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ESSAY

Consciousness, Causality, and Quantum Physics

DAVID PRATT

Nicolaas Tulpstraat 37, 2563 XK The Hague, The Netherlands

Abstract — Quantum theory is open to different interpretations, and this paper reviews some of the points of contention. The standard interpretation of quantum physics assumes that the quantum world is characterized by absolute indeterminism and that quantum systems exist objectively only when they are being measured or observed. David Bohm's ontological interpretation of quantum theory rejects both these assumptions. Bohm's theory that quantum events are party determined by subtler forces operating at deeper levels of reality ties in with John Eccles' theory that our minds exist outside the material world and interact with our brains at the quantum level. Paranormal phenomena indicate that our minds can communicate with other minds and affect distant physical systems by nonordinary means. Whether such phenomena can be adequately explained in terms of quantum effects and the quantum vacuum or whether they involve super-physical forces and states of matter as yet unknown to science is still an open question, and one which merits further experimental study.

Quantum Uncertainty

Quantum theory is generally regarded as one of the most successful scientific theories ever formulated. But while the mathematical description of the quantum world allows the probabilities of experimental results to be calculated with a high degree of accuracy, there is no consensus on what it means in conceptual terms. Some of the issues involved are explored below.

According to the uncertainty principle, the position and momentum of a subatomic particle cannot be measured simultaneously with an accuracy greater than that set by Planck's constant. This is because in any measurement a particle must interact with at least one photon, or quantum of energy, which acts both like a particle and like a wave, and disturbs it in an unpredictable and uncontrollable manner. An accurate measurement of the position of an orbiting electron by means of a microscope, for example, requires the use of light of short wavelengths, with the result that a large but unpredictable momentum is transferred to the electron. An accurate measurement of the electron's momentum, on the other hand, requires light quanta of very low momentum (and therefore long wavelength), which leads to a large angle of diffraction in the lens and a poor definition of the position.

According to the conventional interpretation of quantum physics, however, not only is it impossible for us to ***measure*** a particle's position and momentum simultaneously with equal precision, a particle ***does not possess*** well-defined properties when it is not interacting with a measuring instrument. Furthermore, the uncertainty principle implies that a particle can never be at rest, but is subject to constant fluctuations even when no measurement is taking place, and these fluctuations are assumed to have no causes at all. In other words, the quantum world is believed to be characterized by absolute indeterminism, intrinsic ambiguity, and irreducible lawlessness. As the late physicist David Bohm (1984, p. 87) put it: "it is assumed that in any particular experiment, the ***precise*** result that will be obtained is ***completely arbitrary*** in the sense that it has no relationship whatever to anything else that exists in the world or that ever has existed."

Bohm (1984, p. 95) took the view that the abandonment of causality had been too hasty: "It is quite possible that while the quantum theory, and with it the indeterminacy principle, are valid to a very high degree of approximation in a certain domain, they both cease to have relevance in new domains below that in which the current theory is applicable. Thus, the conclusion that there is no deeper level of causally determined motion is just a piece of circular reasoning, since it will follow only if we assume beforehand that no such level exists." Most physicists, however, are content to accept the assumption of absolute chance. We shall return to this issue later in connection with free will.

Collapsing the Wave Function

A quantum system is represented mathematically by a wave function, which is derived from Schrodinger's equation. The wave function can be used to calculate the probability of finding a particle at any particular point in space. When a measurement is made, the particle is of course found in only one place, but if the wave function is assumed to provide a ***complete and literal description*** of the state of a quantum system — as it is in the conventional interpretation — it would mean that in between measurements the particle dissolves into a "superposition of probability waves" and is potentially present in many different places at once. Then, when the next measurement is made, this wave packet is supposed to instantaneously "collapse," in some random and mysterious manner, into a localized particle again. This sudden and discontinuous "collapse" violates the Schrodinger equation, and is not further explained in the conventional interpretation.

