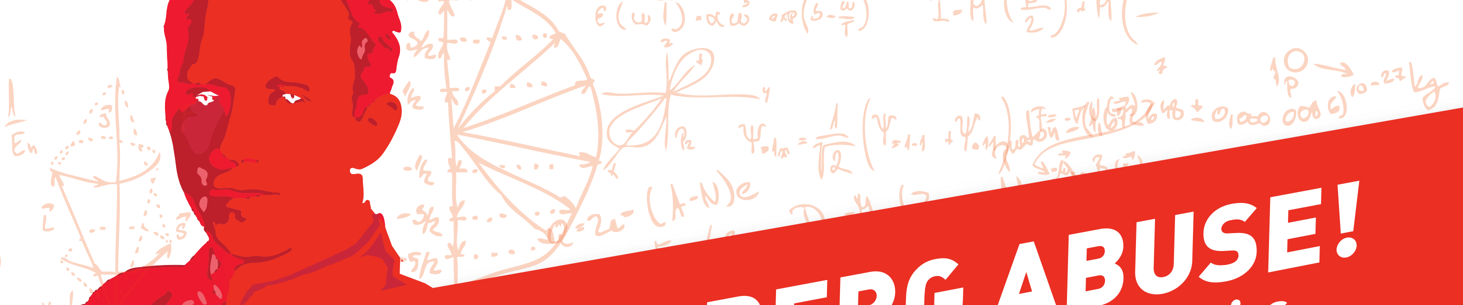

# STOP HEISENBERG ABUSE!

## Three Outrageous Misappropriations of Quantum Physics

**Parapsychologists, academics, and religious figures are all guilty of misusing the ideas of quantum mechanics to bolster their own thoughts. How did these distortions become so popular, and how can we make the public more aware of the rigorous but exciting science underneath?**

DALE DEBAKCSY

We have been living in a quantum world for over a century now, and in that time quantum mechanics has grown from a field hesitantly understood by a handful of men into a full-fledged intellectual industry. Unfortunately, where ubiquity treads, misrepresentation soon follows, and no branch of science this side of evolutionary theory has suffered more distortion from popularization than quantum theory. Trendy parapsychologists, academic relativists, and even the Dalai Lama have all taken their turn at robbing modern physics of a few well-sounding phrases and stretching them far beyond their original scope in order to add scientific weight to various pet theories.

It's time to set the record straight on the most egregious of these abuses, a task rendered more difficult by those well-meaning physics writers who try to make quantum mechanics sexier for the casual reader. As a physics teacher myself, I've been guilty of this more than once in the classroom. "Quantum physics is, like, anarchy, man. No rules! Down with Newton!" pretty well sums up the trend. But this puts the kaboom in the wrong place—quantum mechanics is revolutionary and exciting and breathtaking, but only after a lot of painstaking mathematics has been worked through, and a lot of rules followed. It's in the disregarding of those rules that miscarriages like the following three Big Lies come into being.

## 01 LIE ONE:

"Quantum physics says that mind determines reality, and therefore that Buddhism is right."

### The Argument:

Take an electron and put it in the center of a box. Now replicate that set up a hundred times. If you were to perform a position measurement on the particle after one second in each box, what you would most likely get is a hundred different results. Not because the particle is randomly veering about like a little billiard ball but because the act of measurement imposes a position upon what was previously a complex object of indeterminate location. The measurement created the position. And so, because observation changed the nature of the system, reality is fundamentally a construct of observation, and our minds, which we use to observe the world, are thus the creators of reality. As such, our true minds must not be part of physical reality themselves but rather must be objects in a higher realm of existence, a realization that drags with it the whole corpus of Buddhist principles.

### Why It's Wrong:

Oh so many reasons. The cardinal sin, however, is that of conflating well-defined scientific terms with loosely understood popular ones. So, "measurement" becomes "observation" becomes "thought" becomes "mind" in a chain of ever-decaying precision that admits a correspondingly ever-widening array of wishful thinking to be passed off as science.

