Quantum Onto-Psychology

Peter J. Lewis

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Abstract

Quantum mechanics has a surprisingly long reach; people have claimed consequences from in it many areas of philosophy. In particular, various radical claims about our mental life have been derived from the quantum mechanical description of the world. Albert and Barrett claim that a certain version of quantum mechanics entails that our experience is radically indeterminate; we simply do not have most of the experiences we take ourselves to have. Barbour claims that another version of the theory entails that there is no time, and all temporal experience is illusory. I will explore these claims, and investigate whether they can be squared with our understanding of our own minds and brains. To the extent that they can, then quantum ontology rules out certain intuitive assumptions about human psychology. But if, as I shall argue, they cannot, then the implication goes in the opposite direction; human psychology rules out some popular accounts of quantum ontology.

Is quantum mechanics relevant to psychology—to the nature of our experience? In one sense, of course it is; brain activity at the molecular level is relevant to our experience, and molecular phenomena are only adequately modeled by quantum mechanics. And there has certainly been a lot of speculation about the possibility that consciousness is grounded in specific quantum processes in the brain (e.g. Hameroff and Penrose 1996). But here I want to investigate another connection between quantum mechanics and experience, namely that quantum mechanics entails that the nature of our experience is not at all what we ordinarily take it to be. This has been suggested in a number of places in the literature on the foundations of quantum mechanics. If it is right, then since what we ultimately need to explain—either in physics or psychology—is the nature of our experience, the explanatory task of the sciences is not what we thought it was. We have been misguided about what the empirical adequacy of a theory amounts to.

There are two ways in which writers on quantum mechanics have suggested we might be wrong about the nature of our own experience. The first concerns determinacy. The claim here is that we attribute too much determinacy to our own experience—that our experience has far less content than we ordinarily take it to have. Hence a scientific theory need not ascribe determinate experiences to us in order to be empirically adequate. The second concerns time. In this case, the claim is that time is not any aspect of our experience, and hence a scientific theory need not reproduce temporal phenomena in order to be empirically adequate. I will explain these two cases in turn, and then argue that each places the cart before the horse; rather than quantum mechanics telling us about the nature of our experience, in fact the nature of our experience places empirical limits on possible quantum mechanical theories.

Quantum mechanics is a difficult theory to write about because there is so little agreement on what the theory says. For present purposes it will be sufficient to concentrate on a single version of quantum mechanics—the most minimal version. According to this theory, the physical world is completely described by the quantum state, and this state always, without exception, evolves according to the Schrödinger equation. Some versions of quantum mechanics add to this basic theory by postulating extra representational machinery on top of the quantum state (so-called "hidden variables") or an extra dynamical law that applies under certain conditions (a "collapse mechanism"). The simple version of the theory considered here eschews all such optional extras.

1 Determinacy and disjunctive experience

Particles like electrons and neutrons have a property called *spin* which can take one of two values, spin-up and spin-down (relative to a fixed axis). It is relatively straightforward to build a device that measures spin; such a device will reliably output "spin-up" when fed a spin-up particle and "spin-down" when fed a spin-down particle. But quantum mechanics entails that there are more than just two possible states of the particle; the *superposition principle* says that any linear combination of two possible states is also a possible state.

So if we write the spin-up state of the particle $|\uparrow\rangle_p$ and the spin-down state $|\downarrow\rangle_p$, then any superposition state of the form $a\,|\uparrow\rangle_p + b\,|\downarrow\rangle_p$ is also a possible state of the particle, where a and b are weights such that $|a|^2 + |b|^2 = 1$.

But what does this mean, physically speaking? We (apparently[1]) know this much via experience: when a particle in a superposition state is fed into a spin measuring device, we obtain either the result "spin-up" or the result spin-down, with probabilities $|a|^2$ and $|b|^2$ respectively. We are supposing that the quantum state constitutes a complete description of a physical system, so these probabilities cannot be a measure of our ignorance; it can't be the case that a particle in a superposition state is really either spin-up or spin-down, but we do not know which. So it looks like the state $a\,|\uparrow\rangle_p + b\,|\downarrow\rangle_p$ isn't a state in which the particle is spin-up unless $b = 0$, and it isn't a state in which the particle is spin-down unless $a = 0$. If neither a nor b is zero, it looks like the only option is to say that the particle simply lacks a spin-value; its spin is *indeterminate*. Let us adopt this as a general interpretational principle; if $|p_1\rangle_s$ and $|p_2\rangle_s$ are states of system s in which some property p takes distinct values p_1 and p_2 respectively, then the superposition state $a\,|p_1\rangle_s + b\,|p_2\rangle_s$ only represents s as having a determinate value for property p when $a = 0$ or $b = 0$, and otherwise p is indeterminate.[2]