Since the measuring device that is supposed to collapse a particle's wave function is itself made up of subatomic particles, it seems that its own wave function would have to be collapsed by another measuring device (which might be the eye and brain of a human observer), which would in turn need to be collapsed by a further measuring device, and so on, leading to an infinite regress. In fact, the standard interpretation of quantum theory implies that all the macroscopic objects we see around us exist in an objective, unambiguous state only when they are being measured or observed. Schrodinger devised a famous thought-experiment to expose the absurd implications of this interpretation. A cat is placed in a box containing a radioactive substance, so that there is a fifty-fifty chance of an atom decaying in one hour. If an atom decays, it triggers the release of a poison gas, which kills the cat. After one hour the cat is supposedly both dead and alive (and everything in between) until someone opens the box and instantly collapses its wave function into a dead or alive cat.

Various solutions to the "measurement problem" associated with wave-function collapse have been proposed. Some physicists maintain that the classical or macro-world does not suffer from quantum ambiguity because it can store information and is subject to an "arrow of time," whereas the quantum or micro-world is alleged to be unable to store information and time-reversible (Pagels, 1983). A more extravagant approach is the many-worlds hypothesis, which claims that the universe splits each time a measurement (or measurement-like interaction) takes place, so that all the possibilities represented by the wave function (*e.g.* a dead cat and a living cat) exist objectively but in different universes. Our own consciousness, too, is supposed to be constantly splitting into different selves, which inhabit these proliferating, non-communicating worlds.

Other theorists speculate that it is consciousness that collapses the wave function and thereby creates reality. In this view, a subatomic particle does not assume definite properties when it interacts with a measuring device, but only when the reading of the measuring device is registered in the mind of an observer (which may of course be long after the measurement has taken place). According to the most extreme, anthropocentric version of this theory, only self-conscious beings such as ourselves can collapse wave functions. This means that the whole universe must have existed originally as "potentia" in some transcendental realm of quantum probabilities until self-conscious beings evolved and collapsed themselves and the rest of their branch of reality into the material world, and that objects remain in a state of actuality only so long as they are being observed by humans (Goswami, 1993). Other theorists, however, believe that non-self-conscious entities, including cats and possibly even electrons, may be able to collapse their own wave functions (Herbert, 1993).

The theory of wave-function collapse (or state-vector collapse, as it is sometimes called) raises the question of how the "probability waves" that the wave function is thought to represent can collapse into a particle if they are no more than abstract mathematical constructs. Since the very idea of wave packets spreading out and collapsing is not based on hard experimental evidence but only on a particular interpretation of the wave equation, it is worth taking a look at one of the main alternative interpretations, that of David Bohm and his associates, which provides an intelligible account of what may be taking place at the quantum level.

The Implicate Order

Bohm's ontological interpretation of quantum physics rejects the assumption that the wave function gives the most complete description of reality possible, and thereby avoids the need to introduce the ill-defined and unsatisfactory notion of wave-function collapse (and all the paradoxes that go with it). Instead, it assumes the real existence of particles and fields: particles have a complex inner structure and are always accompanied by a quantum wave field; they are acted upon not only by classical electromagnetic forces but also by a subtler force, the quantum potential, determined by their quantum field, which obeys Schrodinger's equation. (Bohm & Hiley, 1993; Bohm & Peat, 1989; Hiley & Peat, 1991)

The quantum potential carries information from the whole environment and provides direct, nonlocal connections among quantum systems. It guides particles in the same way that radio waves guide a ship on automatic pilot — not by its intensity but by its form. It is extremely sensitive and complex, so that particle trajectories appear chaotic. It corresponds to what Bohm calls the implicate order, which can be thought of as a vast ocean of energy on which the physical, or explicate, world is just a ripple. Bohm points out that the existence of an energy pool of this kind is recognized, but given little consideration, by standard quantum theory, which postulates a universal quantum field — the quantum vacuum or zero-point field — underlying the material world. Very little is known about the quantum vacuum at present, but its energy density is estimated to be an astronomical 10^{108} J/cm^3 (Forward, 1996, pp. 328-37).

In his treatment of quantum field theory, Bohm proposes that the quantum field (the implicate order) is subject to the formative and organizing influence of a super-quantum potential, which expresses the activity of a super-implicate order. The super-quantum potential causes waves to converge and diverge again and again, producing a kind of average particle-like behavior. The apparently separate forms that we see around us are therefore only relatively stable and independent patterns, generated and sustained by a ceaseless underlying movement of enfoldment and unfoldment, with particles constantly dissolving into the implicate order and then re-crystallizing. This process takes place incessantly, and with incredible rapidity, and is not dependent upon a measurement being made.

