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Quantum Mechanics is Probabilistic in Nature

Douglas M. Snyder
Los Angeles, California

Elitzur (1991) maintained that my version of Schrödinger's cat gedankenexperiment does not provide the basis for demonstrating the effect of consciousness on the course of the physical world. The nature of the difference between Elitzur's and my views concerning the gedankenexperiment is discussed, and the key to this difference concerns the fundamentally probabilistic nature of quantum mechanics. Elitzur has failed to see that in quantum mechanics consciousness fundamentally is that through which the physical world is known. Elitzur's characterization of my thesis concerning consciousness and human observation as reflecting radical idealism is discussed. A second gedankenexperiment is noted in which the observer's circumstance, other than the time of measurement, is also a variable and which tests whether or not mind, or consciousness, has an impact on the course of the physical world.

In his response to "On Elitzur's Discussion of the Impact of Consciousness on the Physical World" (Snyder, 1991), Elitzur (1991) maintained that I did not show how quantum mechanics provides a demonstrable effect of consciousness on the course of the physical world. I do not see how I could have provided a more graphic one in the gedankenexperiment I proposed in my article. The nature of the difference between Elitzur's and my views concerning the gedankenexperiment is discussed. In addition, Elitzur's characterization of my thesis concerning consciousness and human observation as untenable and as reminiscent of Berkeley's idealism is discussed. In most experiments in physics, the potential or actual observer's circumstances, other than the time of measurement, are considered uniform, and the physical existents studied are manipulated. A second gedankenexperiment is noted in which the observer's circumstance is also a variable and which tests whether or not simultaneous, mutually exclusive situations for the same concrete experimental circumstances exist.

Requests for reprints should be sent to Douglas M. Snyder, Ph.D., 459 North Spaulding Avenue, Los Angeles, California 90036.

A Demonstrable Effect of Consciousness on the Functioning of the Physical World

In my variation of the Schrödinger cat gedankenexperiment, I proposed that a bomb with a timing mechanism be included in a box with, among other things, a small amount of radioactive material, a flask of hydrocyanic acid, and a living cat. There is a fifty percent chance that within one hour after the box is closed the radioactive material will decay. If the radioactive material decays, a sequence of events leading to the death of the cat due to cyanide poisoning ensues. In addition, a timing mechanism is started leading to the detonation of the bomb one hour and five minutes after the box is closed. An observer looking into the box one hour after the box is closed and who found the cat dead would also see a message warning that there were five minutes until the bomb in the box exploded. The individual who did not look into the box at the designated time would not have the benefit of knowing of the impending explosion and, presumably being in the vicinity of the bomb, would be killed by the explosion.

Elitzur wrote that the thesis that consciousness has an effect on the physical world needs to be falsifiable in order to be tenable. That is just what I provided in the variation of Schrödinger's cat gedankenexperiment that I proposed. Essentially, what concerns Elitzur is the probabilistic nature of quantum mechanics. His response is based on the possibility that there is some more definitive process working behind the scene than that allowed by quantum mechanics. Here is what Feynman, certainly a mainstream physicist, said in this regard:

> *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)

In writing that quantum mechanical description is similar to that of coin tossing, Elitzur ignored the *fundamentally* probabilistic character of quantum mechanics. Rohrlich (1984), another mainstream physicist, wrote concerning a variation of the Einstein–Podolsky–Rosen gedankenexperiment (Einstein, Podolsky, and Rosen, 1935) involving two spinning particles that one of the differences:

> between the coin toss (classical mechanics) and the breakup into two spinning particles (quantum mechanics) is . . . that the coin toss has a detailed dynamics which in principle can be known and then permits one to predict the outcome from the initial conditions, while the breakup does not have such a dynamics (no hidden variables that make the outcome deterministic). (p. 223)

In addition, there are experiments that directly tested for some other more definitive processes behind those allowed for by quantum mechanics. The results supported the thesis that these more definitive processes do not exist (Aspect, Dalibard, and Roger, 1982; Aspect, Grangier, and Roger, 1982).

Once one accepts the fundamentally probabilistic character of quantum mechanics, consciousness cannot help but have a demonstrable impact on the physical world. What quantum mechanics provides about the world are probabilistic predictions concerning the functioning of the physical world. Probabilistic predictions are fundamentally concerned with knowledge. As there are no more definitive features of the physical world in addition to these probabilistic predictions, probabilistic knowledge concerning the functioning of the physical world is all that can be assumed to characterize the physical world itself. As I indicated (Snyder, 1989, 1991), the quantum mechanical probabilities known by an actual or potential observer are specific to that individual. Other potential or actual observers having different information concerning physical measurements may be correctly using a different set of quantum mechanical probabilities with regard to the same physical event. In sum, quantum mechanics has only to do with probabilistic prediction, and probabilistic prediction for an observer or potential observer is based on the measurement information known by that individual. As this information need not be the same for either potential or actual observers, the quantum mechanical probabilistic knowledge must be conscious for the individual observer.

