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■ RESEARCH ARTICLE

A Novel Paradox as An Argument Against The Von Neumann-Wigner Interpretation

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ABSTRACT: This work discusses the foundations of quantum mechanics, and a novel paradox is presented. The quantum measurement problem is a topic still commonly discussed by physicists. The Von Neumann-Wigner Interpretation states that consciousness collapses the wave function, and the mind is the only measurement apparatus. Although this interpretation is widely dismissed now, it is considered valid by some physicists and is still a topic of debate. This idea that consciousness is needed for the wave function collapse can cause a paradox. The states of physical objects can depend on the quantum measurement result. These objects can then be observed without collapsing the wave function. These states can then be reverted by a setup similar to the Delayed Choice Experiment by John Wheeler (in which the unobserved past is changed), thus changing the observed past. The paradox is named "The Zombie Cat Paradox" and can be used as a counterargument to the Von Neumann-Wigner Interpretation.

KEYWORDS: PHYSICS AND ASTRONOMY; Theoretical, Computational, and Quantum Physics; Foundations of Quantum Mechanics; Consciousness; Von-Neumann-Wigner Interpretation.

Introduction

The quantum measurement problem is the problem of how the wave function collapse happens. According to the Copenhagen Interpretation developed by Niels Bohr and Werner Heisenberg, the most popular of the quantum interpretations, wave function collapse occurs when a particle is measured. The Von Neumann-Wigner Interpretation is a sub-interpretation of the Copenhagen Interpretation in which the idea of consciousness causing wave function collapse is suggested.[1] The interpretation is based on Wigner's friend's thought experiment.[2] The concept of consciousness affecting physical events also raises many philosophical questions and fundamentally changes how we interpret our universe. The Von Neumann-Wigner Interpretation is explained in greater detail in the following subsection.

The Von Neumann–Wigner Interpretation:

The Von Neumann-Wigner Interpretation is a variation of the famous Copenhagen Interpretation, which states that measurement collapses the wave function. According to John von Neumann, the collapse of the wave function can be anywhere in the casual chain (a sequence of events causing each other) from the measurement apparatus to the human observer's awareness of the result.[3,4] Eugene Wigner came up with the "Wigner's Friend Experiment" and postulated that only the mind, a non-physical measurement apparatus, could collapse a wave function.[5]

The Von Neumann-Wigner Interpretation suggests that consciousness is necessary for wave function collapse. The wave function collapse must be happening somewhere between the measurement apparatus and the information of the result reaching the conscious observer. Wigner thought that the collapse must occur when an observer is aware of the result.[6,7]

Although Wigner shifted from this idea, and the interpretation is widely dismissed now, it is still considered a valid interpretation by some physicists. A survey conducted at a quantum mechanics conference in 2011 resulted in 6% of participants believing that consciousness is collapsing the wave function.[8] If the interpretation is presumed to be accurate, it can cause the Zombie Cat Paradox explained in the following sections.

This paper is on a novel paradox against the Von Neumann-Wigner Interpretation named The Zombie Cat Paradox. The paradox utilizes the Delayed Choice Experiment developed by John Wheeler and the idea that consciousness causes wave function collapse. The existence of The Zombie Cat Paradox can be used as a counterargument to the Von Neumann Wigner Interpretation. To understand The Zombie Cat Paradox, a basic knowledge of the famous Double-Slit Experiment, and the Delayed Choice experiment is needed. These concepts will be explained in the following sections.

Furthermore, other objections to the Von Neumann-Wigner Interpretation have been made. Eugene Wigner drifted away from the interpretation.[9] Some physicists like Roger Penrose pointed out that the evolution of conscious life depends on the wave function collapsing, making it impossible for consciousness to be the reason for the collapse.[10] The novel paradox presented in this paper aims to act as another counterargument to the interpretation.

Methods

The basics of wave function mathematics, the Double Slit experiment, and the Delayed Choice experiment are used to form the Zombie Cat Paradox and the argument against the Von Neumann-Wigner Interpretation. These concepts are explained in the following subsections.

Wave Functions and the Fundamental Mathematics of Quantum Mechanics:

A wave function is a mathematical description of a quantum state. The Greek letter psi(Ψ/ψ) is commonly used as a symbol for the wave function.[11] Different wave functions are created for different quantum systems by solving the Schrödinger equation for Ψ. The Schrödinger equation was developed by Erwin Schrödinger and is the base of quantum mechanics.[12]

$$i\hbar\frac{\partial\Psi(x,t)}{\partial t}=\left[-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}+V(x,t)\right]\Psi(x,t) \tag{1}$$

Equation 1 states the Schrödinger equation for a single particle in one dimension where:

- Ψ(x,t) is a wave function
- m is the mass of the particle
- V(x,t) is the scalar potential representing the environment
- $\hbar$ is the Planck constant

The square of the wave function is the probability density of finding the particle in a particular state when measured. Wave functions can be represented using the Dirac notation.[13] This notation will be used in later sections. An illustration of the wave function for a particle with two possible states (spin up and spin down) is given in Equation 2 below.

$$|\Psi\rangle=\frac{\sqrt{3}}{2}|spin\ up\rangle+\frac{1}{2}|spin\ down\rangle \tag{2}$$

- The particle is in a superposition of the two states.
- The spin property of the particle has a 3/4 probability of being up and a 1/4 probability of being down when measured.