In Bohm's model, then, the quantum world exists even when it is not being observed and measured. He rejects the positivist view that something that cannot be measured or known precisely cannot be said to exist. In other words, he does not confuse epistemology with ontology, the map with the territory. For Bohm, the probabilities calculated from the wave function indicate the chances of a particle being at different positions regardless of whether a measurement is made, whereas in the conventional interpretation they indicate the chances of a particle ***coming into existence*** at different positions when a measurement is made. The universe is constantly defining itself through its ceaseless interactions — of which measurement is only a particular instance — and absurd situations such as dead-and-alive cats therefore cannot arise.

Thus, although Bohm rejects the view that human consciousness brings quantum systems into existence, and does not believe that our minds normally have a significant effect on the outcome of a measurement (except in the sense that we choose the experimental set-up), his interpretation opens the way for the operation of deeper, subtler, more mind-like levels of reality. He argues that consciousness is rooted deep in the implicate order, and is therefore present to some degree in all material forms. He suggests that there may be an infinite series of implicate orders, each having both a matter aspect and a consciousness aspect: "everything material is also mental and everything mental is also material, but there are many more infinitely subtle levels of matter than we are aware of" (Weber, 1990, p. 151). The concept of the implicate domain could be seen as an extended form of materialism, but, he says, "it could equally well be called idealism, spirit, consciousness. The separation of the two — matter and spirit — is an abstraction. The ground is always one." (Weber, 1990, p. 101)

Mind and Free Will

Quantum indeterminism is clearly open to interpretation: it either means hidden (to us) causes, or a complete absence of causes. The position that some events "just happen" for no reason at all is impossible to prove, for our inability to identify a cause does not necessarily mean that there ***is*** no cause. The notion of absolute chance implies that quantum systems can act absolutely spontaneously, totally isolated from, and uninfluenced by, anything else in the universe. The opposing standpoint is that all systems are continuously participating in an intricate network of causal interactions and interconnections at many different levels. Individual quantum systems certainly behave unpredictably, but if they were not subject to any causal factors whatsoever, it would be difficult to understand why their collective behavior displays statistical regularities.

The position that everything has a cause, or rather many causes, does not necessarily imply that all events, including our own acts and choices, are rigidly predetermined by purely physical processes — a standpoint sometimes called "hard determinism" (Thornton, 1989). The indeterminism at the quantum level provides an opening for creativity and free will. But if this indeterminism is interpreted to mean absolute chance, it would mean that our choices and actions just "pop up" in a totally random and arbitrary way, in which case they could hardly be said to be ***our*** choices and the expression of our own free will. Alternatively, quantum indeterminism could be interpreted as causation from subtler, non-physical levels, so that our acts of free will ***are*** caused — but by our own self-conscious minds. From this point of view — sometimes called "soft determinism" — free will involves active, self-conscious self-determination.

According to orthodox scientific materialism, mental states are identical with brain states; our thoughts and feelings, and our sense of self, are generated by electrochemical activity in the brain. This would mean either that one part of the brain activates another part, which then activates another part, etc., or that a particular region of the brain is activated spontaneously, without any cause, and it is hard to see how either alternative would provide a basis for a conscious self and free will. Francis Crick (1994), for example, who believes that consciousness is basically a pack of neurons, says that the main seat of free will is probably in or near a part of the cerebral cortex known as the anterior cingulate sulcus, but he implies that our feeling of being free is largely, if not entirely, an illusion.

Those who reduce consciousness to a by-product of the brain disagree on the relevance of the quantum-mechanical aspects of neural networks: for example, Francis Crick, the late Roger Sperry (1994), and Daniel Dennett (1991) tend to ignore quantum physics, while Stuart Hameroff (1994) believes that consciousness arises from quantum coherence in microtubules within the brain's neurons. Some researchers see a connection between consciousness and the quantum vacuum: for example, Charles Laughlin (1996) argues that the neural structures that mediate consciousness may interact nonlocally with the vacuum (or quantum sea), while Edgar Mitchell (1996) believes that both matter and consciousness arise out of the energy potential of the vacuum.