This is what we know: If you give me a particle and describe its environment carefully, I can craft a mathematical object, called a wave function, for you. By manipulating it, you can tell how likely it will be for a certain measurement to yield a certain result. If you make a position measurement, the wave function can be used to tell you the probability of finding your particle at, say, location x=4 at time t=3.

What a measurement does is collapse the often ludicrously complicated wave pattern of a particle to a spike centered on one of the possible values allowed by the wave function. So, your measurement can't result in just *any* answer. It's like having a hundred pieces of paper, each with an even number on it, dropped into a hat. When you reach in, you're going to pick out an even number. No matter how hard you think about it, you'll never pull out an odd, and you will never be one hundred percent sure what the next number you are going to pull will be (unless they're all the same number, in which case you're sort of extraneous to the whole process, aren't you?).

A measurement just spins a weighted wheel of predetermined allowed values, and spits out one of them. For the experimenter, the experience is more akin to reading a ticker-tape produced by a deranged monkey typist than "willfully creating reality."

But that's not the worst of it, because the argument totally ignores the rather titanic issue of scale. Put simply, quantum effects stop being observable when the particles involved rise above a certain size. It's actually a fun calculation, and one of the few in quantum mechanics you can do without a couple years' worth of calculus, differential equations, and linear algebra in your hip pocket. Quantum effects are typically observed when a particle's wavelength is bigger than the size of the system the particle lives in. Temperature also plays a role; the colder it is, the more quantum effects tend to be relevant. This is all wrapped up in the formula

$$\lambda = \frac{h}{\sqrt{3mk_B T}}$$

where λ is the particle's wavelength, h is Planck's constant, $k_B$ is Boltzmann's constant, m is the mass of your particle, and T is the temperature of the system. For an electron, zooming around a bar of aluminum, the size of the system is about $4.05 \times 10^{-10}$ meters (the distance between aluminum atoms). At a room temperature of 298 Kelvins, we get $\lambda = 6.25 \times 10^{-9}$ meters for the electron, and so indeed, electrons behave in a "quantum" manner under normal circumstances, and therefore our measurements will collapse their observable quantities down in a way consistent with the wave equation's probabilistic predictions.

However, for one of the aluminum nuclei in this system, with a mass millions of times greater than that of the electron, quantum effects don't manifest until the temperature drops to .001 K, i.e., a thousandth of a Kelvin above *absolute zero*. Experiments like this are being done (See, for example: http://www.nature.com/nnano/journal/v7/n5/full/nnano.2012.34.html), using lasers to drop the energy, and therefore temperature, of particles down to the level where quantum effects are observable even on the molecular level. However, when it comes to day-to-day, dude-in-his-room-meditating existence, we're really talking only about particles around the mass of an electron exhibiting anything like the finickiness toward measurement that we come to expect from quantum mechanics.

Measurements do impact systems, and the mechanism behind that impact is still incompletely understood. And yet the impact of a measurement is far less dramatic than what quantum Buddhism would have us believe. Its "reality-creating" aspect is only in evidence for subatomic particles (or extremely cold small atoms), and even then it isn't so much creating reality as selecting one of several predetermined possible states. And none of it has anything to do with consciousness or mind or any other human attribute that sounds kind of sort of like "measurement."

At best we can say, "Measurements randomly select values." But that is indeed a far cry from "Mind creates reality."

## 02 LIE TWO:

**"Quantum entanglement means that precognition and telekinesis probably exist."**

### The Argument:

In the phenomenon of quantum entanglement, pairs of particles are seemingly able to transmit information to each other faster than the speed of light. The classic example is that of a decaying pi meson particle breaking up into an electron and a positron. The spin of the original meson was zero and, in order to conserve angular momentum, that must be the sum of the resulting particles' spins as well. What we have found is that, no matter how far away the two particles are, when I measure the spin of, say, the electron, the spin of the other particle is simultaneously fixed as well. So, if the electron is spin *up*, the positron will be spin *down*. Before the measurement, the electron had no definite spin (remember, the act of measurement selects the value that actually manifests in reality), but the instant that it is measured and a spin sign is obtained, somehow the other particle "senses" it and changes itself accordingly to preserve angular momentum.

