How Knowledge Can Lead to the Demise of Schrodinger's Cat Through a Negative Measurement/Null Measurement (A Quantum Mechanical Measurement in Which There is No Physical Interaction Between a Physical Measuring Apparatus and the System Measured)

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Abstract

The Schrodinger cat experiment (SCE) is presented. An alteration follows where the LACK of radioactive decay leads to the demise of the cat instead of the ACT of radioactive decay. The lack of radioactive decay is a negative (null) measurement (where there is NO physical interaction between the radioactive material and the Geiger counter). The negative (null) measurement is non-trivial because all knowledge about the radioactive material (rm) is derived from its associated wave function which itself has no physical existence. The wave function is how we make probabilistic predictions regarding systems in quantum mechanics. So when the wave function changes in a negative (null) measurement, that is exactly what happens in a positive measurement where there is a physical interaction between entity measured and a physical measuring apparatus. (continued on next slide)

Abstract

Before the box in the original SCE is opened, the wave function for the radioactive material is: $\psi_{\text{rad_mat}} = 1/\sqrt{2} [\psi_{\text{rad_mat_does_not_decay}} + \psi_{\text{rad_mat_does_decay}}]$ which leads to the possibility of interference before the cat is observed.

As Schrodinger wrote: “The ψ function of the entire system [including radioactive material and cat] would express this by having in it the living and the dead cat (pardon the expression) mixed or smeared out in equal parts.” The radioactive material is the foundation for knowledge in both positive and negative (null) measurements since the probabilities are derived from the radioactive material using the wave function and the wave function contains all the information concerning a system. This alteration of the SCE presented here emphasizes this point and shows that the lack of radioactive decay in the original SCE is also a negative (null) measurement that leads to the **continued life of the cat.**

Abstract

Before the box in the alteration of the SCE is opened, the wave function for the radioactive material is the same as in the original SCE: $\psi_{\text{rm}} = 1/\sqrt{2} [\psi_{\text{rad_mat_does_not_decay}} + \psi_{\text{rad_mat_does_decay}}]$. In both the original and altered SCE, the probability of the cat being alive when the box is opened is $\frac{1}{2}$ and the probability of the cat's not being found alive when the box is opened is also $\frac{1}{2}$.

And when the measurement is complete in either scenario for the SCE, the wave function for the radioactive material is either:

$\psi_{\text{rad_mat}} = \psi_{\text{rad_mat_did_not_decay}}$
or instead

$\psi_{\text{rad_mat}} = \psi_{\text{rad_mat_did_decay}}$ •

Text

Schrödinger (1935/1983) presented his cat gedankenexperiment in a paper that was written in response to a paper by Einstein, Podolsky, and Rosen (1935). Schrödinger wrote:

A cat is penned up in a steel chamber, along with the following diabolical device (which must be secured against direct interference by the cat): in a Geiger counter there is a tiny bit of radioactive substance, so small, that perhaps in the course of one hour one of the atoms decays, but also, with equal probability, perhaps none; if it happens, the counter tube discharges and through a relay releases a hammer which shatters a small flask of hydrocyanic acid.

If one has left this entire system to itself for an hour, one would say that the cat still lives if meanwhile no atom has decayed. The first atomic decay would have poisoned it. The ψ -function [wave function] of the entire system would express this by having in it the living and the dead cat (pardon the expression) mixed or smeared out in equal parts. It is typical of these cases [of which the foregoing example is one] that an uncertainty originally restricted to the atomic domain becomes transformed into macroscopic uncertainty, which can then be resolved by direct observation (p. 157).

Depiction of Schrodinger Experiment *When Box is Closed* with Experiment Set to Run

When box is closed, the ψ -function for the radioactive material itself can be represented as

$\psi_{\text{radioactive material}} = 1/\sqrt{2} [\psi_{\text{radioactive material does not decay}} + \psi_{\text{radioactive material does decay}}]$

Cat is alive when box is closed.