Wave functions will be used to represent quantum states in the following sections.

The Double Slit Experiment:

Thomas Young first conducted the Double-Slit Experiment in 1801 to display the wave-like behavior of light. In the experiment, light is sent through two slits into a screen, and an interference pattern emerges, which is the expected result for objects displaying wave-like behavior. Later, other variations of the experiment were conducted with beams of electrons instead of light.[14]

In the modern Double-Slit Experiment, electrons are shot to a screen through two slits. These electrons are expected to behave like particles and create a clumped pattern on the net. However, these electrons generate an interference pattern displaying wave-like behavior. Physicists thought that these electrons must be interfering with each other. Despite that, when the electrons are shot one by one, the interference pattern is created again, showing that the electrons are interfering with themselves and not with other electrons. The electrons pass through both slits simultaneously and show wave-like behavior when shot. The electrons are not particles or waves before measurement but rather wave functions.[15] A simple Double- Slit Experiment setup is given in Figure 1.

Since the electrons are in a superposition of two states, the state of electrons that have been shot can be represented as:

$$|\Psi\rangle=\frac{1}{\sqrt{2}}|right\ slit\rangle+\frac{1}{\sqrt{2}}|left\ slit\rangle \tag{3}$$

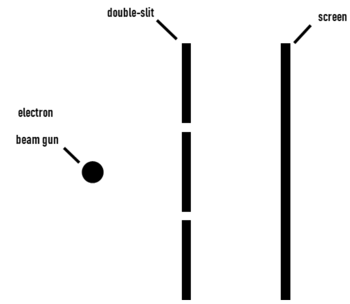

Figure 1: Setup for the Double Slit Experiment.

Observer Effects on the Double-Slit Experiment:

When a measuring device is put before the slits identifying which slit each electron is passing through (gathering the "which-path" information), the interference pattern disappears, and a clumped pattern emerges. This means that the electrons display particle-like behavior when a measurement device is present. The act of measurement changes the outcome of the experiment.[16]

When the measurement is made, the wave function collapses, and the electrons behave as particles. In fact, the wave function collapses if the "which-path" information is known. This is a key point for the following sections. A setup for the Double-Slit Experiment with observer effects is given in Figure 2.

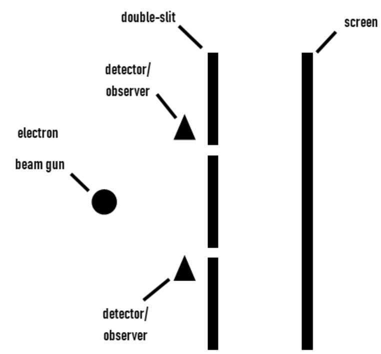

Figure 2: Setup for the Double-Slit Experiment with Observer Effects.

Since measurement has been made and the wave functions of the electrons have collapsed, the state of electrons can be represented as:

$$|\Psi\rangle=\frac{1}{1}|right\ slit\rangle+\frac{0}{1}|left\ slit\rangle \tag{4}$$

or

$$|\Psi\rangle=\frac{0}{1}|right\ slit\rangle+\frac{1}{1}|left\ slit\rangle \tag{5}$$

A modified version of the Double-Slit Experiment is used to create the Delayed Choice Experiment explained in the following section.

The Delayed Choice Experiment:

The Delayed Choice Experiment is an experiment proposed by John Wheeler. It is quite similar to the Double-Slit Experiment, but the detectors are behind the slits, causing the measurement to be made after the electrons pass through the slits. A clumped pattern emerges on the screen, although no measurement is made to collapse the wave function before passing the slits. The experiment results suggest that the electrons must pass through both slits as wave functions but collapse after passing the slits and deciding on a slit to pass. The results of the experiment reveal that the unobserved past can be changed.[17] A setup for the Delayed Choice Experiment is given in Figure 3.

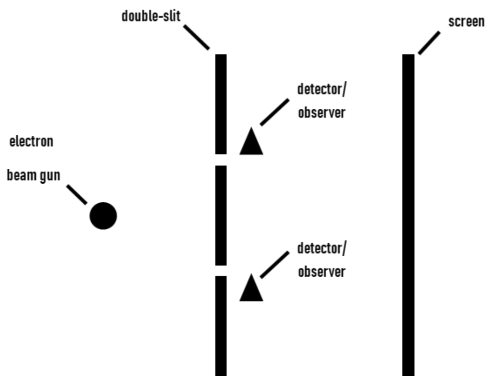

Figure 3: Setup for the Delayed Choice Experiment.

Results and Discussion

The results of the Delayed Choice experiment and the Von Neumann-Wigner Interpretation contradict each other. This contradiction is presented as a paradox in the following subsection.