Untenable Conclusions

Elitzur is concerned that allowing for the influence of consciousness on the physical world leads to untenable conclusions. Though I did not attempt to argue in my article any of the "bizarre" (Elitzur, 1991, p. 304) points noted by Elitzur, it is important to point out that many apparently unlikely conclusions of quantum mechanics are accepted by mainstream physicists. Here are a few of them:

1. A particle in an energy eigenstate may have a specific magnitude for its momentum. In addition, for such a particle in an energy eigenstate, the probabilities of locating the particle at various locations in space may remain the same over time. In non-technical terms, the probabilities of locating certain moving particles at various locations in space may be constant.

2. If a particle is confined to a certain region of space, the expected value for the momentum when measured must be non-zero and the expected value for the kinetic energy when measured must be non-zero.

3. In certain circumstances, a particle can penetrate a potential energy barrier that is greater than the energy of the particle. In non-technical terms, a particle may penetrate a barrier stronger than the particle. It is also very interesting that this possibility for penetration follows the mathematical requirements for the eigenfunctions that are solutions to the time independent Schrödinger wave equation (Eisberg and Resnick, 1985; Snyder, 1986).

4. Identical particles known as fermions cannot be in the same quantum state. An electron is an example of a fermion. There is, effectively, a repulsive type of force between fermions that is due only to their identical natures. Eisberg and Resnick (1985) provided an unreferenced quotation from Pauli that bears on this feature of identical particles:

> If all the electrons in an atom were in the innermost shell [and were in the same quantum state], then the atom would essentially be like a noble gas. The atom would be inert, and it would not combine with other atoms to form molecules. If electrons did not obey the exclusion principle this would be true of all atoms. Then the entire universe would be radically different. For instance, with no molecules there would be no life! (p. 309)

One should not forget the most fundamental and yet the oddest, in a classical sense, characteristic of quantum mechanics, namely that a physical existent has both wave and particle characteristics. For example, as a wave, a physical existent can demonstrate interference. As a particle, its detection is as a discrete unit. In addition, it should be noted that in quantum mechanics there are many other such unlikely and yet well accepted results.

Why then does Elitzur see the impact of consciousness on the functioning of the physical world as untenable in quantum mechanics when other unlikely conclusions are readily accepted by mainstream physicists, presumably by Elitzur as well? The reason for this circumstance is also responsible for Elitzur's philosophical view of my thesis as idealistic and will be addressed shortly.

Idealism

Elitzur associated my position on the impact of consciousness on the physical world with radical idealism. Placed within this context, Elitzur asked: "Why are there physical laws in a world determined by mind" (p. 305)? Elitzur's characterization of my thesis in this manner reflects the underlying philosophical concern of many physicists. This concern is: If consciousness has an impact on the physical world (and not just on how this world appears to an individual), then do we not immediately find ourselves in a completely subjective world and snared by solipsism? In his concern that my thesis leads to complete subjectivity, Elitzur incorrectly characterized my position as reflecting radical idealism.

There is evidence in quantum mechanics that consciousness, and mental activity in general, play a role in the functioning of the physical world (Goswami, 1990; Schrödinger, 1935/1983; Snyder, 1983, 1986, 1989, 1990a, 1990b, 1990c, 1991, in press; Wigner, 1961/1983). There is evidence as well that they play a role in the functioning of the physical world in classical physics (i.e., relativity and Newtonian mechanics) and statistical mechanics as well (Adler, 1989; Brewer and Hahn, 1984; Cooper and Shepard, 1984; Snyder, 1985, 1986, 1987, 1989, 1990b, 1990c, 1991, 1992). This does not mean that the physical world is determined only by mind or that experience is not important in assessing theory. But it is to say that there is no sharp division where the physical world leaves off and mind begins. The exact relation between mind and the physical world will grow out of experiments and an in depth exploration of the theory underlying these experiments. It will not grow from avoiding what accepted quantum theory indicates (or for that matter such indications in relativity theory, Newtonian mechanics, and statistical mechanics) concerning the relation of mind to the physical world.

Simultaneous, Mutually Exclusive Situations

It is a feature of quantum mechanics that only one spin component of a particle along one of three orthogonal axes (x, y, and z) can be precisely known at a time. When one is known precisely, the other two are completely unknown. There are only two possible values that can be precisely known for the spin component of a fermion along an axis. Let us call these values up and down. So, for example, if the spin component along the z axis for a fermion, such as an electron, is up along this axis, there are equal probabilities that the spin component along the x axis is up or down and the spin component along the y axis is up or down. More specifically, according to quantum mechanical theory, well supported by empirical evidence, if the spin component along the y axis is measured, one will get an eigenvalue, a particular value, corresponding to either the spin component along the y axis being up or down. Then the probabilities that the spin component along the x axis is up or down are equal and the probabilities that the spin component along the z axis is up or down are equal.