After the box is closed the ψ -function for the cat itself can be represented as $\psi_{\text{cat}} = 1/\sqrt{2} [\psi_{\text{cat remains alive}} + \psi_{\text{cat's demise}}]$

Pertinent features of the experiment for our needs: the ψ -function of the entire system would have in it a 50-50 chance that the 1 atom in the radioactive material will decay and a 50-50 chance that not a single atom in the radioactive material will decay.

The two measurement options where there is the possibility of radioactive decay are:

Radioactive material decays leads to cat's demise, or instead

The radioactive material does NOT decay and the cat remains alive.

Possibility 1 is a positive measurement beginning with an interaction between the radioactive material and the Geiger counter, then the counter tube and the relay and the hammer and the flask of hydrocyanic acid and the cat.

Possibility 2 is a negative (or null) measurement where there NO interaction between the radioactive material and the Geiger counter, resulting in nothing happening to the counter tube and the relay and the hammer and the flask of hydrocyanic acid and the cat. *The fact that option 2 is a negative measurement indicates that knowledge is responsible for it, meaning that it becomes known that option 2 has occurred when the time has elapsed over which the a positive measurement has occurred.*

The ψ -function for the radioactive material itself can be represented as $\psi_{\text{radioactive material}} = 1/\sqrt{2} [\psi_{\text{radioactive material does not decay}} + \psi_{\text{radioactive material does decay}}]$

The ψ -function for the cat itself can be represented as $\psi_{\text{cat}} = 1/\sqrt{2} [\psi_{\text{cat remains alive}} + \psi_{\text{cat's demise}}]$

Depiction of Schrodinger Experiment *When Box is Opened* and Experiment Has Completed Running-1 hour has elapsed

Cat is found either alive or not alive when box is closed

$\psi_{\text{radioactive material}} =$
 $\psi_{\text{radioactive material did not decay}}$

$\psi_{\text{cat}} = \psi_{\text{cat remains alive}}$

or

$\psi_{\text{radioactive material}} =$
 $\psi_{\text{radioactive material did decay}}$

$\psi_{\text{cat}} = \psi_{\text{cat is no longer alive}}$

The Importance of Knowledge in Measurement in Quantum Mechanics

“We would like to emphasize a very important difference between classical and quantum physics. We have been talking about the probability that an electron will arrive in a given circumstance. We have implied that in our experimental arrangement (or even in the best possible one) it would be impossible to predict exactly what would happen. We can only predict the odds! This would mean, if it were true, that physics has given up on the problem of trying to predict exactly what will happen in a definite circumstance. Yes! physics has given up. *We do not know how to predict what would happen in a given circumstance , and we believe now that it is impossible - that the only thing that can be predicted is the probability of different events.* (Feynman, Leighton, and Sands, 1965, chap. 1, p. 10)....No one can “explain” any more than we have just “explained.” No one will give you any deeper representation of the situation. We have no ideas about a more basic mechanism from which these results can be deduced.”

Feynman held that all we have are probabilities which are dependent on the wave function for predicting what will happen in measurements. Everything in quantum mechanics relies on the wave function to predict what will occur – no exceptions.

Probabilities have to do with knowledge. If all we have are probabilities regarding how to make predictions regarding measurement events (observations), then it should perhaps be possible to leave out the physical interaction in a measurement and make the measurement only through deducing what the knowledge is in a situation. We do have an area where this occurs and this is in negative (null) measurements. So in classical mechanics we have measurements where the properties of a particle are intrinsic to that particle with no extrinsic factors (such as a non-physical wave function) and the principles of physics are then used to determine those properties precisely. But in quantum mechanics, the information about the state of a system is in the wave functions from which one can develop only probabilistic predictions concerning the future state of the system. The introduction of the wave function results in a minimum uncertainty in knowledge certain pairs of measurable quantities. The relationship between properties such as position and momentum of a particle are mediated by the quantum mechanical wave/s associated with the particle which have no physical presence but instead are knowledge.

It is the central role of the wave function in quantum mechanics that makes a negative (or null) measurement significant where there is NO interaction between physical entities non-trivial. Knowledge itself is the key to a measurement result. Manipulation of the knowledge itself affects the result of a negative (or null) measurement.