The Zombie Cat Paradox:

The Setup for The Zombie Cat Paradox is given in Figure 4, and the paradox is explained in the following parts.

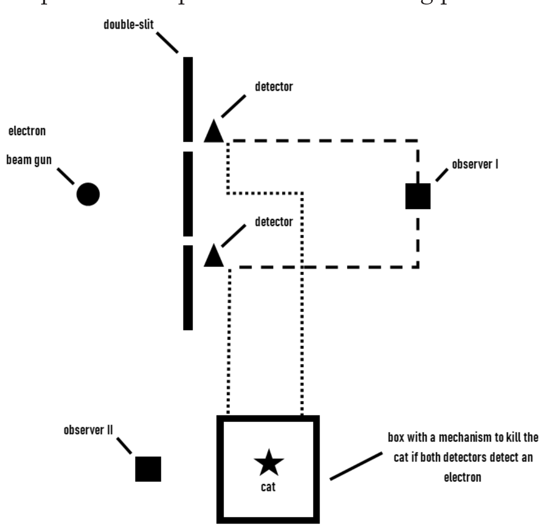

Figure 4: Setup for The Zombie Cat Paradox.

Under the assumption that the cat is not conscious, if conscious awareness of the result collapses the wave function at the time the awareness happens:

i) When the electrons are shot without observers making any observations, the cat dies since the particle goes through both slits simultaneously.

ii) After shooting the electrons and killing the cat, if observer I makes an observation, the cat should come back to life. In other words, the observation of observer I should change the unobserved past (the state of the electrons while passing through the slits), similar to the Delayed Choice Experiment. When the past is changed, the cat's state should also change.

iii) After shooting the electrons and killing the cat, if observer II opens the box, the cat will be found dead. However, this observation will not collapse the wave function since finding the dead cat does not give the observer the "which path information" of the electron.

iv) After shooting the electrons, killing the cat, and observing the dead cat, an observation by observer I should change the cat's state again. Thus, changing the observed past and bringing the cat we observed to be dead back to life.

The breakdown of each argument of The Zombie Cat Paradox is given in the corresponding experiment setup in Figure 5.

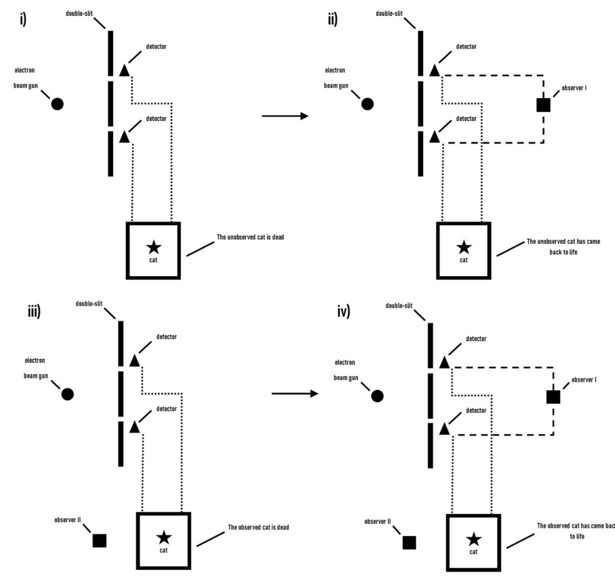

Figure 5: Breakdown of The Zombie Cat Paradox.

If the dead cat is taken out of the box after being observed by observer II and later observer I makes an observation, either we should end up with two cats, one dead and one alive, which is against the fundamental laws of physics, or observer I's observation would not be able to change the past which is against the premises of the experiment. Furthermore, the more fundamental assumptions of the experiment, like the observed past being altered and the cat returning to life after death, are not possible. Despite this, according to the Von Neumann-Wigner Interpretation, the experiment itself is not flawed. Thus, the Von Neumann-Wigner Interpretation and the idea that consciousness causes wave function collapse must be flawed.

It could be argued that the effects of quantum mechanics may not apply to a macro-object such as a cat. However, the cat could be replaced with any object with quantum properties that has two states (such as an electron with spin as the parameter to create the two states), and the experiment results would not change.

Conclusion

This paper covers basic quantum mechanics concepts, like the Double-Slit Experiment and the wave function. Later, the Delayed Choice Experiment which states that the unobserved past can be changed, and the Von Neumann-Wigner Inter

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pretation of quantum mechanics is explained. A novel paradox utilizing the premises of the Delayed Choice Experiment is presented as an argument against the Von Neumann-Wigner Interpretation.

It is argued that consciousness affects physical events and collapses the wave function in the Von Neumann-Wigner Interpretation of quantum mechanics. A modified version of the Delayed Choice experiment can be used to create The Zombie Cat Paradox. This paradox suggests that consciousness having a role in wave function collapse is against the fundamental laws of physics, and postulating the Von Neumann-Wigner Interpretation to be true would allow changes in the observed past. Therefore, consciousness cannot be the reason the wave function collapses. Thus, the Von Neumann-Wigner Interpretation must be flawed.

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