Running head: Non/understanding QM

Quantum Mechanics:

To Understand or Not Understand; that is the Superposition

Seth T. Miller

Abstract

This essay explores the relationship between everyday experience and quantum mechanics. Does an understanding of quantum mechanical principles have an effect on an average person's life? Do we even understand quantum mechanics, and if so, does such an understanding change our lived epistemology? Or must our epistemology be forever locked to the scale of experiences that occupy our normal experiences of the world? Both sides of the issue are explored.

Quantum Mechanics:

To Understand or Not Understand; that is the Superposition

About 100 years ago the birth of quantum theory changed forever how humans perceive the universe… sort of. Certainly “quantum physics” is a phrase found far outside the boundaries of physics classrooms, and has even achieved a fairly wide popularity through movies such as *What the Bleep* and works like Fritjof Capra’s *Tao of Physics*. Does this mean, for the average person who has at least been introduced to some basic ideas from quantum mechanics, that reality will never be the same? Or do ideas from quantum mechanics (QM) remain something of a curiosity—fascinating and mind-boggling but so far removed from ‘normal’ everyday experience as to be essentially irrelevant?

Take a moment and ponder this question for yourself. Can you remember how you were affected when you first heard of electron tunneling, the EPR paradox, entanglement, the uncertainty principle, or more likely, Schrodinger’s cat? Did your view of the world change? A more relevant question might be: how do you know? Perhaps the next time you looked at the shimmer of a butterfly’s wings or the more prosaic spectrum reflected off a thin layer of oil on pavement you gave an intellectual nod to the underlying quantum mechanical principles which give rise to these phenomena… and then went on about your day just like it was 1904 (the year before Einstein’s four seminal papers revolutionized the world of physics—many other worlds are still playing catch up).

Now, quantum mechanics is, without a doubt, one of the *best* theories ever produced by human minds. The *effects* of QM are likewise undeniable in their scope, and have reached every corner of the Earth, influencing the course of the 20th century *immeasurably*, mostly through the various technologies it has made possible (from computers and just about everything electronic—transistors, anyone?—to advances in medicine, communications, manufacturing, and more). But the problem here is that relatively only a very few individuals need to *understand* principles of QM for all of this to be possible, while the rest of us can simply make or use the resulting technologies *without ever changing our epistemology*. My cell phone works just fine whether I understand how it works, just as I can see my computer screen perfectly well, even though if I wish to understand how this is possible, a number of quantum principles are required. Heck, even the scientists who understand and apply the principles of QM in new and ingenious ways aren't *required* to change their epistemology—the fundamental assumptions upon which their knowledge and actions are based—they can simply *use the principles logically* to predict future experiments.

But this leads us to an interesting point—aptly made by one of the greatest physicists of all time, Richard Feynman, who said: "I think I can safely say that nobody understands quantum mechanics" (Feynman, 1965). Now if someone *who has won the Nobel Prize in physics* for developing quantum electrodynamics doesn't understand his own field, what hope do we have that its principles can precipitate an epistemological shift *at all*, let alone do so for your average person? Let's take a look at why Feynman can say something like this—and mean it—because this will help throw some light on the issue.

Part 1: Why we don't understand quantum mechanics

Rather than being facetious, Feynman is attempting to point out a subtle but important issue that arises when we try to understanding QM: the way the world works on a quantum scale is *nothing like* how it appears to us on an everyday scale. The entirety of our daily experience occurs in ways that belie the existence of the laws operative at the quantum level. In other words, we don't experience the principles of quantum mechanics at work in any *direct* way, nor *can we*, because all our sensory and conceptual tools have evolved to deal with the vastly larger scale on which human experience plays out (although this very point is increasingly in debate).