The Schrodinger Experiment Using the **Absence of Radioactive Decay** (a Negative Measurement) Leading to the Cat's Demise

The possibility of radioactive decay is preserved but instead of the radioactive decay leading to the cat's demise, the absence of radioactive decay leads to the cat's demise. Here, we still use a flask of hydrocyanic acid to lead to the cat's demise. In this case the flask breaks open on its own 59 minutes after the experiment begins and the box with the experiment in it is closed. Here, radioactive decay will trigger the hammer that will poke a hole in another flask that releases an antidote to hydrocyanic acid. If the decay occurs before 59 minutes has elapsed, then the cat will be protected from the hydrocyanic acid when the flask opens. If the decay does not occur within an hour the flask with the hydrocyanic acid breaks apart leading to the cat's demise. This is a negative measurement. There has been no physical interaction between the radioactive material and a measuring device and yet the cat no longer lives.

The Schrodinger Experiment Using the **Absence of Radioactive Decay** (a Negative Measurement) Leading to the Cat's Demise - *When Box is Closed* and Experiment Set to Run

Cat is alive when box is closed.

When box is closed, **the ψ -function for the radioactive material itself** can be represented as

$\psi_{\text{radioactive material}} = 1/\sqrt{2} [\psi_{\text{radioactive material does not decay}} + \psi_{\text{radioactive material does decay}}]$

After the box is closed, **the ψ -function for the cat itself** can be represented as $\psi_{\text{cat}} = 1/\sqrt{2} [\psi_{\text{cat remains alive}} + \psi_{\text{cat's demise}}]$

Depiction of Schrodinger Experiment *When Box is Opened* ith Experiment Has Completed Running-1 hour has elapsed

Cat is found either alive or not alive when box is closed

$\Psi_{\text{rad_mat}} = \Psi_{\text{radioactive}}$
material did decay

$\Psi_{\text{cat}} = \Psi_{\text{cat}}$ remains alive

or

$\Psi_{\text{rad_mat}} = \Psi_{\text{radioactive}}$
material did not decay

$\Psi_{\text{cat}} = \Psi_{\text{cat}}$'s no longer alive

Further Discussion of the Reason a Negative (Null) Measurement is Non-Trivial.

It is non-trivial because properties normally associated with a particle are mediated by the wave function in quantum mechanics. This wave function determines the shape of probability distributions of the particle since one determines probabilities of different outcomes using the wave function. So we see in the probability distributions wave features even though the particles when detected are detected as discrete entities unlike waves.

Liboff (1992) wrote in “An Introduction to Quantum Mechanics”
All information regarding the state of the system is contained in the wavefunction.” (p. 78).

Eisberg and Resnick (1974/1985) wrote in Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles:

“The fact that wave functions [in quantum mechanics] are complex function[having mathematically real and imaginary parts] should not be considered a weak point of the quantum mechanical theory. Actually it is a desirable feature because it makes it make it immediately apparent that **we should not attempt to give to wave functions a physical existence in the same sense that water waves have a physical existence.** *The reason is that a complex quantity cannot be measured by an actual physical instrument.* Therefore, we should not try to answer, or even pose the question: Exactly what is waving, and what is it waving in? The student will remember that consideration for just such questions concerning the nature of electromagnetic waves led the nineteenth century physicists to the fallacious concept of the ether....*We shall see...that a wave function actually contains all the information which the uncertainty principle allows us to know about the associated particle*” (p. 147).

So in the next diagram we have 2 different probability distributions for electrons passing through a double slit apparatus, the shapes of which are like those found for waves. **(Possibility 1) The peaks and valleys in one distribution indicate the presence of interference, a wave property and are associated with not knowing which hole of the two holes the electron went through. (Possibility 2) The one round hump is indicative of diffraction at the individual holes that sum to the one wide hump. Diffraction is also a wave property. The diffraction at the individual holes is associated with knowing which of the two holes the electron went through on its way to the detection screen.** The wave functions associated with the electrons lead to the probability distributions showing either diffraction, a wave property, or interference, also a wave property. The waves have no physical presence but carry only information or better yet knowledge. The waves themselves cannot be detected. It is very interesting that in a null measurement (like the null measurement in our Schrodinger cat experiment), one obtains a probability distribution diffraction at the hole where light is not capable of interacting with the electrons passing through that hole that is very similar to that due to diffraction when the light can and does indeed interact with the electrons passing through that hole.

