Quantum Reality and Consciousness - Synopsis

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Here two viewpoints on quantum mechanics are reviewed: (a) it is purely formulas for calculations and predictions vs. (b) the formulas describe the behavior of real physical objects. What makes the latter a challenge to accept is such objects would not fall easily within the common paradigm of materialism – particles moved around by forces as governed by cause and effect. If it is accepted, also including consciousness in the quantum field becomes a relatively small addition that can help build quantum-neurological models of conscious experience.

Quantum reality does not require mathematical reality – the view that mathematical objects (sets, etc.) are real, and theorems are facts about reality. Quantum mechanics, like other wave models, postulates a mathematical object, the wavefunction, whose movements follow a wave equation. The electromagnetic wavefunction, for instance, is regarded as a real object that behaves according to its wave equation. Quantum realists hold that the quantum wavefunction is similarly real. This replaces wave-particle duality – which historically was not viewed as reality, but as two modes of description – sometimes things behave like waves, sometimes like particles. An advance was collapse theory, postulating that quantum wavefunctions become real particles when a measurement is observed. This involves consciousness, which is not part of the quantum system and is not explained. Quantum realists reject collapse theory and as a result have built up skepticism about any discussion of consciousness re quantum matters.

The quantum realist view, per Carroll (2019) is:

- "Atoms aren’t mostly empty space; they are described by wavefunctions that stretch throughout the extent of the atom."
- "Quantum mechanics ultimately unified particles and fields into a single entity, the wavefunction."
- "Quantum reality is a wavefunction."

In classical physics, like electromagnetics, the context determines whether the wavefunction being discussed is a mathematical function or the physical wave, but to be careful here, let’s call the wavefunction the mathematical entity and the wave it describes a “function wave.”
To obey the wave equation, it would have to be a new type of wave – not a force. Function waves are not energy waves and do not work by applying forces, but somehow else, called here “functional influence.” Two highly correlated function waves, perhaps far apart, can both change everywhere instantly from the measurement of one of them. Relativity limits propagation of force waves, but not function waves, to the speed of light. There is no movement of forces and no action at a distance when coherent waves change everywhere when one of them is measured.

Classically, energy waves propagate in force fields, like the electromagnetic (EM) field, which takes values in its state space, a two-dimensional Euclidean space. The pair (e,m) gives the strength of the electric and magnetic components. The state space for wavefunctions in basic quantum mechanics (QM) is a two-dimensional space called the complex plane, with axes labeled real and imaginary. The pair (a,b) is usually written a+bi, where b is the value on the imaginary axis. The EM and QM state spaces are Hilbert spaces – which can be thought of as spaces having a distance function. Quantum field theory has a more complicated Hilbert space. Using alternative state spaces is not a big problem for moving to quantum reality, as state spaces are not regarded as part of the real universe. The big step is accepting the physical reality of function waves that do not carry forces. Like electromagnetic waves, they would exist in our world, and their influences would be observed.

Consider a wavefunction for the location of an electron. At point (x,y,z,t,a+bi), the modulus of the wave, \( \sqrt{a^2 + b^2} \), gives the probability that the electron is at spacetime point (x,y,z,t). If the electron shrinks into a much smaller region through measurement, its resulting location is random but is guided by its probability distribution. This can be verified by repeated measurement of like waves. When working outside of the quantum realm, the probabilities can also be treated as the distribution of the charge and mass of the electron over space-time.

The wave modulus is not affected by positive vs. negative or real vs. imaginary distinctions. E.g., -b + ai would have the same modulus as a + bi. But those distinctions affect the movement of wavefunction according to the Schrödinger wave equation. The probability distributions of mass and charge of electrons is not enough to predict their future behavior. That needs the whole wavefunction in quantum space. There is no Schrödinger force that enforces this behavior – it is functional influence, not cause and effect due to the application of forces.

Electrons in an atom are often portrayed in orbital shells, which are mostly ellipsoids around the nucleus. The electron function waves are standing waves in set
positions throughout the atom. The wavefunction is constrained by the charges of the electrons and protons. With those constraints, the orbitals are surfaces of maximal modulus values. The wavefunction is not zero off those surfaces: some probability is located between them. The atom can be described as having a cloud of electrons, where the density of the cloud is highest on the orbitals.

There is a region near the nucleus where the wave equation makes the probability zero, so nothing is there. That is what prevents electrons from collapsing into the nucleus from electrical attraction. There is no force operating to oppose the attraction – the probability being zero is what keeps atoms from annihilation. Non-causal influence from function waves is critical for maintaining the existence of atoms. That is part of the motivation for considering the waves to be real, physical things.

