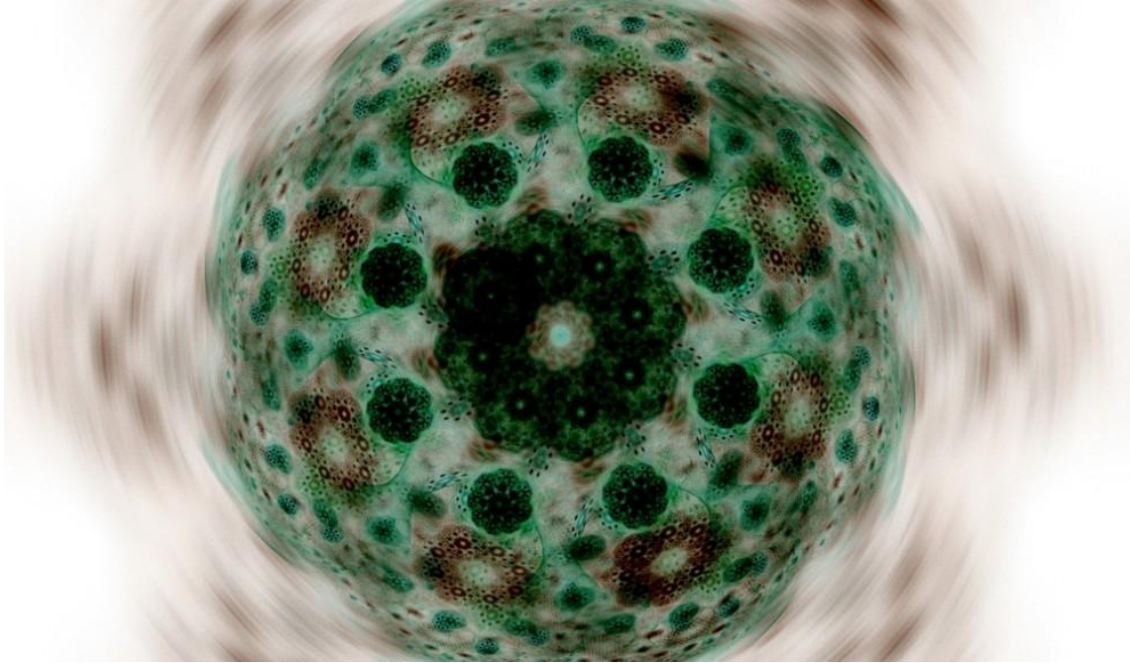

What Does Quantum Mechanics Suggest About Our Perceptions of Reality?



Quantum mechanics suggests that we perceive at most a tiny sliver of reality. Of course we already knew that! We knew that the visible spectrum is only a small part of the spectrum of electromagnetic radiation. We knew that the universe is much, much larger than our ancestors believed. And we already knew that we are made of things that are too small for our eyes to see. So how is it news that we only perceive a tiny sliver of reality?

It's news because quantum mechanics says that the part of reality that we do *not* perceive is radically different than the part of the world that we do perceive. The difference is so profound that we still don't fully understand how to talk about quantum reality. There doesn't seem to be any direct analogy between quantum reality and the reality we perceive with our senses.

Before I explain the gap between our perceptions and reality, I want to state that I completely disagree with the idea that quantum mechanics forces us to accept an idealist view of reality. Idealism says that the physical universe is made out of our perceptions – in other words, out of spiritual reality. Several early interpreters of quantum mechanics thought that it supported

this idealistic understanding of reality. Why would they have thought this? The reason, quite simply, is that they didn't know how to cope with the issue of quantum indeterminacy.

Quantum indeterminacy is the unavoidable fact that not all quantities can simultaneously have determinate values. For example, if an electron has a location, then it simply has no speed – it is neither at rest, nor is it moving slowly, nor is it moving quickly. There simply is no fact of the matter about its state of motion. Similarly, if an electron is in a definite state of motion, then it's not in any particular place – not here, nor there, nor anywhere.

Let's be completely clear about what we're saying here. We are not just saying that if you know the position of the electron, then you don't know whether or not it's moving. We're saying that if the electron *has* some position, then it does *not* have any state of motion. What could this possibly mean? Nobody is quite sure.

But the story gets more interesting. Whenever a conscious observer tries to determine the position of the electron, she will always find that it does indeed have a position. Similarly, whenever a conscious observer tries to determine the state of motion of an electron, she will always find that it does indeed have some particular state of motion. If these facts weren't true, then we wouldn't be able to test the predictions of quantum mechanics! So how are we to reconcile the fact that sometimes the electron doesn't have a position with the fact that, whenever we look, it does have a position?