Humans seem to *experientially* occupy a meso-scale realm between the quantum and the relativistic. We are the peanut butter and jelly sandwiched between two infinite slices of bread: one infinitely large, the other infinitely small. Yet our uncanny ability to think logically (and therefore mathematically) has led us to formulate theories of these other realms which are not otherwise accessible to our thinking. This is to say that the closest we can get to *really understanding* the quantum (or alternatively, relativistic) scales of the universe is by virtue of the logic of the maths that describe such scales.

Humans don't do so well when we are forced to understand something *solely* in terms of its logical relations; we want, and perhaps *need* something more visceral in the experience of understanding, something we can *relate to.* But this is just the problem: as soon as we try to think about *what it is like* for the universe to have the strange relations that the mathematics of QM implies, our thoughts simply *fail* its principles; we can't do them justice through the *way we normally experience the world*.

"What it is like" is a question that has embedded within it a particular kind of epistemology—one thoroughly embedded within and adapted to the 'normal' scale of human experience. As soon as we attempt to step outside the formal logical relations embodied in the mathematics in order to translate or *understand* what the relations *really mean* or signify for our experience of the universe, we necessarily dispose of (at least some of) the very elements we are trying to keep intact. Quantum 'weirdness' is *quantum* weirdness; translating it into terms, images, or metaphors that can be understood by your average person (although, if Feynman is right, *it doesn't matter at all* who you are) makes the quantum weirdness into *normal* weirdness, capable of being dealt with through all the normal epistemological modes we have been using to deal with the 'normal', Newtonian scale of things.

Feynman's unequivocal statement is a stark wake-up call: we can manipulate the mathematical symbols in accordance with the rules which allow us to properly predict the results of experiments (no test of QM has ever failed to uphold these rules… yet), but we simply are not built in such a way as to be able to *understand* what these rules *mean*, because questions of meaning necessarily fall within the scale of experiences that are *actually available to human consciousness*. In other words, you can't imagine the impossible, because if you can it has already been subjected to the rules and limitations embedded in the epistemology underlying your imagination (regardless of whether these have any reality outside your imagination). Only the unimagined is truly impossible, lying outside the realm of consciousness altogether.

Okay, fine. We don't understand the meaning of quantum mechanics *in situ*; we can simply calculate results of quantum-scale experiments and use them to our benefit, and that's the end of the story… or is it?

Part 2: Why we do understand quantum mechanics

The "Copenhagen" interpretation of QM, spearheaded by Niels Bohr, invites us to make statements about 'reality' *only* when an actual experiment has been performed, and then we are only allowed to say what occurred as a result of the experiment. This is because questions about the universe that are not *actually* answered experimentally are meaningless questions (this has been characterized as the "shut up and calculate" approach by David Mermin). Why? Because reality *is something* only by virtue of the particular questions we ask of it; i.e. the experiments we perform. Outside the context of such experiments, we must simply be silent, because the answer to a question *depends* on how you ask it. Ask it one way, you get one answer; ask it another way, you get a completely different answer.

Now, human as he was, Bohr couldn't help but extrapolate this view into a full-fledged principle called *complementarity*. This principle states that the universe can exhibit multiple, seemingly contradictory manifestations, but not simultaneously. Actual experiments determine whether reality will be one way or the other. Unfortunately for Bohr, making this statement violates the very principle he is attempting to uphold: he is making a *generalization* about how the universe *really operates*, but doing so *without an actual experiment*. Indeed, the principle of complementarity itself, by its own formulation, *cannot* come from experiment, but must be an *interpretation* of at least two experiments whose results are contradictory. This is to say that Bohr, and those who insist that physics doesn't deal with ontological questions ("Shhhh! Back to your calculators!"), are simply deluding themselves. This is okay, because it also simply means that such people are human after all.

So Bohr, the foremost champion of keeping our thinking and language clean with respect to attempts at 'interpreting' QM nevertheless does so himself. He extrapolates from the mathematics and arrives at a principle, strange as it may be to 'normal' experience, that is at least *understandable* there: how I approach the world plays a not insignificant role in how the world appears to me.