Based on this finding, then, certain popular writers in the parapsychological community have theorized that it is the scientific mechanism behind precognitive abilities.

The reason that one person can sense things about a person thousands of miles away, they explain, is that his state and that of the target human are entangled, allowing for faster-than-light communication between the two. And, if information can travel faster than the speed of light, then there exist frames of reference where that information is actually traveling backward in time, so our psychic is not only being influenced by that distant target but by the *future* of that distant person. If entangled particles can act at a distance upon each other, why can't people entangle themselves with each other and so determine things about each other's states and futures?

Further, if a measurement on one particle changes the state of a far-distant particle instantaneously, then I should be able, by manipulating the parts of my mind entangled with an outside object, to exert an influence on it, and therefore affect it with only the power of thought, which leads to telekinesis, remote mind control, and various other staples of comic books that are picking up a steady following as areas of scientific pursuit.

### But Don't Order Your X-Man Uniform Just Yet:

Again, this is taking an interesting phenomenon and twisting it into an unrecognizable heap of an idea. Quantum entanglement is the guardian of conserved quantities and the Uncertainty Principle. It ensures that the constraints on particles associated at one point in time are enforced when those particles become separated, no matter how vast that separation grows. But this only applies to constraints dealing with conserved quantities of the original system, like angular momentum. When two particles get entangled, they share a superpositional state between them that collapses jointly and instantaneously upon measurement into values that preserve the original quantity being measured.

This is a decidedly mathematical beast that quickly devolves into nonsense when taken from its native habitat. What precisely is the superpositional state into which two minds become locked? What is the mechanism of measurement that causes the collapse of one of the two people into a definite state? And precisely what is the thing being conserved, anyway? Pressed on these points, most parapsychologists will revert to allegory, and though the conversation grows increasingly lovely and whimsical as a result, it is also manifestly less sensible.

Entanglement is beautiful enough as it is without tarting it up with the freakish rouges of pop parapsychology. It is an effect that resoundingly preserves the strictest of quantum dictates about uncertainty by preventing us from doing two different measurements on two once-combined particles and using those measurements to learn more than we're allowed about the original system. Not only that, but it keeps some of our most basic quantities conserved in a manner that classical mechanics would not have permitted. Within the realm of these quantities and responsibilities, it can do incredible things (take a look at Walmsley's phononic diamond experiment to see a really clever application of entanglement on a macroscopic scale [http://www.nature.com/news/entangled-diamonds-vibrate-together-1.9532]). Step outside of that realm, however, and the situation immediately devolves to little more than metaphorical flailing that only makes sense if you strip entanglement of its conservative role, which is to say, if you gut it utterly of its central operating principle.

## 03 LIE THREE:

**Heisenberg's Uncertainty Principle means that science has failed in its fundamental goal of explaining reality, and we should therefore open ourselves up to alternative reality-explaining language games, such as are offered by religion."**

**The Argument**: Three hundred years ago, the phenomenal results of Newton's calculus-based explanation of the natural world caused people to rush too eagerly into the arms of mathematical science as the vehicle that would unveil the universe's mysteries. They overconfidently asserted that everything could be known through the tools of scientific investigation. In the 1920s, Werner Heisenberg brought that whole structure crumbling down via his Uncertainty Principle. Science, far from the flawless edifice it considered itself, is in fact filled with vast yawning gaps impenetrable by experiment, no matter how clever the experimenter, and so it has reached the limit of its explanatory powers. Therefore, it is time for other, less mathematical, perhaps more holistic or spiritual, investigatory processes to take their turn in the spotlight.

### Celebration Premature:

What Heisenberg's Uncertainty Principle decidedly does *not* say is that chaos reigns in the physics kingdom. It is actually a relatively benign, but incredibly powerful, statement about what happens when two quantities don't play well together. It's worth writing it in its most general form to get a full sense of its meaning, rather than the usual position-momentum form that looks nicer but that only tells the dark side of the story:

$$\sigma_A^2 \sigma_B^2 \geq \left(\frac{1}{2i}\langle[\hat{A},\hat{B}]\rangle\right)^2$$

What this says is that if I have two quantities I want to measure, A and B, each limits the certainty of the other's measurement in a way determined by $[\hat{A}, \hat{B}]$. This is the "commutator" of $\hat{A}$ and $\hat{B}$, and tells us how well these two quantities commute with each other, or in other words what the difference is between $\hat{A}\hat{B}$ and $\hat{B}\hat{A}$ (recall that, in normal mathematics, multiplication is *always* commutative—it doesn't matter what order I multiply 2 and 3 in, I'll always get 6. That's not always the case with the mathematical operations involved in quantum measurements).

