Quantum Mechanics and the Source of Awareness

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Sept. 16, 2009
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Abstract

Quantum mechanics gives many simultaneously existing versions of reality, but we are aware of only a single, particular one. Quantum mechanics does not specify which one we are aware of, so interpretations of the mathematics have arisen, hoping to explain how the particular version is chosen. It is argued that there is little reason to be optimistic that any of the three primary interpretations—particles, collapse, or many-worlds—is correct. In the current state of physics, the most reasonable interpretation, the only one that requires no changes or amendments to the highly successful mathematics, is that we each harbor a non-physical Mind, outside the laws of physics, which is the source of our awareness. This Mind only perceives; it does not alter the wave function in any way. An experimental test of the Mind interpretation is proposed.

Prologue.

Perhaps the most profound result one could hope to derive from quantum mechanics would be a proof that the basic source of our awareness, rather than being in the physical brain, is outside the physical universe. If that can be done, then a full understanding of awareness lies beyond the limits of the physical sciences.

Schrödinger's Cat.

How could a theory of the physical world possibly imply anything about a concept as abstract as awareness? To see we consider the Schrödinger's cat thought experiment, devised by Schrödinger himself to show how "nonsensical" quantum mechanics is. A cat is put in a box along with a vial of cyanide. Outside the box are a radioactive source and a detector of the radiation. The detector is turned on for five seconds. If it records one or more counts of radiation, an electrical signal is sent to the box, the vial of cyanide is broken, and the cat dies. If it records no counts, nothing happens and the cat lives.

Classically, there is no problem here (unless you are a cat lover). Either an atom radioactively decays, the cat dies and you perceive a dead cat when you open the box; or no atom decays, the cat lives and you perceive a live cat. Schematically, in the classical case,

either
[atom decays] [cat dies] [you perceive a dead cat]
or
[no atom decays] [cat lives] [you perceive a live cat]

But the atomic radioactive decay is a process in which quantum mechanics—with its wave function, representing "spread-out matter"—must be taken into account. And in the quantum mathematics, there is both a part of the wave function corresponding to an undecayed atom *and* a part corresponding to a decayed atom. That is, the wave function at a given time is

[the atom radioactively decays]
and, simultaneously
[the same atom does not decay]

Both options, both *branches* of the wave function, exist simultaneously!

Each of these branches has its own consequences in the macroscopic world we perceive, so that after a while, the wave function of the atom, the cat, and you (as the observer) is

[atom decays] [cat dies] [version 1 of you perceives a dead cat]
and, simultaneously
[atom does not decay][cat lives] [version 2 of you perceives a live cat]

There are now two full-blown, simultaneously existing versions of physical reality. In one, there is a dead version of the cat, in the other there is a live version. In one, version 1 of you perceives a dead cat, in the other, version 2 of you perceives a live cat; there are two simultaneously existing versions of you, each perceiving something different!

Awareness and Interpretations of Quantum Mechanics.

This example shows there is a connection between quantum mechanics and awareness. If you are the observer, your actual awareness corresponds to only one of those versions. However, quantum mechanics treats the two versions equally, so it does not give any clue about which one corresponds to the real you. Thus we have the question: Why does our awareness correspond to one particular version?

Physicists have known about this "awareness" or "real you" problem for many decades. During that time, they have devised *interpretations*—explanatory conjectures that go beyond the mathematics—of quantum mechanics. The main ones are: (1) That *particles* objectively exist, and that the reality we are aware of corresponds to the particles rather than the wave functions. (2) That the wave function *collapses* down to just one version—the cat dead version might simply go away, for example—leaving a unique live-cat version of reality. And (3), that we can live with the many versions of reality—the *many-worlds* interpretation of Everett. If we wish to show that quantum mechanics does indeed imply that awareness originates outside the physical universe, it is necessary (but not sufficient) to show that these three potential, physically-based explanations are incorrect. As we will see, if none of these three works, then we are pretty much forced to assume awareness of just one version originates "elsewhere."

The Particle Interpretation.

