) explains that observers, observed systems and geometric structures emerge in a stable pattern and have underlying quantum structures, instead of viewing the universe as co. RDQ draws from ontic structural realism (OSR), and non-dual philosophies–this treats consciousness as the ontological ground of reality. OSR is a position of philosophy where they argue that the fundamental nature of reality aren't objects, but rather the structure and relations between them. In quantum mechanics, this means that particles and spacetime are secondary to the relational structure that connects them (Murphy, 2022) . RDQ also draws from non-dual philosophies, such as Advaita Vedanta, where the apparatus separation between subject and object is just an illusion (*The Non-Dual Philosophy of Ashtavakra Gita: Understanding the Illusion of Separation*, n.d.). In this view, consciousness isn't a mere byproduct of material processes, but rather the fundamental "stuff" of reality itself. This perspective expresses that each quantum interaction is an intrinsic act of awareness, ensuring that subjective experience and physical reality co-derive from the same relational field. In other words, this means that every quantum interaction isn't just a physical act, but rather the act of awareness. For instance, according to Alfred Whitehead's process philosophy, where reality is made of "drops" of experience, each quantum event is a percussion of experience itself (Cronshaw, 2012). RDQ therefore has implications to the wavefunction collapse and the

measurement problem. For instance, the collapse of the wave functions aren't just mysteries, but rather a natural update in the relation field which therefore corresponds to an act of awareness (*Ivesic, 2022*). The traditional measurement problem disintegrates because there is no need for an external observer to trigger the collapse because awareness is essentially built into every quantum interaction (*The Quantum Measurement Problem: A Review of Recent Trends*, n.d.).

Table 10: *Comparison of Key Models of Consciousness and Wavefunction Collapse within a neuroscience perspective*

Model	Key Features
Orchestrated Objective Reduction (Orch OR)	Quantum computations in microtubules, collapse corresponds to conscious events
Integrated Information Theory (IIT)	Consciousness as integrated information, combined with CSL for collapse
Objective Collapse Models	Objective collapse, some models link collapse to integrated information
Subjective-Objective Collapse (SOC)	Collapse depends on physical property correlated with consciousness
Process-Based Approach	Consciousness causes collapse, inspired by Whitehead's philosophy

Note. This table provides a concise composition of the key models discussed, highlighting their main features.

Table 11: *Comparative Summary Table*

Model/Philosophy	Consciousness Role	Collapse Mechanism	Ontological Commitment
Relational Quantum Dynamics (RQD)	Fundamental, universal ground	Awareness updates in relational field	Informational/idealist, non-dual
Orch OR	Fundamental, brain-centered	Objective reduction tied to consciousness	Quantum gravity, microtubule processes
IIT + Quantum Extensions	Emergent, quantifiable	Collapse linked to integrated information	Information-theoretic, physicalist
Objective Collapse (Consciousness)	Secondary or fundamental	Collapse operator depends on consciousness	Materialist with consciousness parameter
SOC Model	Correlated, physical property	Collapse influenced by consciousness	Empirically testable, dual-aspect
Process-Based/Idealist	Causal agent, universal	Consciousness causes collapse	Process philosophy, idealist

Results:

The data reveal a clear positional trend in median values across groups, with the Neutral group showing the lowest median, followed by the Control group, and the Expected group exhibiting the highest median. Notably, the Expected group displays approximately twice the interquartile range (IQR) of the Control and Neutral groups, indicating greater variability in its results. No outliers were detected in any group based on the 1.5×IQR criterion, suggesting the data distributions were robust within each condition. Contextually, these observations align with the study's hypothesis that an observer's mental state may influence quantum measurement outcomes. Specifically, the Expected group, primed with prior knowledge and expectation, yielded the highest median value of 63, suggesting that expectation may amplify the observed results. The Neutral group, representing baseline awareness, recorded the lowest median of 57, while the Control group's results occupied an intermediate range, tightly clustered between 61 and 63.

The results of the one-way ANOVA revealed a significant difference in the means between at least two of the groups, with an F-value of 19.35 and a highly significant p-value of 0.000014. Post-hoc analysis using Tukey's HSD further clarified these differences. While there was no significant difference between the Control and Expected groups (mean difference = 1.2, p = 0.5981), significant differences were observed between the Control and Neutral groups (mean difference = 5.0, p = 0.00001) as well as the Expected and Neutral groups (mean difference = 3.8, p = 0.0004). These findings indicate that the Neutral group consistently differed from both the Control and Expected groups. Additionally, the effect size, calculated using Eta Squared (η^2 = 0.64), suggests a large effect, meaning that group membership accounts for 64% of the variance in the observed outcomes.