But here we are presented with the complementary side to the coin presented in part 1: the possibility that we *can* approach the world in such a way as to draw out aspects of the world *which would otherwise be unavailable to us*. Specifically, maybe it is possible that the realm of quantum mechanics can be approached not *solely* mathematically, but in other ways as well—perhaps in ways that allow us to experience it more directly than at first seems possible. Approaching it in such a way *reveals something different* than would be the case if one stuck fervently to the pure logical formulations of the underlying principles, but this does not *necessarily* mean that the resulting understanding is simply "wrong" or irrelevant.

There is room for hope here, on at least two fronts. The first front has roots in what is known as "the measurement problem" in quantum physics. The rules of QM have no *implicit* scale of operation: the laws can apply to systems of *any* size (although we can only do approximations for even the smallest systems because of the infinite complexity involved: for example, calculating the influences on a single electron would ultimately require taking into account *every other electron in the universe*; this would make one very late for dinner). In other words, there does not seem to be in the rules of QM itself any place where, when looking at a system of just slightly larger size, it apologetically shrugs at the experimenter and says "Sorry, chap, I get real tired at scales over a few nanometers; can't you just use Newton's stuff from here on up?" No, if there are any limitations, they seem to be ours; *we* give up long before the math does.

Given this situation, the previous argument that we don't experience things on a quantum scale and thus can never really understand QM may have a tiny loophole: presumably *the whole world operates by the principles of quantum mechanics, including sensory and conceptual tools we use to experience the world.* Now, granted, this is an arguable point: it may be that there is no *inherent* connection between the underlying quantum mechanical rules on which our thinking processes are based and our ability to understand those rules. Perhaps the ability to think about QM is an *emergent* property that, while relying for its very existence on quantum mechanical processes, is far enough removed from them as to completely miss them when they pass by on the street.

This may not be as big a problem as it first appears, however. ALL thinking is removed from its foundations, considered physically. Nevertheless, we have evolved to a point where we *can* understand quite a lot about these very foundations, an understanding owed to an advancement in thinking and to an extension of perception. To say that our experience is somehow *ultimately* limited to a very particular scale (between a tiny speck of dust and the distant horizon, between a fraction of a second and many years) because these scales are the only ones *directly* amenable to experience is likely to be simply wrong.

Human ingenuity has provided us with tools that extend both our conceptual capacities (QM not the least among these), as well as our sensual capacities (both through application of technologies as well as through the ability to *self-transform*—more about this in a minute). It is the *combination* of conceptual and perceptual capacities that gives us hope in regards to our ability to understand, in a non-trivialized way, the principles of quantum mechanics.

When I first had a chance to look through a good telescope at the planet Saturn, I was struck by how much it looked… exactly like someone cut out a tiny picture of the planet from an astronomy book and pasted it at the end of the telescope. It was an odd experience: to see something in person for the first time that looked *so much like itself* that it seemed *fake*; it was just too *real* to be, well, *real*. Now, if I didn't know that Saturn was *millions and millions* of miles away, I would have 'trusted my senses' which were telling me that the image was a tiny cutout about four feet away from my eyeball. This would be a case of my thinking becoming subject to my perception. But because I *did* have prior concepts about Saturn, in this case my *thinking* modified my *perception*, so that ultimately the combination of the two (where knowing takes place) allowed me to have a much more accurate *visual* sense of its true distance and size.

The point is that *both* thinking and perception are *fluid and malleable*; they mutually modify each other to create a space in which *new knowing* can happen that otherwise would be inaccessible, as was probably the situation in the famous (and at least partly apocryphal[1]) case of those who looked through Galileo's telescope without 'seeing' the moons of Jupiter.

This, then, is the second front of attack: we human beings are capable of real and radical change and evolution, both in our thinking and in our perception. The ideas of quantum mechanics have been around only for a century, an insignificantly tiny portion of the span of human development as a whole. Yet even in that time our understanding has advanced considerably, and not just through "sheer logical manipulation". It takes human *creativity* to suggest places that look promising for exploration in the quantum tunnels (if you'll forgive the pun). Physicists even speak of a sort of quasi-magical 'intuition' that is both innate and *capable of being developed* which suggests how to think about things in new ways that lead to interesting insights, experiments, and theories. Feynman was something of a master at this.