We must show there is good reason to suppose none of the three standard potential interpretations is correct. We start with particles. There are a number of observations which seem to imply there are particles, with the primary ones being: (a) In the traditional view of matter, influenced by the classical physics of the nineteenth century, it seems necessary to have mass and charge carried by a discrete, localized entity—a particle. (b) Compton scattering of light by an electron can be explained by supposing there is a particulate photon with mass 0 which collides with a particulate electron, and that energy and momentum are conserved. (c) If a spread-out photon wave function hits many grains of film, it is found experimentally to expose only one of them. And (d), charged particles leave particle-like trajectories in cloud and bubble chambers.

A careful analysis, however, shows that all of these particle-*like* properties can be shown to be properties of the wave function alone [1]. We start with (a). Group representation theory applied to the linear theory of quantum mechanics can be used to mathematically prove that mass, energy, momentum, spin, and charge are properties of the *wave function* (or more properly the state vector). Thus it is not necessary to postulate the existence of particles as carriers of these quantities.

To address Compton scattering, we note that energy and momentum (as well as charge and angular momentum) are conserved in quantum mechanics. Thus, because the Compton scattering depends only on mass, energy, momentum and the conservation laws, which are all quantum mechanical properties, it can be fully explained *within quantum mechanics*, without the assumption of the existence of particles. Virtually the same explanation can also be used to explain the photoelectric effect using quantum mechanics alone.

Explaining the exposure of only one grain when many are hit by a spread-out wave function is more involved. First we note that in the Schrödinger's cat experiment, the wave function divides into two simultaneously existing branches, one with a live cat and one with a dead cat. These two branches are not superimposed on each other in space, however. Instead, the mathematics tells us they "exist" in entirely different, non-communicating universes. We perceive the events in only one of them, *exactly as if* we lived in one universe or another.

Now when we go to the many-grain problem, because of the linearity of the theory, we can break the light wave function into a sum of many localized parts. In each term in the sum, the localized part hits and thereby exposes just one grain. Each of the terms is a branch of the wave function and corresponds to a different universe, isolated from the others. We then invoke the principle from the Schrödinger's cat experiment that we perceive *as if* we lived in only one of the universes. But in each of these universes, one and only one grain is exposed. And so whatever universe we live in, we see one and only one grain as being exposed, even though the wave function hits all of them! (See [1] for a fuller explanation.) Because only one *localized* grain is perceived as exposed, we see how the mythical picture of a localized particle arises from properties of the wave function.

The same reasoning, compounded, shows that we will perceive a single particle-like trajectory in a cloud or bubble chamber even though the wave function is widely spread out. Each of the millions of potential particle-*like* trajectories exists in a different universe, and we perceive a particular trajectory, as if we lived in only one of the universes.

Thus we see that the particle-*like* properties—mass, energy, momentum, spin, charge, the conservation laws, and localization—can all be explained by properties of the wave function alone. Wave-particle duality is a duality solely in the properties of the wave function, so only the wave function need exist to explain both particle-*like* and wave-like properties. The net result is that there is no *experimental* evidence for particles.

What about the theory side? Bohm [2] devised a particle-like model, based on the Schrödinger equation, which succeeds in reproducing the probability law. In it, the "hidden variables" that determine the single outcome of an experiment are particle-like trajectories, with "the particle" riding along on just one branch of the wave function. But the model, although mathematically correct, has two major questionable assumptions in the way it relates to physical reality [1].

First, the one-to-one link between particle and wave function must be put in "by hand" (rather than being derived). Second, and this is most important, it is not made clear why the branch of the wave function that has the particle on it is the one we are aware of. The particle which travels on the trajectory has no awareness of its own. And the other, non-particled, branches still have perfectly valid wave functions for the observers, so there is no obvious reason why those versions of the observer cannot be aware. There is no "outside" judge or referee who declares that the particled branch (or the particles themselves) corresponds to awareness.

The conclusion is that the Bohm particle model does not adequately explain why we perceive a particular branch. Further, the same criticisms that apply to his model would also presumably apply to any other underlying theory of particles or hidden variables (although there are currently no others that are well-developed). Thus the theoretical situation for particle-like underlying theories is most definitely not encouraging.

The Collapse Interpretation.