With light source off,
get wavy black line for
probability distribution
of electrons at detection
screen

wave function
associated with
projected electron

electron gun emitting
electrons

With light source off,
get 1 hump red line for
probability distribution
of electrons at detection
screen

In the diagram, in the case where **we do not know** (cannot determine) whether the electron goes through hole 1 or hole 2, the total probability amplitude for this case is:

$\psi_{\text{electron}} = 1/\sqrt{2} (\psi_1 + \psi_2)$ where ψ_{electron} is the total probability amplitude for the electron, ψ_1 is the probability amplitude that the electron goes through hole 1, ψ_2 is the probability amplitude that the electron goes through hole 2.

The probabilities that the electron is detected at different locations at the backstop is given by:

$$P = 1/2 |\psi_1 + \psi_2|^2 = (\psi_1^* \psi_1) + (\psi_2^* \psi_2) + (\psi_1 \psi_2^*) + (\psi_1^* \psi_2) .$$

$(\psi_1 \psi_2^*) + (\psi_1^* \psi_2)$ is the term that introduces interference.

In the case where we do know (where **we** can determine) whether the electron goes through hole 1 or hole 2, the probability amplitude the electron for this case is either:

$\psi_{\text{electron}} = 1/\sqrt{2} \psi_1$ for the possibility the electron goes through hole 1

or instead

$\psi_{\text{electron}} = 1/\sqrt{2} \psi_2$ for the possibility the electron goes through hole 2

The probabilities that the electron is detected at different locations at the backstop is given by:

$P = |1/\sqrt{2} \psi_1|^2 + |1/\sqrt{2} \psi_2|^2$ which is the sum of the probabilities that electron is detected at different locations at the backstop when we know it went through hole 1 ($|\psi_1|^2$) or instead when we know that it went through hole 2 ($|\psi_2|^2$).

Feynman wrote in his Lecture on Physics (Quantum Mechanics)

https://www.feynmanlectures.caltech.edu/III_01.html

“We make now a few remarks on a suggestion that has sometimes been made to try to avoid the description we have given? “Perhaps the electron has some kind of internal works—some inner variables—that we do not yet know about. Perhaps that is why we cannot predict what will happen. If we could look more closely at the electron, we could be able to tell where it would end up.” So far as we know, that is impossible. We would still be in difficulty. Suppose we were to assume that inside the electron there is some kind of machinery that determines where it is going to end up. That machine must also determine which hole it is going to go through on its way. But we must not forget that what is inside the electron should not be dependent on what we do, and in particular upon whether we open or close one of the holes. So if an electron, before it starts, has already made up its mind (a) which hole it is going to use, and (b) where it is going to land, we should find P_1 for those electrons that have chosen hole 1, P_2 for those that have chosen hole 2, and necessarily the sum $P_1 + P_2$ for those that arrive through the two holes.

Continues on next slide

Feynman quote Continues from previous slide

There seems to be no way around this. But we have verified experimentally that that is not the case. And no one has figured a way out of this puzzle. So at the present time we much limit ourselves to computing probabilities. We say “at the the present time,” but we suspect very strongly that is something that will be with us forever—that it is impossible to beat that puzzle—that this is the way nature really is.” (Section 1-7) v. 3 qm Feynman lectures.

At least 40 years of trying to prove that what Feynman holds is not true, that physics really is classical and wave functions are not really what is going on, have led nowhere. And physicists keep looking to prove that they are correct. A physical reality independent of knowledge is the “ether” of Einstein’s time. All these experiments that have shown that a classical framework does not explain what happens in quantum mechanics show in the converse that probabilistic knowledge is all we have, just as Feynman wrote almost 60 years ago.