Key Observations

- *Positional trend: Neutral < Control < Expected in median values.*
- *Spread: Expected group shows 2× the IQR of Control/Neutral, indicating higher variability.*
- *No outliers detected in any group using the 1.5×IQR rule.*

The data aligns with the paper's hypothesis that observer mental states may influence quantum measurement outcomes:

- *Expected Group (primed with prior knowledge) yielded the highest median (63), suggesting expectation may amplify observed values.*
- *Neutral Group (baseline awareness) recorded the lowest results (median=57).*
- *Control Group (standard observation) occupied an intermediate range.*

These patterns tentatively support the proposed link between conscious states (e.g., expectation/knowledge) and quantum phenomena.

Visuals of the Results:

Figure 1:

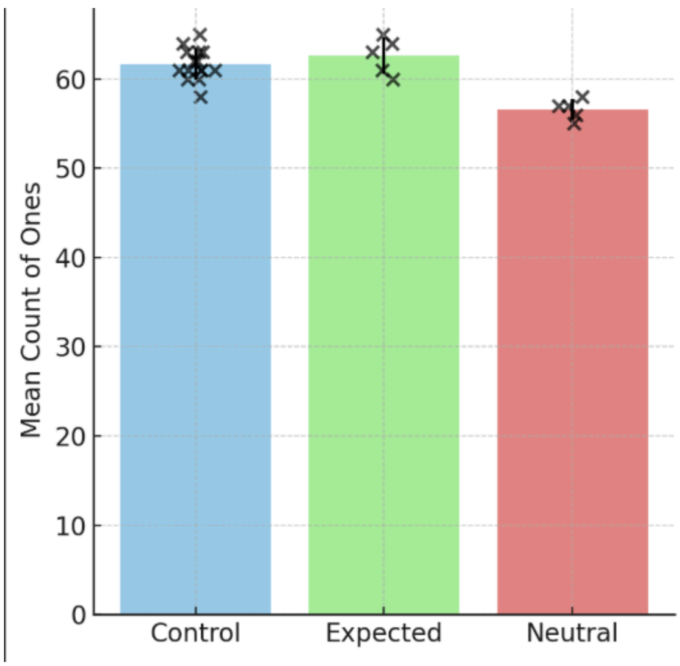


Figure 2:

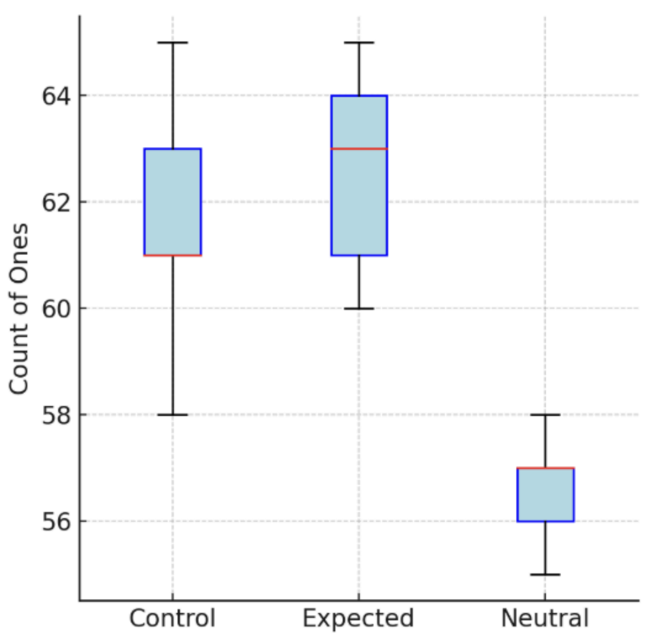


Figure 3:

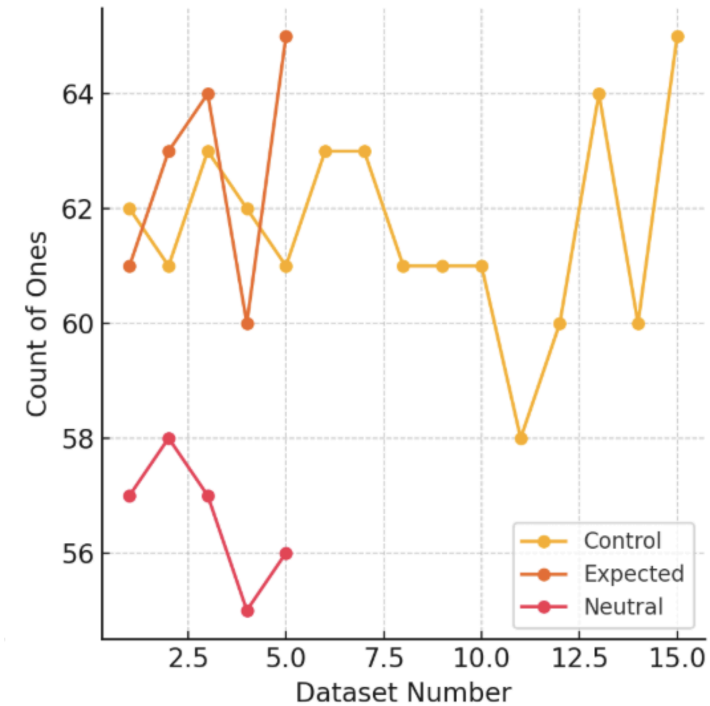


Figure 4:

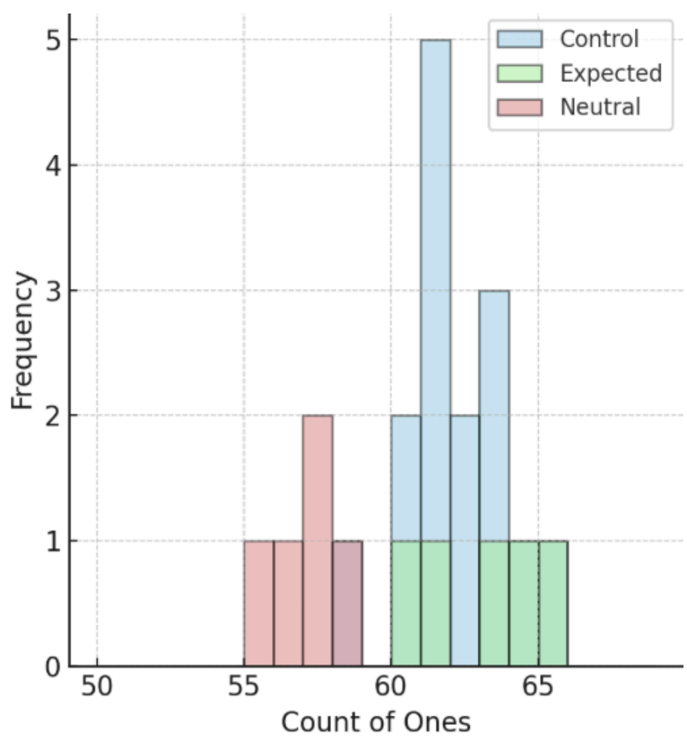
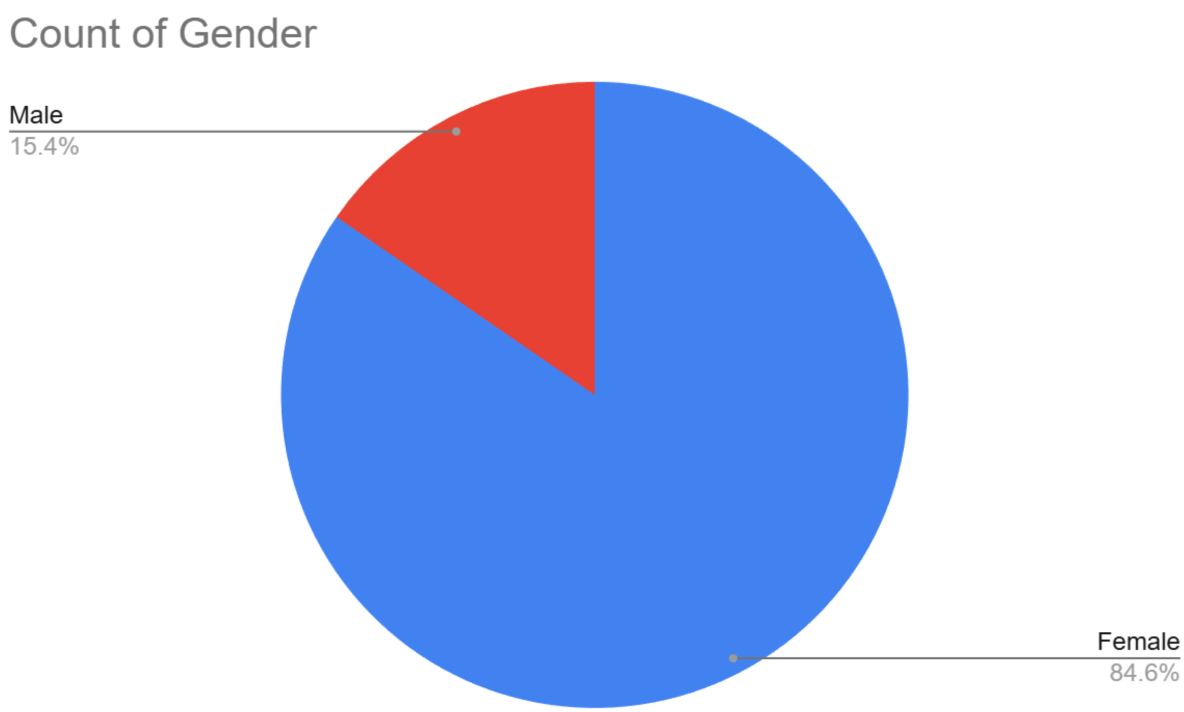