We next consider the collapse interpretation [3]. Suppose we re-write the wave function for Schrödinger's cat as

(a)[atom decays] [cat dies] [version 1 of you perceives a dead cat]
and, simultaneously
(b)[atom does not decay][cat lives] [version 2 of you perceives a live cat]

where a and b are numbers whose squares sum to 1. Then collapse says that, for some reason, in a very short time (microseconds) after the experiment is completed, a goes to zero and b goes to 1. That is, the "cat dies" branch of the wave function has simply gone away.

This interpretation is attractive because it corresponds to what we perceive. If we see a live cat, we continue to see a live cat, never a dead one. It is certainly *as if* the other branch has gone away. This scheme has been given an elegant mathematical form by Ghirardi, Rimini and Weber [4], and Pearle [5]. In it, very weak but fast processes are postulated to act on the many different atomic-level wave functions making up the total wave function of a detector, or an observer, with the result that either a or b goes to zero and only one branch is left after a short time.

Such a mathematical collapse process should have observable consequences. A number of experiments have been done [3,6], including interference effects between large molecules, but none have turned up any evidence for collapse. That is, there is no experimental evidence for collapse.

Further, when one looks closely at the theory, there are several properties which make it seem unreasonable. The forces on the different atomic-level wave functions, which are localized to about one nanometer, must be coordinated over distances of a meter and more. Physically, such long-range coordination, in all circumstances, is most unlikely. Further, there must be coordination between the *different branches* of the wave function, something that is absolutely forbidden in conventional, linear quantum mechanics. So even though the proposed theory is elegant and accomplishes its purpose, it does not seem believable.

Thus there is neither experimental evidence nor a satisfactory theory of collapse. We conclude, although somewhat less strongly than in the particle case, that the collapse interpretation is quite unlikely to hold.

The Many-Worlds Interpretation.

We have indicated that there is no *experimental* evidence for either collapse or the existence of anything besides the wave function. We have further argued that there are strong to severe difficulties in constructing an underlying *theory* of either particles (hidden variables) or collapse. Thus the current state of physics is that, most likely

Only the wave function, with all its branches, physically exists.

So at this point in time, it is imperative that we construct an interpretation consistent with this result.

The many-worlds interpretation of Everett [7] is one such possibility. In this interpretation, all branches are presumed to simultaneously exist—but as we said, in different universes. This would imply there are many equally valid versions of each of us, all simultaneously existing! What allows this to be a possible interpretation is that, because of the isolation of the universes, each version of you would be unaware of anything in the other universes, including what the versions of you in the other branches are aware of.

There is, however, a severe problem with this interpretation, having to do with the probability law [8]. If we look at the wave function for Schrödinger's cat in the Collapse section, the probability law says that the probability of our perceiving the cat alive (dead) is proportional to b^2 (a^2). Now the only entities that perceive in the many-worlds interpretation are the versions of the observer. So the probability law *must be stated in terms of the perceptions of the versions* of the observers. But *this cannot be done*; each version *always* perceives its respective outcome, so there can be no *probability* of perception by the versions. Hence there can be no probability of perception in the many-worlds interpretation. (There is also a second, somewhat more involved problem concerning probability; see [8].)

We therefore conclude that since the probability law cannot even be stated in the many-worlds interpretation, it surely cannot hold there. And if the probability law cannot hold, the interpretation cannot be valid.

The Non-Physical Mind Interpretation.

So let us review. We have seen that it is quite reasonable to assume that only the wave function, with all its branches, exists. But if this is *all* that exists, as in the many-worlds interpretation, the probability law cannot hold. Therefore something besides the wave function must exist. And that something must be responsible for our awareness of one specific branch.

As far as I can see, there is only one way to get past the no-hidden-variable, no-collapse, no-many-worlds barrier to an awareness of one branch [8, v2]. To obtain some idea of what is needed, we summarize the connection between the mathematics of quantum mechanics and our perceptions:

> *In any given instance, there is always one quantum version of reality whose characteristics corresponds exactly—qualitatively and quantitatively—to our physical perceptions.*

This tells us that existence is constructed *exactly as if* there were a non-physical Mind looking in from outside physical reality—that is, from outside the rules of quantum mechanics—and being aware of just one quantum version of the wave function of our brain. And so that is what we will assume in the Mind interpretation whose properties are given below.

Basics of the Mind Interpretation of Quantum Mechanics.

