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Quantum Mechanics & Its Broader Implications: The von Neumann– Wigner Interpretation

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"Quantum mechanics is certainly imposing…The theory says a lot, but does not bring us any closer to the secret of the old one. I, at any rate, am convinced that He [God] does not throw dice."
~Albert Einstein

The Interpretation

Like the popular Copenhagen Interpretation, the von Neumann-Wigner Interpretation of quantum mechanics posits that measurement causes a collapse of the wavefunction. Once observed, the wavefunction collapses from a superposition of various states to just one of the possibilities. While the Copenhagen Interpretation does not identify what constitutes a measurement, an observer, or an observation, the von Neumann-Wigner Interpretation specifies that consciousness is necessary for the measurement process to occur (we might say a *reading* of the measurement), and that it is consciousness itself that causes wavefunction collapse. In simple terms, the von Neumann-Wigner Interpretation may be thought of as a more detailed or specific variation of the widely-used Copenhagen Interpretation, but with much more explicit and detailed theological and philosophical ramifications.

In 1932, John von Neumann published his book postulating that the measurement which actually collapses the wavefunction is in the connection of mind and brain; it only occurs when a conscious entity observes it. If an observer is a purely physical object, a more comprehensive wavefunction may now be written which encompasses not only the state of the thing being measured, but also of the observer. The various possible measurements that could be observed are now in superposition states, representing different observations. However, this leads to a problem: you would now need another measuring device to collapse this larger wavefunction, but then it would go into a superposition state. Another device would be needed to collapse this state, and another device for that one, and so on. This problem - known as the von Neumann chain – is a regression of measuring devices, whose stopping point is presumed to be the conscious mind (i.e. not a purely physical measurement device, but a conscious entity who actually *reads* said measurement, effectively stopping the chain). The regression can be finite, or infinite (a recursion).

Von Neumann's measurement theory may be summarized as the following. There are two ways that the state vector of a system evolves in time. One: it evolves smoothly as dictated by the Schrödinger Equation. Two: it evolves suddenly and sharply, when measured (this is wavefunction collapse). **[1]** Von Neumann hypothesized that a conscious observer must be beyond and outside of the calculations,

concluding that the Schrödinger Equation cannot account for *how* the wavefunction collapses, only the final result. **[1], [9], [6]**

In 1939, Fritz London and Edmond Bauer published a book in which they supported the idea of consciousness as the final barrier that collapses the wavefunction, and summarized von Neumann's measurement theory. In the 1960s, physicist Eugene Wigner published various materials in which he outlined his concerns with and amendments to the measurement theory. Abner Shimony condensed Wigner's views in 2002 **[7]**, which lead to their current form. Although he did not engage von Neumann's mathematical analysis, his work was elucidating, and was incorporated into what ultimately became known as the von Neumann-Wigner Interpretation of quantum mechanics. **[6]**

Probably the best known of Wigner's contributions to the measurement theory is the "Wigner's Friend" thought experiment, which was later streamlined by David Deutsch in the 1980s **[3]**. The thought experiment is a reformulation of Schrödinger's Cat in which Wigner has a friend who is in the lab alone, performing a measurement on the cat (a physical system). The friend will be happy if the cat is alive, but sad if it is dead. However, Wigner does not believe that his friend is both sad and happy until observed, he just does not know which. Wigner did not think that conscious observers can be in superposition states; he thought that the wavefunction had already been collapsed when his friend observed the cat. Consciousness here is taken to be unlike other physical processes, and that it is therefore mathematically different.

Upon close examination, this differentiation of purely physical devices used for measurement and observers reading those measurements seems to make sense. If the wavefunction of the system including the measurement device were to be put into the Schrödinger Equation, it would never spontaneously collapse, yet we as observers do not experience a superposition reality. **[6]** Otherwise, the observer - meaning a conscious mind - would experience several possible realities at once. Essentially, there is a fundamental difference between a device taking a measurement and the *reading* of that measurement; an unread (unobserved) measurement does nothing to the wavefunction **[6], [2]**. What exactly constitutes a measurement or a reading is part of The Measurement Problem in quantum mechanics, and is one problem which the von Neumann-Wigner Interpretation seeks to at least address, if not solve.