Figure 5:
Distribution of Gender



Discussion:

The findings directly relate to the research question because the observed differences between the groups align with the hypothesis that subjective mental states could modulate wavefunction collapse. This can be stated especially because of the amplification of measured values in the Expected group. These patterns and the perspectives discussed in the paper therefore support the relationship between conscious states, like expectation and quantum phenomena. This supports previous studies that have argued that different variables, such as mental states could impact quantum systems, lending empirical weight to the idea that the mind could possibly play an active role in shaping measured reality. These results could introduce new insights. For example, the considerable variability observed in the Expected group can suggest that while expectation and knowledge can amplify measurement outcomes, it could also project fluctuation. This special nuance has not been consistently expressed in previous literature, which often focuses on directional effects of conscious influence; they never explored variability as a potential consequence. This specific spread could indicate that the strength and variance of expectation could lead to a range of outcomes. Moreover, contrary to previous studies that have proposed either an all-or-nothing role for consciousness in wave function collapse, this study suggests that there is a more graded influence, where differing mental states could modulate, rather than fully determining the outcomes. Because this is more of a middle ground perspective, it urges further research.

Unexpectedly, the Neutral group demonstrated lower and more tightly clustered outcomes than anticipated. Given that the Neutral group represents baseline awareness without expectation or priming, it was originally hypothesized that their results would mirror those of the Control group. The observed discrepancy suggests that even subtle differences in the participants' mindset, potentially influenced by task framing or unconscious cues, may have affected the measurement outcomes. Further studies should investigate whether truly neutral awareness is achievable in experimental settings or whether participants inherently develop implicit expectations when participating in measurement-based tasks.

Moreover, while these findings are suggestive, further rigorous statistical testing and replication are required to establish the significance and generalizability of the observed effects. In addition, because the sample size for each group is relatively small, it lacks representation. Therefore, for future studies, a larger demographic and size should be focused on. The testing environments should be more standard to limit the possibilities of third variables; future studies should ensure the testing takes place in one setting for all the participants. The mental states of the participants were operationalized in a relatively simplistic manner, and no direct physiological or psychological measures (such as EEG or self-report scales on cognitive engagement) were used to confirm the depth or consistency of these mental states during measurement. Potential confounding variables, such as participant fatigue or environmental distractions, were not tightly controlled and may have influenced the variability observed, particularly in the Expected group.

Future research should address these limitations by integrating objective measures of cognitive and emotional states. Incorporating neuroimaging or psychophysiological assessments could provide deeper insights into the relationship between neural activity and measurement outcomes. Additionally, future studies could explore varying degrees of expectation or attention to determine whether the influence of consciousness on quantum outcomes is dose-dependent. Exploring different types of mental states, like distraction, focused attention, or emotional arousal may also help clarify the specific aspects of consciousness that are most relevant to the measurement process.

Conclusion:

This study provides preliminary evidence that conscious mental states, particularly expectation, may measurably influence quantum measurement outcomes. The observed positional trends and increased variability in the Expected group suggest that the observer's mindset is not merely a passive condition but may actively modulate the measurement process. While the findings align with and expand upon previous research linking consciousness to quantum phenomena, they also introduce new considerations regarding variability and individual cognitive influence. Nonetheless, this work offers a meaningful step toward understanding the complex relationship between consciousness and the physical world and underscores the need for continued interdisciplinary research to further explore this potential connection.

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