1. The non-physical Mind. Associated with each individual person is an individual Mind that is not subject to the mathematical laws of quantum mechanics. In particular, the Mind has no wave function associated with it. We use a capital M to distinguish this Mind from the usual usage of the word "mind." Because quantum mechanics describes the physical world so well, we will *define* anything outside its laws to be 'non-physical.' So with this definition, the Mind is non-physical.

2. The Mind perceives only the brain-body. The individual Mind perceives only the wave function of the individual brain (brain-body); it does not directly perceive the quantum state of the external world. This is an acknowledgement of the fact that we are not directly aware of the external world; we are only aware of the neural state of our brain. The process of perception of the wave function (or state vector) by the Mind is not understood.

3. The Mind picks out only one version of the wave function. The individual Mind concentrates on one version of the wave function of the brain-body, and it is the concentrated-upon version that becomes the content of our conventional awareness.

4. No collapse. The Mind does not collapse the wave function or interfere with the mathematics of quantum mechanics in any way.

> A primary objection to dualism—a non-physical Mind separate from a physical brain-body—is that the non-physical aspect must exert a force or otherwise have some effect on the physical. The non-physical Mind scheme circumvents this objection because the non-physical aspect only *perceives*; it does not affect the physical world—made up of wave functions—in any way.

Agreement among observers. The overarching MIND.

The model as it has been given so far leaves two important questions unanswered—why observers agree on what they perceive, and why the probability law holds. To make the first question specific, consider again the Schrödinger's cat experiment and suppose we have two observers. Then according to the rules of quantum mechanics, the wave function is

[cat alive]
[obs 1's brain state corresponds to cat alive]
[obs 2's brain state corresponds to cat alive]
—and—

[cat dead]
[obs 1's brain state corresponds to cat dead]
[obs 2's brain state corresponds to cat dead]

Suppose observer 1's Mind focuses on the version of the associated brain corresponding to cat alive so that observer 1 perceives, in the everyday sense, a live cat. We know from everyday experience that observer 1 and observer 2 (and the cat) must be in agreement. And we know from quantum mechanics itself that two observers can never disagree. But still, how do we guarantee in our Mind model, that observer 2's Mind is also focused on the "live" version of the brain? There is a way to bring about agreement but it is bound to make scientists even more skeptical of this proposal because it is far outside the realm of traditional science.

> **5. The overarching MIND.** Instead of each individual Mind being separate from all others, each Mind is a fragment or facet of a single overarching MIND. Each individual Mind is that aspect of MIND which is responsible for perceiving the state of the associated individual physical brain. Perception of a particular version of the wave function by one individual Mind is then presumed to set the perception of that *same* version by the overarching MIND. And that in turn sets the perception of the same version by all the other individual Minds.

So to obtain agreement among observers in this scheme, we are apparently forced to substitute the MIND assumption for the conventional particle or collapse assumptions that give a single-version physical world. The scientist will say there is no evidence to justify such an outrageously non-scientific assumption. But the counter-argument is that there is no evidence to justify the particle or collapse schemes either. And if there is no collapse and there are no particles—which is the quite reasonable scenario we are exploring here—we seem to be *forced* to the Mind-MIND interpretation.

The Probability Law.

How could the probability law arise in the Mind interpretation? There is actually a somewhat natural way. Suppose we run a two-state experiment N times, with N very large, and look only at the final results for the number of 1 states perceived. Then in terms of the number of times, m, the counter records state 1 (with amplitude a_1), the amplitude squared after N runs has a very sharp maximum at $m = |a_1|^2 N$. So if the non-physical Mind is "more likely" to perceive a state with a large amplitude, the probability law will follow. The non-physical Mind doesn't have to follow the $|a_i|^2$ probability law, or *any* probability law; it only has to be very likely to perceive a state with a relatively very large amplitude. If that holds, then the $|a_i|^2$ probability law follows *for long runs in which intermediate results are not observed.*

Experimental Test of the Probability Law.

Since the probability law holds in the Mind interpretation only when the experiment is repeated many times and intermediate results are not observed, there is a way to experimentally test this interpretation. Suppose we do experiments on photons polarized at an angle θ to the x-axis. We use a crystal to split the photon wave function into two parts that follow separate trajectories. On one trajectory will be the part of the wave function corresponding to polarization along the x-axis and on the other trajectory will be the part polarized along the y-axis. We then introduce detectors on the two trajectories. The result, according to standard quantum theory, will be that "the photon" will be perceived as polarized along the x-axis on a fraction $p_x = \cos^2\theta$ of the runs and along the y-axis on a fraction $p_y = \sin^2\theta$ of the runs.