Where the Light is Located Near Only One Hole

It is very interesting that in a null measurement indicating which hole the electron went through (like the null measurement in our Schrodinger cat experiment), one obtains an electron distribution that looks like it results from diffraction even at the hole where light does not interact with the electrons passing through that hole. In this case, the light is located only near one hole so that electrons passing through the other hole do not interact with the light, as depicted in the next slide.

With light source OFF,
get wavy black line for
probability distribution
of electrons at detection
screen

wave function
associated with
projected electron

electron gun emitting
electrons

With light source ON,
get 1 hump red line for
probability distribution
of electrons at detection
screen

Figure 4

In null measurement, no light flash
when electron passes through
lower hole, still obtain this
distribution for electrons passing
through lower hole.

Knowledge itself is the key to a measurement result in a null measurement. Manipulation of the knowledge itself affects the result of a negative (or null) measurement.

The foregoing also applies to positive measurements (where there is a physical interaction between a measuring instrument and the particle measured) as well, not just negative measurements. This point is what underlies Feynman's argument in the previous two slides. The probabilities that Feynman refers to in these slides is dependent on the wave function regarding the system and the wave function in turn reflects knowledge regarding the system.

Also for positive measurements, all that can be known is held in the wave function. Where interactions occur in measurements, everything going forward other than the interaction itself is mediated by the wave function. So any effect on the particles in the interaction is governed directly by the relevant wave function/s. That is a physical interaction that is a measurement likely changes the wave function of the physical entity being measured. And it is the wave function that tells us the probabilities of various events when a subsequent measurements is made. The laws of physics are taken into account in how the wave functions develops. But the laws of physics work only through the wave functions and the mathematical structure that is applied to the wave functions. Keep in mind that the relevant wave functions themselves have no physical presence but instead contain information that leads to probabilistic predictions.

References

1. Schrodinger, E. (1983). The present situation in quantum mechanics. In J. A. Wheeler and W. H. Zurek, Quantum theory and measurement (pp. 152-167) (J. Trimmer, Trans.)
2. Einstein, A., Podolsky, B., and Rosen, N. (1935). Can quantum-mechanical description of physical reality be considered complete? *Physical Review*, 47, 777-780.
3. Liboff, R. (1992). *Introductory quantum mechanics* (2nd ed.). Reading, Massachusetts: Addison-Wesley.
4. Eisberg, R., and Resnick, R. (1985). *Quantum physics of atoms, molecules, solids, nuclei and particles* (2nd ed.). New York: Wiley. (Original work published 1974)
5. Feynman, P. R., Leighton, R. B., and Sands, M. (1965). *The Feynman lectures on physics: Quantum mechanics* (Vol. 3). Reading, Massachusetts: Addison-Wesley.
https://www.feynmanlectures.caltech.edu/III_01.html

References to Null Measurements

Epstein, P. (1945). The reality problem in quantum mechanics. *American Journal of Physics*, 13, 127-136.

Snyder, D. M. (December 19, 1995). On the Nature of the Change in the Wave Function in a Measurement in Quantum Mechanics. <https://arxiv.org/abs/quant-ph/9601006v2> .

Snyder, D. M. (1995).

https://www.researchgate.net/publication/326583735_The_Mind_and_the_Physical_World_A_Psychologist's_Exploration_of_Modern_Physical_Theory .

Snyder, D. Negative Observations in Quantum Mechanics. (December 6, 1999). <https://arxiv.org/abs/physics/9912015> .

Snyder, D. M. (1995).

<https://www.researchgate.net/publication/326583735> The Mind and the Physical World A Psychologist's Exploration of Modern Physical Theory .

Snyder, D. M. (2003). Reversing a Negative Measurement in Process with Negative Events: A Haunted Negative Measurement and the Bifurcation of Time.

<http://cds.cern.ch/record/633797> ;

<https://www.researchgate.net/publication/332870683> Reversing a Negative Measurement in Process with Negative Events A Haunted Negative Measurement and the Bifurcation of Time .

Additional Reference

Snyder, D. M. (March 22, 2001). On Whether People Have the Capacity to Make Observations of Mutually Exclusive Physical Phenomena Simultaneously.

<https://arxiv.org/abs/physics/0103072> .