Neuroscientist Sir John Eccles dismisses the materialistic standpoint as a "superstition," and advocates dualist interactionism: he argues that there is a mental world in addition to the material world, and that our mind or self acts on the brain (particularly the supplementary motor area of the neocortex) at the quantum level by increasing the probability of the firing of selected neurons (Eccles, 1994; Giroldini, 1991). He contends that the mind is not only non-physical but absolutely non-material and non-substantial. However, if it were not associated with any form of energy-substance whatsoever, it would be a pure abstraction and therefore unable to exert any influence on the physical world. This objection also applies to anti-reductionists who shun the word "dualist" and describe matter and consciousness as complementary or dyadic aspects of reality, yet deny consciousness any energetic or substantial nature, thereby implying that it is fundamentally different from matter and in fact a mere abstraction.

An alternative position is that which is echoed in many mystical and spiritual traditions: that physical matter is just one "octave" in an infinite spectrum of matter-energy, or consciousness-substance, and that just as the physical world is largely organized and coordinated by inner worlds (astral, mental, and spiritual), so the physical body is largely energized and controlled by subtler bodies or energy-fields, including an astral model-body and a mind or soul (see Purucker, 1973). According to this view, nature in general, and all the entities that compose it, are formed and organized mainly from within outwards, from deeper levels of their constitution. This inner guidance is sometimes automatic and passive, giving rise to our automatic bodily functions and habitual and instinctual behavior, and to the regular, law-like operations of nature in general, and sometimes it is active and self-conscious, as in our acts of intention and volition. A physical system subjected to such subtler influences is not so much acted upon from without as ***guided from within.*** As well as influencing our own brains and bodies, our minds also appear to be able to affect other minds and bodies and other physical objects at a distance, as seen in paranormal phenomena.

EPR and ESP

It was David Bohm and one of his supporters, John Bell of CERN, who laid most of the theoretical groundwork for the EPR experiments performed by Alain Aspect in 1982 (the original thought-experiment was proposed by Einstein, Podolsky, and Rosen in 1935). These experiments demonstrated that if two quantum systems interact and then move apart, their behavior is correlated in a way that cannot be explained in terms of signals traveling between them at or slower than the speed of light. This phenomenon is known as nonlocality, and is open to two main interpretations: either it involves unmediated, instantaneous action at a distance, or it involves faster-than-light signaling.

If nonlocal correlations are literally instantaneous, they would effectively be non-causal; if two events occur absolutely simultaneously, "cause" and "effect" would be indistinguishable, and one of the events could not be said to cause the other through the transfer of force or energy, for no such transfer could take place infinitely fast. There would therefore be no causal transmission mechanism to be explained, and any investigations would be confined to the conditions that allow correlated events to occur at different places.

It is interesting to note that light and other electromagnetic effects were also once thought to be transmitted instantaneously, until observational evidence proved otherwise. The hypothesis that nonlocal connections are absolutely instantaneous is impossible to verify, as it would require two perfectly simultaneous measurements, which would demand an infinite degree of accuracy. However, as David Bohm and Basil Hiley (1993, pp. 293-4,347) have pointed out, it could be experimentally falsified. For if nonlocal connections are propagated not at infinite speeds but at speeds greater than that of light through a "quantum ether" — a subquantum domain where current quantum theory and relativity theory break down — then the correlations predicted by quantum theory would vanish if measurements were made in periods shorter than those required for the transmission of quantum connections between particles. Such experiments are beyond the capabilities of present technology but might be possible in the future. If superluminal interactions exist, they would be "nonlocal" only in the sense of non-physical.

Nonlocality has been invoked as an explanation for telepathy and clairvoyance, though some investigators believe that they might involve a deeper level of nonlocality, or what Bohm calls "super-nonlocality" (similar perhaps to Sheldrake's "morphic resonance" (1989)). As already pointed out, if nonlocality is interpreted to mean instantaneous connectedness, it would imply that information could be "received" at a distance at exactly the same moment as it is generated, without undergoing any form of transmission. At most, one could then try to understand the conditions that allow the instant appearance of information.