Henry Stapp, an American physicist and mathematician, has propounded von Neumann's interpretation, and has written a book and articles on the subject. In his article, *Quantum Theory and the Role of Mind in Nature* (2001), Stapp elegantly explains and argues for von Neumann's position, while addressing significant issues he saw in von Neumann's work to integrate consciousness with physical reality **[9]**. Prominently, he acknowledges that von Neumann worked only non-relativistically and

attempts to reconcile von Neumann's approach with the theory of relativity. However, the details of his work on von Neumann's theory will not be elaborated on here, aside from the process he delineated.

The von Neumann approach may be interpreted as saying that the entire universe can be represented by a basic state - the state of the universe. The state of a conscious entity's brain would be a subsystem of the universal state. Stapp integrated his position and that of the von Neumann interpretation in a process which will be referred to as the von Neumann-Stapp Process, and has sometimes been referred to thus in literature (see **[2])**. The process has three parts, which describe the dynamics of the aforementioned system. Process 1, often called "The Heisenberg Choice", is the conscious decision the observer makes to act in a certain way (free will). Process 2 is the quantum version of the classical kinematics equations; it represents local equations of motion which are quantized and effectively convert microscopic uncertainties to macroscopic reality. Process 3, often called "The Dirac Choice" (since Dirac called it the choice "of Nature"), is the 'answer' to the action, or question, that the observer made in Process 1. This is the final result that is observed. **[2]**

Philosophical/Theological Considerations

Now that we have a base understanding of the von Neumann-Wigner Interpretation, we can address its philosophical and theological implications. There are some serious theological questions which such an interpretation raises, especially in the light of Christianity and science.

One major consideration is the question of how to reconcile God's omniscient with this interpretation (to say nothing of the rest of quantum mechanics). If God is truly all-knowing, then would God not be constantly observing *all* wavefunctions – or the wavefunction of the universe – and causing them to constantly collapse to specific states? Since the von Neumann-Wigner Interpretation posits that a conscious observer causes collapse, the universe under Divine observation would constantly collapse. This in turn would prevent the universe to experience time-evolution. Total observation (omniscience) would also imply knowing everything simultaneously. However, quantum mechanics dictates that there are certain observable quantities that do not commute, meaning they are by nature not simultaneously knowable.

It is the view of this author that these problems do not necessarily mean God is not omniscient, but that God can *choose* to not know all things, if God wishes. As pointed out by another writer, if we limit God to a certain quality by asserting that God is infinite, for example, we are effectively denying God the quality of finiteness **[4]**. Similarly, if we declare God to be omniscient, we prevent God from not knowing all things – even if that were to be God's choice. If God chooses to 'play by God's rules', in reference to the so-called laws of nature, the God would not allow Godself to know things that are not

simultaneously knowable, quantum-mechanically. This author does not wish to dictate what God can and cannot know, and thereby suggests that God's ability to be omniscient is not inherently problematic for quantum mechanics or the von Neumann-Wigner Interpretation.

Another problem, of a more philosophical nature, arises from the ambiguity this interpretation leaves regarding what has consciousness – the interpretation does not define a limit (in all fairness, that could be a potentially impossible thing to quantify, but the question still remains). Would a cat, for example, constitute a conscious mind, and therefore be an observer? That question aside, if consciousness is the cause of collapse, it is difficult to make sense of a pre-conscious-entity universe. Without a conscious observer, there is no way to discuss pre-life events, such as the Big Bang. The very evolution of conscious life could not have coalesced without the presence of consciousness, which is of course a paradox. As Roger Penrose eloquently put it,

> "[T]he evolution of conscious life on this planet is due to appropriate mutations having taken place at various times. These, presumably, are quantum events, so they would exist only in linearly superposed form until they finally led to the evolution of a conscious being—whose very existence depends on all the right mutations having 'actually' taken place!" **[5]**

From a Christian standpoint, we might be tempted to say that God could conveniently be the observer when any other conscious observers did not yet exist, but this is dangerously close to a form of God-in-the-Gaps. It would be all too convenient to put God where our theories fall short. However, this has proven to be dangerous, and ultimately only convenient or seemingly useful until we discover what actually belongs in the figurative 'gap' where we placed God. This author does not in good faith wish to make such an assertion, but puts forth that is it a possibility, as all things are possible with God.