But instead of doing a long series of runs before looking at the result, suppose we look at the results of single events, in real time, as the experiments are being run. If we repeat this many times, and if the Mind interpretation is correct, then we would expect the probabilities to differ from the standard p_x, p_y. This gives us a relatively simple test; if the probabilities for long runs of singly-observed events follow the usual $\cos^2\theta$ law, then the Mind interpretation is most probably not valid.

> Two notes: First, this proposed test obviously flies in the face of classical ideas on probability, but still, it is not logically inconsistent. See [8, v2]. Second, we are not invoking any kind of psychic ability to change the results here. We are simply conjecturing that the standard $|a_i|^2$ law will not hold when every result is perceived.

Summary.

The wave function of quantum mechanics often splits into several potential versions of reality. We are aware of only one of these, but quantum mechanics does not tell us why our awareness alights on one particular version of reality. There are three proposed interpretations of quantum mechanics which attempt to solve this mystery.

The first is to assume there are particles which ride along on just one version of reality, and that version is the one we are aware of. But this does not work, first, because there is no experimental evidence for particles, and second, because the construction of an underlying theory of particles encounters difficulties. In addition, since the particle itself has no awareness, it does not really explain why we are aware of the version associated with the particle.

The second possible explanation is to suppose the wave function collapses to just one version of reality. But in spite of a number of attempts, utilizing diverse physical phenomena, no experimental evidence for this has been found. In addition, there are problems in constructing a theory of collapse.

The third possibility is the many-worlds interpretation, which says that all versions of the observer are equally aware, equally valid. This possibility can be ruled out, however, because the probability law of quantum mechanics cannot hold in such an interpretation.

The only apparent option left is to suppose that a non-physical Mind, not subject to the laws of quantum mechanics, rides along on one branch. The Mind associated with each individual is aware of the quantum state of the individual's brain. This non-physical Mind, rather than the physical brain, is the basic source of one's awareness.

The non-physical Mind does not collapse the wave function or affect physical reality in any other way; it only perceives. Thus one advantage of this interpretation is that, in contrast to particle or collapse interpretations, the highly successful mathematics of quantum mechanics need not be altered or amended.

The probability law holds in this picture, under minimal assumptions, for long runs of an experiment in which intermediate results are not observed. But it will presumably not hold if intermediate results are observed. This provides a simple way of experimentally testing whether or not the non-physical Mind interpretation is correct.

A good deal remains to be done before one can unequivocally say that quantum mechanics implies the source of awareness is outside the physical universe. The theoretical arguments against hidden variables and collapse need to be tightened. More definitive experimental tests of these two interpretations are also necessary. Further, one needs to be absolutely certain of the reasoning in the many-worlds case. And the proposed experimental test of the probability law should be carried out.

References

[1] Casey Blood, *No evidence for particles*, arXiv:Quant-ph/0807.3930 (2008).

[2] David Bohm, *A suggested interpretation of quantum theory in terms of "hidden variables"*, Phys. Rev. **85** 166,180 (1952).

[3] Casey Blood, *Difficulties with collapse interpretations of quantum mechanics*, arXiv:Quant-ph/0808.3699 (2008).

[4] G. C. Ghirardi, A. Rimini and T. Weber, *Unified dynamics for microscopic and macroscopic systems*, Phys. Rev. D**34**, 470 (1986); Phys. Rev. D**36**, 3287 (1987).

[5] Philip Pearle, *Ways to describe dynamical state-vector reduction*. Phys. Rev. A**48**, 913 (1993).

[6] Philip Pearle, *How stands collapse II.* arXiv:quant-ph/0611212v3 (2007).

[7] Hugh Everett, III, *Relative state formulation of quantum mechanics.* Rev. Mod. Phys. **29** 454 (1957).

[8] Casey Blood, *Problems with probability in Everett's interpretation of quantum mechanics*. arXiv:Quant-ph/0901.0952 (2009).