The alternative position is that information — which is basically a pattern of energy — always takes time to travel from its source to another location, that information is stored at some paraphysical level, and that we can access this information, or exchange information with other minds, if the necessary conditions of "sympathetic resonance" exist. As with EPR, the hypothesis that telepathy is absolutely instantaneous is unprovable, but it might be possible to devise experiments that could falsify it. For if ESP phenomena do involve subtler forms of energy traveling at finite but perhaps superluminal speeds through super-physical realms, it might be possible to detect a delay between transmission and reception, and also some weakening of the effect over very long distances, though it is already evident that any attenuation must be far less than that experienced by electromagnetic energy, which is subject to the inverse-square law.

As for precognition, the third main category of ESP, one possible explanation is that it involves direct, "nonlocal" access to the actual future. Alternatively, it may involve clairvoyant perception of a probable future scenario that is beginning to take shape on the basis of current tendencies and intentions, in accordance with the traditional idea that coming events cast their shadows before them. Bohm says that such foreshadowing takes place "deep in the implicate order" (Talbot, 1992, p. 212) — which some mystical traditions would call the astral or akashic realms.

Psychokinesis and the Unseen World

Micro-psychokinesis involves the influence of consciousness on atomic particles. In certain micro-PK experiments conducted by Helmut Schmidt, groups of subjects were typically able to alter the probabilities of quantum events from 50% to between 51 and 52%, and a few individuals managed over 54% (Broughton, 1991, p. 177). Experiments at the PEAR lab at Princeton University have yielded a smaller shift of 1 part in 10,000 (Jahn & Dunne, 1987). Some researchers have invoked the theory of the collapse of wave functions by consciousness in order to explain such effects. It is argued that in micro-PK, in contrast to ordinary perception, the observing subject helps to specify what the outcome of the collapse of the wave function will be, perhaps by some sort of informational process (Broughton, 1991, pp. 177-81). Eccles follows a similar approach in explaining how our minds act on our own brains. However, the concept of wave-function collapse is not essential to explaining mind-matter interaction. We could equally well adopt the standpoint that subatomic particles are ceaselessly flickering into and out of physical existence, and that the outcome of the process is modifiable by our will — a psychic force.

Macro-PK involves the movement of stable, normally unmoving objects by mental effort. Related phenomena include poltergeist activity, materializations and dematerializations, teleportation, and levitation. Although an impressive amount of evidence for such phenomena has been gathered by investigators over the past one hundred and fifty years (Inglis, 1984, 1992; Milton, 1994), macro-PK is a taboo area, and attracts little interest, despite — or perhaps because of — its potential to overthrow the current materialistic paradigm and revolutionize science. Such phenomena clearly involve far more than altering the probabilistic behavior of atomic particles, and could be regarded as evidence for forces, states of matter, and non-physical living entities currently unknown to science. Confirmation that such things exist would provide a further indication that within the all-embracing unity of nature there is endless diversity.

The possible existence of subtler planes interpenetrating the physical plane is at any rate open to investigation (see Tiller, 1993), and this is more than can be said for the hypothetical extra dimensions postulated by superstring theory, which are said to be curled up in an area a billion-trillion-trillionth of a centimeter across and therefore completely inaccessible, or the hypothetical "baby universes" and "bubble universes" postulated by some cosmologists, which are said to exist in some equally inaccessible "dimension."

The hypothesis of super-physical realms does not seem to be favored by many researchers. Edgar Mitchell (1996), for example, believes that all psychic phenomena involve nonlocal resonance between the brain and the quantum vacuum, and consequent access to holographic, nonlocal information. In his view, this hypothesis could explain not only PK and ESP, but also out-of-body and near-death experiences, visions and apparitions, and evidence usually cited in favor of a reincarnating soul. He admits that this theory is speculative, unvalidated, and may require new physics.

Further experimental studies of consciousness-related phenomena, both normal and paranormal, will hopefully allow the merits of the various contending theories to be tested. Such investigations could deepen our knowledge of the workings of both the quantum realm and our minds, and the relationship between them, and indicate whether the quantum vacuum really is the bottom level of all existence, or whether there are deeper realms of nature waiting to be explored.

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