Some quantum pioneers, such as Heisenberg and Wigner, thought that the act of "looking" caused the electron to take on a definite state of motion, or a definite position. And then it wasn't much of a further leap for them to suggest that, before anybody looks, there wasn't any electron. If that were the case, then physical reality is brought into existence by our acts of perception.

But the path from quantum indeterminacy to subjective idealism involves several illogical leaps. First of all, why think that before a measurement occurs, *no* quantities possess values? Whilesome quantities must lack values, it was proven by Jeff Bub and Rob Clifton that many quantities can possess values even when nobody is looking.

Perhaps the reason Heisenberg and others fell into idealism is that they just couldn't see any reason why some quantities would have values while others wouldn't. Why would an electron have a state of motion, but not have a position? Perhaps they felt like Buridan's ass, who starved because he couldn't see any reason to prefer one pile of straw to another identical pile.

I grant that there's a puzzle here that needs to be solved — how can we figure out which quantities have determinate values? Several people have tried to solve this puzzle. For example, according to an idea of Louis de Broglie, which was later developed by David Bohm, reality is made out of small corpuscles that always have completely determinate positions. But why treat particle configurations as special? One reason for thinking that particle configurations are always determinate is our eyes seem to tell us that this is the case! Another good reason for thinking that particle configurations are determinate is that it's possible to describe how they move in terms of elegant dynamical laws. Thus, the possibility of Bohmian mechanics shows that subjective idealism is by no means forced on us by quantum mechanics.

Be that as it may, Bohmian mechanics does *not* suggest that our perceptions mirror the nature of fundamental reality. For Bohmian mechanics also postulates the existence of a hidden field that guides the particle configurations – and this field is so mysterious that Einstein rejected it as an explanation of quantum reality. So Bohmian mechanics might be a *realist* interpretation of quantum mechanics, but it doesn't license a return to *naive* realism. If Bohmian mechanics is true, then the physical world radically different from our perceptions of it.

There are other interpretations of quantum mechanics that describe a deep reality that is hidden from our perception. Two of the most plausible, but also most wild, suggestions are the configuration space interpretation of quantum mechanics, and the Everett interpretation of quantum mechanics.

According to the configuration space interpretation of quantum mechanics, the world of our perception is just a projection of an incredibly high dimensional configuration space. Again,

this interpretation of quantum mechanics is realist in that the space of all configurations has its existence and properties quite independent from our observations. But once again, this configuration space is perceptually inaccessible to us — we can only see the effects it has within our much smaller three-dimensional space. The upshot, as before, is that if you really believe quantum mechanics, then you believe that the physical world outruns our perceptions of it.

Another popular way to think of quantum mechanics is in terms of the Everett, or “many worlds,” interpretation of the theory. In this case, the configuration space doesn’t cause any ontological headaches; however, the wave function of the universe must be taken to be a real thing. But now we have some real work to do in explaining why human experience portrays the world in a very different light, i.e. as something that looks to have determinate properties, when in fact it doesn’t.

But what could we possibly mean by this? How could something without determinate properties explain the appearance of determinate properties? Well, good Everettians would say that the wave function *does* have properties — just not those properties that appear in our observation reports (e.g. “the particle is in position ”). But what properties does the wave function have? According to a famous proponent of the Everett interpretation,

Every mathematical property of the wave function describes, or corresponds to, some property of the real, physical world.

This is an intriguing idea. But what exactly are the mathematical properties of the wave function? As a mathematical object, a wave function is a function; and a function is a certain sort of set of ordered pairs. What kinds of properties can a set of ordered pairs have? Well, it might contain the pair consisting of the emptyset and the number 17. But what physical property corresponds to that mathematical property? What if it didn’t contain that pair, but instead contained the pair consisting of a singleton set and the number 17. What would the corresponding difference be in the physical world? As you can see, these are fruitless

questions. It's a bad idea to say that the wave function represents a thing whose properties are in one-to-one correspondence with that function's mathematical properties.

Realists about quantum mechanics – such as Bohm and Everett – say the wave function is “real”; and I think that's a good thing to say. But let's be careful. To call the wave function a “thing” is to commit a basic grammatical error: a state is not a thing, but a *way of being*. A wave function is more like a “situation” or a “possible world,” not a thing you can touch or pick up. Sure, we could say that situations and possible worlds “exist,” but they're of a different kind than “things.” Situations aren't the fundamental bearers of properties — instead, a situation is composed of things bearing properties. Thus, we can grant that the wave function is real while denying that it is a thing; and if this is right, then it's a mistake to think that the wave function has properties.