Another consequence of the wave equation is the Pauli exclusion principle: similar particles cannot be in the same place. This keeps atoms from interpenetrating. There is no Pauli force that carries it out. Thus the hardness of matter is due to functional determinism as well. The world as we know it – solid atoms that do not collapse – is created by functional effects not intermediated by forces.

Specifying the nature of function waves is an open question in quantum realism. They are not mathematical but are not traditionally material either. Mental states as experienced have those characteristics. Postulating a mental aspect for function waves would start to offer a view of what they are like, and would also create research paths for modeling conscious experience in neural networks. This would not be inconsistent with anything in QM and would have practical modeling benefits.

We now know that conscious experience is an emergent property of neural networks. But that does not yet explain what creates the consciousness. Dehaene and Changeux (2011) summarize studies on the Global Neuronal Workspace (GNW) model “according to which conscious access occurs when incoming information is made globally available to multiple brain systems through a network of neurons with long-range axons densely distributed in prefrontal, parieto-temporal, and cingulate cortices.” A signal is greatly amplified “in a cascading manner, quickly leading the whole stimulus-relevant network into a global self-sustained reverberating or ‘ignited’ state.” This is “flexibly shared by many cortical processors.” GNW identifies necessary and sufficient conditions for conscious experience, as indicated by subjects’ reports. Massively parallel replication of a signal holistically across multiple brain regions could amplify whatever conscious potential the signal contains, elevating it above lower-level background static. The cortices mentioned combine sensory processing with other higher-order mental processing.
But knowing that experience is emergent is not enough to specify how it comes about. Emergent properties arise from behavior of components. E.g., the group behavior of bird flocks, which can move like single entities, comes from two individual-bird traits: a strong tendency to follow others and a weak tendency to deviate. When a bird deviates, it is often not followed, but when it is, the whole flock can turn. Such an explanatory mechanism has not been found for emergence of experience in neural networks. The pieces all work together and seem to produce conscious experience, but how they manage to do that is not explained. An implementing ingredient is missing. Research is planned to find out more detail about types of neurons, their roles, and connections, but that is not enough to find such an explanatory mechanism. Quantum-neurology incorporating wavefunctions that produce consciousness is a possible way to model the needed mechanism.

Fisher (2015) identifies a phosphorus molecule that can maintain quantum qubits for a fairly long time within living systems. If they last long enough, the brain could act like a huge quantum computer. Player and Hore (2018) detail reasons why these qubits can last just a few seconds, which isn’t enough for Fisher’s goals. Still, it is long enough for GNW brain events. Fisher (2016) notes that he began looking for neural quantum effects when he learned that two chemically virtually identical isotopes of lithium differing in quantum coherence duration affect murine behavior differently.

The physical nature of the quantum field is unknown. The modulus gives the probabilities, but the individual influences of real, imaginary, positive, and negative components are unspecified. There is a lot happening in the quantum wavefunctions that does not show up in the probabilities. Some function other than the modulus could be a measure of awareness levels and serve as an input feature for neuronal processes. Pure awareness could be an aspect of the quantum field but would not necessarily entail a subject of experience: the logic of “x Experiences ⇒ x Exists” has been challenged. E.g., Strawson (1967) holds that that expression is not well-formed as existence is not a predicate.

A simpler measure than the modulus could be that |b| indicates the level of awareness, i.e, consciousness is imaginary. That’s one of many possible quantifications. Pradhan (2012) suggests that consciousness is measured by the complex conjugate of the wave value, a – bi.

It is reasonable for people to hold that the laws of quantum mechanics are purely descriptive, as processes that are not the causal action of forces are too radically different to accept as physical reality. Yet wavefunctions have such key roles in the existence and behavior of the physical universe that they are compellingly at least
as real as anything else. Quantum computing knows how to manipulate wavefunctions and make them work for us. In the famous two-slit experiment, an electron wave interferes with itself. If they are not real, then how could anything made from them – atoms, molecules, etc. – be real?

The nature of function waves is unknown but is not traditionally material. If they are considered real, it would not be a major further step to take them as incorporating consciousness. The advantage is that would open up avenues for quantum-neurological modeling of conscious experience within physics. Having something other than the modulus as the quantification of awareness levels in the quantum field would not change the predictions of QM about the material world. It would leave both consciousness and the material world determined by the quantum field in an intertwined manner, but not affecting each other causally.

References