Inconclusion

Now let's put this all together, or at least overlap things a bit. Humans seem primed by instinct to deal with Newtonian scale events, which occupy the vast bulk of our lives. But we are also primed with the capacity to *change our capacities* through a variety of means, both externally and internally. We have been thinking about thinking for at least two or three millennia, and have arguably made considerable progress with how we understand our

---

[1] http://bedejournal.blogspot.com/2006/11/who-refused-to-look-through-galileos.html

understanding. That techniques for modifying understanding (esoteric technologies, we could call them) can produce experiences that lie *far* outside normal scales of everyday life seems to give testament to the human ability of overcoming our 'built-in' limitations. Perhaps the numerous accounts of trans-personal experiences (among which experiences of the infinitely large and the infinitely small in both space and time are not the least important) are possible precisely *because* of QM? Maybe these types of experiences could even be considered just as 'direct' in regards to the quantum mechanical realm as an experience of throwing a baseball is with regards to the Newtonian realm?

We have also extended our outer sensory capacities through various technological means, which has opened up whole new worlds to experience. With corresponding changes in our conceptual abilities, human beings seem capable of moving past the Newtonian scales that otherwise bind our experience. As an example, even if we personally have never seen them, we can easily imagine a whole realm of germs, parasites, and viruses that cannot be seen with the naked eye, and what's more, *we actually live our lives* with this realm partly in mind.

It doesn't seem like we have evolved to *understand* QM, even if we have evolved *with* and even *because of* QM, at least in part. But sewn into the very fabric of this tapestry is the thread of its own unraveling: evolution isn't over, and may indeed be speeding up and changing course in ways we have barely begun to imagine. It seems much too hasty to declare that our *present* inability to directly understand the science of QM will remain true for even the relatively close future.

The whole history of humanity shows us, over and over again, how human understanding has changed and adapted with the types of sensations, environments, and capacities that are both unconsciously encountered and consciously developed. Quantum mechanics is so recent we have barely (collectively, that is) sat down next to it at the bar, let alone asked it out in a date. How could we be expected to know what it would be like if we moved in together, not to mention that out of the corner of our eye we keep seeing sexy string theory (or mysterious M-theory) throwing meaningful glances our way? Perhaps Feynman would agree with the uncertainty (and thus openness) of our future; his statement was in the present tense, after all.

Human epistemologies are adaptive and flexible. They are also capable of reorganization on the basis of intent, at least to some extent. It may be that the appearance of present limits to understanding are temporary, or at least amenable to shifts. New ways of experiencing the universe, both conceptually and perceptually, provide the opportunity to explore new modes of knowing, which do not necessarily retain the limits imposed upon us by our innate biology. Our biology, in a sense, can be extended; our consciousness can be extended as well. Some curious fellows seem to have been exploring this kind of extension for thousands of years, but the rise of technological methods for extending perceptual capacities (and the corresponding conceptual advances) have created a completely new situation in this respect with regards to experiences available to the average person.

The extent to which humans can embody and enact new epistemologies on the basis of changing perceptual and cognitive resources is unknown. But it does seem that a dynamic set of possibilities lies between the two extremes, allowing at least a partial ability by which humans create situations that lead to significant changes in the way we conceptualize and interact with the world. Quantum mechanics may very well contribute to such a shifting. The situation, like a quantum wave-function, is continuing to evolve through a vast array of superpositions. Maybe once we get to first base the wave-function will collapse and we'll have a picture of where the relationship is headed; for now, though, it looks like we're still flirting at the bar.

References

Feynman, R. P. (1965). *The character of physical law*. Cambridge,: M.I.T. Press.