Another important point to keep in mind is that perception cannot possibly reveal the wave function. The impossibility here follows from the “no cloning theorem” of quantum mechanics. According to the no cloning theorem, no physical object whatsoever can reliably track (by changing its state) the quantum state of another object. In other words, the laws of nature *do not* allow for the existence of a machine that copies quantum states; consequently, the human brain cannot possibly track the wave function of a physical object. So, if reality is the wave function, then we simply cannot perceive reality as it is in itself.

Where does that leave us? The remarkable thing is that we can still reliably track *aspects* of reality. Whatever quantity you want to measure — be it position, momentum, or spin — if you measure it twice, within a short span of time, you will find that it has the same value. Thus, we have good reason to think that our measurements provide reliable information about reality. This sort of reliability is good enough to guide our actions, and it provides strong evidence of the hidden reality behind our perceptions.

Discussion questions

1. How does quantum mechanics bear on the age-old philosophical debate between materialism and idealism? Does it tip the scale in either direction?
2. Which view of quantum reality is most plausible? The Bohmian view? The Everett view?

3. Is the quantum wave function real? What does it mean to say that it's real?
4. The author argued that the quantum wave function is not a thing. But then what does exist according to quantum mechanics?
5. Does the no-cloning theorem support a form of perspectivalism, i.e. that our knowledge of the world is always bound to a particular perspective, and cannot encompass all aspects of reality?

Discussion Summary

In the **original piece**, I claimed that there is a gap between reality in itself (at least reality at the fundamental physical level) and the reality that we perceive. I also claimed that the most elusive component of the microworld is the quantum wavefunction, which is “real,” but is not (I claimed) a “thing”. Finally, I pointed out that, due to the no-cloning theorem, human beings cannot know the quantum wavefunction of an object.

It seems that the commentators agreed mostly with the major claim that there is a large gap between reality as perceived by us, and reality in itself. There was also substantial agreement on the fact that there our perceptions do not create reality. Our discussion then revolved mostly around the question: how are we to understand the quantum wavefunction? In order to understand it, would we need to describe it in traditional metaphysical categories, such as substance and property? Or can we do no better than to represent it by means of the formalism of quantum mechanics?

Unsurprisingly, we were unable to provide definitive answers to these questions. Indeed, they are some of the most difficult questions in the interpretation of quantum mechanics. We did, nonetheless, make some progress on the question of whether or not the wavefunction is a “thing.” In the original piece, I said that it is a “grammatical confusion” to consider the wavefunction to be a thing. Eddy Chen, in his comment, challenged me on this point — and suggested that there are more liberal accounts of ontology where properties (for example) also count as things.

I concede this point to Chen — we could, for example, say that properties (e.g. “whiteness” or “yellowness”) are also things. But should we then allow that properties themselves have properties? For example, should we say that the property of whiteness has the property of being a color, or perhaps the property of being a property? (But beware of falling into logical paradox here! Does the property of whiteness have the property of whiteness?) The reason this question is important is because we want to understand whether the wavefunction itself is a physical object with properties, or whether it’s just a property of other things.

Chen argued that the really interesting question here is where to locate the wavefunction in our ontological framework. Is it merely a summary of particle configurations? Is it like a law of nature? Or is it a physical field? And if it’s a physical field, on which space is it defined — on n -dimensional physical space, or on some higher dimensional configuration space?

Although much of the discussion focused on the nature of the wavefunction, there was also a lively discussion, initiated by Roger Sawtelle, about whether the laws of quantum mechanics apply to the entire physical world, or just the microworld. These days, the default assumption among physicists and philosophers of physics is that the macroscopic world *does* obey the laws of quantum mechanics; but somehow the measurement process and/or decoherence gives rise to the appearance that the macro-world obeys the laws of classical physics. Of course, this assumption has yet to receive strong confirmation from within physics itself. Perhaps in the coming years, experiments — such as tests of the violation of the Leggett-Garg inequality — will provide more information about the relationship between the physics of the macro- and microworlds.

Further Big Questions:

1. What is the relationship between the micro- and macro-world? Are the laws of the micro-world adequate to describe all occurrences in the macro-world?
2. How can experiments be used to probe quantum reality? Can quantum-mechanical experiments provide information about the correct interpretation of quantum mechanics, and about the relationship between quantum mechanics and the macroworld?

3. Does the quantum wavefunction exist? Does anything else besides the quantum wavefunction exist?