But why does state $a\,|\uparrow\rangle_p + b\,|\downarrow\rangle_p$, in which the particle has no determinate spin value, yield one or the other value on measurement? Can we account for these probabilistic properties of superposition states using the resources of quantum mechanics? It is not clear that we can. An important property of the Schrödinger equation is that it is linear; a superposition of initial states evolves to a superposition of final states with exactly the same weights. Suppose that $|R\rangle_m$ is the state of our measuring device when it is ready to make a measurement, $|\uparrow\rangle_m$ is its state when it indicates the result "spin-up", and $|\downarrow\rangle_m$ is its state when it indicates the result "spin-down". Our device reliably outputs "spin-up" when fed a spin-up particle; that is, the initial state $|R\rangle_m\,|\uparrow\rangle_p$ of the combined device-particle system evolves to the final state $|\uparrow\rangle_m\,|\uparrow\rangle_p$. Similarly, the initial state $|R\rangle_m\,|\downarrow\rangle_p$ evolves to the final state $|\downarrow\rangle_m\,|\downarrow\rangle_p$. But now suppose that we feed in a particle in a superposition

[1] I say "apparently" because what it is we know via experience is precisely the subject of the current paper.

[2] The system will have determinate values for properties other than p when a and b are non-zero. For example, a particle in the state $\frac{1}{\sqrt{2}}\,|\uparrow\rangle_p + \frac{1}{\sqrt{2}}\,|\downarrow\rangle_p$ has no determinate spin relative to our designated fixed axis, but it does have a determinate spin along an axis at right-angles to it.

state, so that the combined device-particle system begins in a superposition $a\,|R\rangle_m\,|\uparrow\rangle_p + b\,|R\rangle_m\,|\downarrow\rangle_p$ of those initial states. Then by the linearity of the Schrödinger equation, the final state will be the corresponding superposition of the final states, i.e. $a\,|\uparrow\rangle_m\,|\uparrow\rangle_p + b\,|\downarrow\rangle_m\,|\downarrow\rangle_p$.

There is no obvious way to interpret this single final state as supporting the probabilistic results we see; sometimes we see the result spin-up, and sometimes we see the result spin-down, but the physical state of the measuring device is the same superposition state in either case. We can, if we like, incorporate the observer who reads the measuring device into the analysis, but this just deepens the mystery. Suppose $|R\rangle_o$ is the state of the observer when she is ready to make an observation, $|\uparrow\rangle_o$ is her state when she sees the measuring device reading "spin-up", and $|\downarrow\rangle_o$ is her state when she sees it reading "spin-down". Then if the initial state for the combined observer-device-particle system is $|R\rangle_o\,|R\rangle_m\,|\uparrow\rangle_p$, the final state is $|\uparrow\rangle_o\,|\uparrow\rangle_m\,|\uparrow\rangle_p$, and if the initial state is $|R\rangle_o\,|R\rangle_m\,|\downarrow\rangle_p$ the final state is $|\downarrow\rangle_o\,|\downarrow\rangle_m\,|\downarrow\rangle_p$. Applying linearity again, if the particle begins in a superposition state, the initial state of the observer-device-particle system is $a\,|R\rangle_o\,|R\rangle_m\,|\uparrow\rangle_p + b\,|R\rangle_o\,|R\rangle_m\,|\downarrow\rangle_p$, and so the final state is the corresponding superposition state $a\,|\uparrow\rangle_o\,|\uparrow\rangle_m\,|\uparrow\rangle_p + b\,|\downarrow\rangle_o\,|\downarrow\rangle_m\,|\downarrow\rangle_p$. How can this single state be one in which the observer sometimes has the experience of seeing "spin-up" and sometimes has the experience of seeing "spin-down"? We are supposing that the quantum state is a complete representation of the physical state of the system, and there is nothing in this state that distinguishes between the two experiences of the observer.

One possible move at this point is to modify quantum mechanics, either by denying that the quantum state is a complete representation of the physical world, or by modifying the law by which states evolve so that it is not (always) linear. The former approach is leads to hidden-variable theories of quantum mechanics, and the latter approach leads to collapse theories. These are both respectable (if somewhat problematic) research programs, but as noted above, for present purposes I have set such modification aside. The problem is that there doesn't seem to be anything in the physical state that could ground the observer's determinate experience of the outcome of the measurement—either determinately spin-up, or determinately spin-down. And the radical proposal I wish to entertain here is that observers simply do not have determinate experiences in such situations; there is simply no determinate measurement outcome that the observer sees. Let us call this radical proposal the *bare theory* (following Albert 1992, 124).