In psychological tests of spatial orientation, a psychologist, Stratton (1896, 1897a, 1897b), wore an optical apparatus that inverted the incoming light on the retina from its normal position of being "upside down." Essentially incoming light was rotated 180 degrees around the line of sight. In the first experiment, he wore the apparatus for three days, and in the second experiment, he wore the apparatus for eight days. In each of the experiments, Stratton reported that he progressively came to see objects in the world right side up. He concluded after the first experiment:

> The difficulty of seeing things upright by means of upright retinal images seems to consist solely in the resistance offered by the long-established experience. There is certainly no peculiar inherent difficulty arising from the new conditions themselves. If no previous experience had been stored up to stand in opposition to the new perceptions, it would be absurd to suppose that the visual perceptions in such a case would be inverted. (Stratton, 1896, p. 617)

Stratton's results in the second experiment supported this conclusion.

Stratton's conclusion has relevance for quantum mechanics. Consider a gedankenexperiment combining features of both quantum mechanics and Stratton's experiment. In this gedankenexperiment, incoming light upon the retina of one observer B is, and has been for some days, rotated along the line of sight by ninety degrees. For observer A, incoming light has not been, and is not, rotated. Let both observers see before them the same concrete experimental circumstances, namely the same fermion exiting a measuring device designed to measure its spin component along one axis. The fermion will exit this device moving up or down along this axis. Let this axis be the z axis for observer A, running "up" and "down," vertically, orthogonal to the line of sight. Stratton's results indicates that for observer B, the fermion will also exit the measuring device moving "up" or "down." Only now this axis is not the z axis, but an axis orthogonal to the z axis (i.e., the x axis). (Remember that in quantum mechanics, one cannot know precisely the spin component of a fermion along two orthogonal axes at the same time.)

This is a surprising result: the simultaneous existence of that which is also in principle mutually exclusive. Stratton's work, though, indicates that quantum mechanics does support the existence of these types of simultaneous, mutually exclusive situations. Consider this result in terms of the Schrödinger cat gedankenexperiment. It is as if in one situation the radioactive material decayed leading to the cat being dead when observed, while simultaneously in the other situation the radioactive material did not decay leading to the cat being alive when observed. If mind, or consciousness, did not play a role in the functioning of the physical world, one would not expect the existence of simultaneous, mutually exclusive situations. In the gedankenexperiment just outlined, one would expect observers A and B not to see the motion of the fermion identically (in the case at hand, as up or down along the axis of the "upright" direction). One would expect that concrete experimental circumstances could support only one of the mutually exclusive possibilities for the functioning of the physical world. Thus, one would expect that observer A would see the fermion exit either "up" or "down" along the axis of the "upright" direction and observer B would see the fermion exit "sideways" either to the "right" or to the "left." The implication of this gedankenexperiment combining quantum mechanics and Stratton's results is that mind, or consciousness, does have an impact on the course of the physical world.

Consciousness as the Means Through Which the Physical World is Known

Elitzur mentioned that psychology and physics "do not get along well, especially when the subject of consciousness is brought up" (p. 306). In noting that physics sees "no observable evidence" (p. 306) for the existence of consciousness, Elitzur inadvertently raised an important issue. (It is interesting that this is his position given his earlier concern that the thesis that in quantum mechanics consciousness influences the course of the physical world reflects radical idealism.) As represented in the Schrödinger cat gedankenexperiment or the second gedankenexperiment discussed, in quantum mechanics, one does not look at consciousness as one looks at a physical existent. In quantum mechanics, and in experience in general, consciousness fundamentally is that through which the physical world is known. In quantum mechanics, consciousness need not be an object in the same sense that a physical existent, such as a fermion, is an object for observation. In obtaining evidence that the predictions of quantum mechanics concerning physical existents are correct, one obtains evidence for the means in quantum mechanics through which information is gained in measurement and theoretical formulations, namely consciousness and human observation. For example, in both the Schrödinger gedankenexperiment and the second gedankenexperiment discussed, the data measured are those concerning physical existents. In manipulating how these data are received, the significance of consciousness in quantum mechanics is demonstrated. Elitzur's failure to see the key role of the act of observation in quantum mechanics led to his not seeing that the probabilities in quantum mechanics are fundamentally concerned with an individual's knowledge of the physical world. Elitzur's not seeing this latter connection led to his failure to realize the significance of the variation of Schrödinger's gedankenexperiment that I presented regarding the influence of consciousness on the physical world.

Conclusion

The version of the Schrödinger cat gedankenexperiment that I proposed provides for a demonstrable effect of consciousness on the physical world. A second gedankenexperiment combining features from experimentally well-established results of quantum mechanics and the results of experiments in psychology was proposed. The second gedankenexperiment discussed also indicates that in quantum mechanics consciousness influences the course of the physical world by showing that simultaneous, mutually exclusive situations can exist. This influence stems from the fundamentally probabilistic character of quantum mechanics. Elitzur looked at consciousness as an object for observation as if it were a physical existent. In doing this, Elitzur missed that the probabilistic predictions of quantum mechanics are concerned with knowledge specific to an individual and that consequently this predictive knowledge and the observation with which it is concerned are conscious.

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