One theological strength of this interpretation is that is it not purely materialistic. As Christians, we believe in the transcendence of the spirit – that we are much more than just our physical bodies, and that our being is more than the atoms that make up our corporeal existence. It is refreshing when an affirmation, or at least an acknowledgement, of this higher level of being comes from science. This is especially true when, as in this case, the nod comes from theoretical physics in such a way as to say that the mind *must* be something totally different than the physical brain. However, this interactionist dualism is a reason for some physicists to object to this interpretation, saying it fails to adhere to the materialism they assume necessitated by the laws of physics.

Another strength, one which the author believes to be stronger than the aforementioned, is that this interpretation is strongly in support of free will. As outlined above, the first part of the Neumann/Stapp Process is the decision of the observer, as they choose to make it. The causal origin of the

choice is not dictated by the interpretation, and is the direct result of the mental action of the observer. This not only allows for free will, but requires it for the ongoing function of reality.

The Author's Views

I started this essay with a quote from Albert Einstein, and it is one which happens to resonate very well with me. From my (albeit very limited) experience, I do not think that the current state of the theory of quantum mechanics is wrong, in that what is there is not false, but I am certain it is not the entirety of reality ('the whole picture'). Scientifically, my view is that a comprehensive, all-encompassing theory most likely exists, given the logical, structured nature of the universe. Countless times, scientists have predicted discoveries because it followed from the mathematics in the chemistry, physics, etc., that the thing in question must be there. And countless times, they have been correct. Each new model has led to greater agreement between sciences, and I think it is only a matter of time before the next theory which can help unify current models is discovered.

My personal position is that reality is much more than just its physical materiality, and that there must be some physics and mathematics which can describe this transcendence. Since I am a Christian, I was drawn to von Neumann's work and intrigued by it. Can this interpretation of quantum mechanics be used in the free-will defense? I believe it can, although with what degree of certainty is another question entirely. Perhaps the von Neumann-Wigner Interpretation of quantum mechanics is on the cusp of that discovery, simply awaiting the missing link that connect brain and mind. Or perhaps such a discovery is a long way off, almost unimaginable, in terms of what we already know. Still, I am all but certain that it exists. I personally believe God is too great a mathematician to not have created a grand equation for everything; a Grand Unified Theory if you will.

Note from the author: The reader may have noticed – dare I say observed? – that I do not use a specific pronoun when referring to God, even if such a pronoun might make life a little bit easier. This is because I see the triune God as not having a specifically male gender; for example, the metaphor of God as a Father is very helpful, but is just that – a metaphor. This does make the language a bit more clunky in places, and I am aware of and recognize that. Any input to improve this is welcome.

References

1. Barr, S. M. (2016). The Believing Scientist: Essays on Science and Religion. Eerdmans.
2. Caponigro, M. (2017). Observer as Consciousness (?): Quantum Mechanics \& von Neumann Chain.
3. Deutsch, D. (1985). "Quantum theory as a universal physical theory". International Journal of Theoretical Physics. 24 (1): 1–41. Bibcode:1985IJTP...24....1D. doi:10.1007/BF00670071
4. Heller, M. (2003). *Creative Tension: Essays on Science & Religion*. Templeton Press.
5. Penrose, R. (1989). *The Emperor's New Mind.* Penguin Books.
6. Sen, R. N. (2010). Causality, measurement theory and the differentiable structure of space-time. Retrieved from https://ebookcentral-proquest-com.ezproxy.messiah.edu
7. Shimony, A (2002). Wigner's contributions to the quantum theory of measurement, in: Proceedings of the Wigner Centennial Conference, P´ ecs, Hungary, 2002, Article 51.
8. Simmons, E. (2014). Theology, Science, and Quantum Theory. In the Entangled Trinity: Quantum Physics and Theology (pp. 121-142). Minneapolis: Augsburg Fortress. doi:10.2307/j.ctt22nm9mz.11
9. Stapp, H. (2001). "Quantum Theory and the Role of Mind in Nature". Foundations of Physics. 31 (10): 1465–1499. arXiv:quant-ph/0103043. doi:10.1023/A:1012682413597.