What popular accounts of the Uncertainty Principle tend to leave out is that there are *plenty* of measurable quantities that work together just fine, for which $\hat{A}\hat{B}$ and $\hat{B}\hat{A}$ are exactly the same. The measurement that determines total energy, and that which determines the magnitude of angular momentum, for example, commute perfectly with each other, so $[\hat{A}, \hat{B}] = 0$, and measuring one has no impact on the other.

**I can take some sensationalism in the name of grabbing the attention of students long enough to sedulously expose them to some beautiful ideas. What I can't stand is misappropriating a handful of sexy-sounding terms and then applying them metaphorically to add scientific heft to one's particular intellectual fetish.**

There are, however, quantities that don't work so chummily, measurements of which get in each other's way unavoidably. *Position* and *momentum* are the classic examples, though more irresponsible mischief has been wrought from the fact that *energy* and *system change time* form another such pair. Here it's true that, if I want to take infinitely precise measurements of both members of a pair, I'll be in for nothing but frustration. Collapsing the position spike down to a fine and prominent peak will of necessity mess with my ability to measure the wavelength of the particle and therefore its momentum, and if I somehow do make a new measurement that figures out the wavelength, it will so change the particle's wave pattern that the original position measurement no longer applies.

Frustrating, yes, and to a generation of existentialists who found common ground with their own concerns in the word *uncertainty*, much was made of it. Nearly a century later, we have generally overcome that initial philosophy-brokered sky-is-falling sensationalism, and can take the inequality for what it is. It is an expression that allows us to know the upper limit on how badly two quantities will mess with each other's measurement. Sometimes the answer is "Not at all" and sometimes the answer is "A bit." Either way, quantum experimentalists needn't ready themselves to hand over the keys of the kingdom just yet. Ironically, and much to the chagrin of scientific detractors, the mathematical consequences of the Uncertainty Principle have allowed us deeper and more precise insights into the nature of reality than were ever dreamt of under the Newtonian model. It is not a sign that experimental physics has reached the limits of its efficacy—quite to the contrary, it is a century-old testament to our continually refined sense of how the observable quantities of our universe work together.

I adore quantum physics, and I welcome anybody who responsibly takes the task in hand of explaining its integral laden insights for students and the general public. It was one such book, John Gribbin's *In Search of Schrödinger's Cat*, which fell into my hands in seventh grade and set me on the road to a career as a math and science teacher. (Looking at my old copy now, there are a few things that make me cringe, but I imagine they've been corrected in the three decades since its first printing. Really, though, if you have the mathematical chops David Griffith's *Introduction to Quantum Mechanics* is the way to go.)

I can take some sensationalism in the name of grabbing the attention of students long enough to sedulously expose them to some beautiful ideas. What I can't stand is misappropriating a handful of sexy-sounding terms and then applying them metaphorically to add scientific heft to one's particular intellectual fetish. But authors (and Dalai Lamas) will continue to do so until they find themselves routinely exposed for their imprecision. I've provided the briefest sketch of some of the abuses and their worst faults, but for every one I listed there are ten left unmentioned. It is a seemingly endless battle against a lineup of feckless opportunists who never seem to diminish in number, but I figure, electrons have done a lot for us, why not return the favor? ■

**Dale DeBakcsy** holds graduate degrees in mathematics and intellectual history and has been a physics and calculus teacher since 2003. His science and culture blog can be found at skepticfreethought.com, and his favorite function, since you asked, is sin (1/x). He wrote "When Big Evidence Isn't: The Statistical Pitfalls of Dean Radin's *Supernormal*" in our January/February 2014 issue.

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