The bare theory might be taken as simply absurd; we *know* that we get determinate results to our experiments, via direct first-person experience, so this is not something that can simply be denied to facilitate the interpretation of quantum mechanics. But the originators of the bare theory have a story to tell according to which it will *seem* to you as if you get determinate results to your experiments, even though you don't (Albert 1992, 118; Barrett 1999, 98). The key to the story is yet further applications of the linearity of the Schrödinger equation. Suppose that the observer measures a particle which is in the state $|\uparrow\rangle_p$. She ends up in the state $|\uparrow\rangle_o |\uparrow\rangle_m |\uparrow\rangle_p$, a state in which she determinately sees the result "spin-up", so if I ask her whether she has some determinate experience concerning the spin of the particle right now, presumably she will say "Yes". Physically, the state $|\uparrow\rangle_o |\uparrow\rangle_m |\uparrow\rangle_p$ in which she sees the result "spin-up" evolves to the state $|y\rangle_o |\uparrow\rangle_m |\uparrow\rangle_p$ in which she utters the word "Yes". But by the same token, if the particle is initially in state $|\downarrow\rangle_p$, the observer will end up in the state $|\downarrow\rangle_o |\downarrow\rangle_m |\downarrow\rangle_p$ in which she determinately sees the result "spin-down", and if I ask her whether she got a determinate result, she will again say "Yes". So state $|\downarrow\rangle_o |\downarrow\rangle_m |\downarrow\rangle_p$ also evolves to state $|y\rangle_o |\downarrow\rangle_m |\downarrow\rangle_p$.

Now what if the particle is initially in a superposition state? Then the observer ends up in the superposition state $a |\uparrow\rangle_o |\uparrow\rangle_m |\uparrow\rangle_p + b |\downarrow\rangle_o |\downarrow\rangle_m |\downarrow\rangle_p$, and if I ask an observer in this state whether she got a determinate result to her measurement, this state will evolve to $a |y\rangle_o |\uparrow\rangle_m |\uparrow\rangle_p + b |y\rangle_o |\downarrow\rangle_m |\downarrow\rangle_p$ (by linearity again). But note that in both terms of the superposition the observer is in the state in which she answers "Yes" to my question. That is, this last state is mathematically equivalent to $|y\rangle_o \left(a |\uparrow\rangle_m |\uparrow\rangle_p + b |\downarrow\rangle_m |\downarrow\rangle_p\right)$, which is a state in which the observer has a determinate property, namely that of answering "Yes" to my question. So even though the observer is having no determinate experience concerning the result of the spin measurement, she will tell me that she does have a determinate experience. And if we take her utterances to be reliable guides to her beliefs, then we can conclude that she believes that she got a determinate result to her measurement, even though there is no determinate result that she believes she got.

Notice first how incredibly odd this is; our observer is deluded about her own occurrent beliefs. Even Descartes didn't countenance this sort of epistemic failure; as Barrett notes, this account of experience "makes Descartes's demon and other brain-in-a-vat stories look like wildly optimistic appraisals of our epistemic situation" (1999, 94). According to Descartes, there are at least some things we can't be deluded about, such as the current content of our minds. The above account takes even that modest epistemic crutch away.

But Cartesian infallibilism is less fashionable these days; perhaps we should not take it as axiomatic. Furthermore, there are numerous episodes in the history of science that suggest that dogged adherence to supposed "facts of experience" can be a barrier to scientific progress. If we take it as a fact of experience that the Earth is stationary, then heliocentric astronomy is a non-starter. This suggests that we should take our best scientific theories as a guide to the interpretation of our own experience, rather than resting content with what we pre-theoretically take our experience to be. That is, as long as heliocentric astronomy can explain why it seems to us as if the Earth is stationary, then our experience does not rule out heliocentric astronomy. Rather, heliocentric theory shows how our experience can be misleading, and should be reinterpreted.

Barrett argues that the same considerations apply to quantum mechanics. Pretheoretically, it might seem to us that it is a fact of experience that measurements have determinate outcomes. But if we analyze measurement situations by means of the bare theory itself, the kinds of consideration rehearsed above suggest that we mistakenly attribute ordinary determinate experience to ourselves when in fact we are having what Barrett calls a *disjunctive experience* (1999, 110). When the observer answers "Yes" to my question above, she does so because she is having an experience that is indistinguishable from the experience of *seeing spin-up or seeing spin-down*. But note that the experience she is having is not indistinguishable from the experience of *seeing spin-up*, since if I ask "Do you see spin-up?" her state will not be one in which she determinately answers "Yes". Nor is her experience *distinguishable* from the experience of *seeing spin-up*, since if I ask "Do you see spin-up?" her state will not be one in which she determinately answers "No". Similarly, her experience is neither distinguishable nor indistinguishable from the experience of *seeing spin-down*. But since her experience *is* indistinguishable from the experience of *seeing spin-up or seeing spin-down*, she will mistakenly believe that she experienced *some* determinate outcome.

Note that if the bare theory is correct, it is not just spin measurements that produce disjunctive experiences. Quantum mechanics (without hidden variables or collapses) entails that the states of ordinary objects will typically be superpositions of ordinary observable properties. So the coffee cup on my desk, my desk itself, even the building I am in do not have determinate locations, and neither do I experience them as having determinate locations. But my experience of them is indistinguishable from their having some-or-other determinate property, so (the story goes) I am non the wiser. Just as heliocentric astronomy can explain why we mistakenly believe that the Earth is stationary, so the bare theory can explain why we mistakenly believe that objects have determinate locations. Rather than our experience ruling out the bare theory, the bare theory shows that we should reinterpret most of our experience as disjunctive.

2 Timeless experience

In *The End of Time*, Julian Barbour considers a timeless universe—a universe that has a unique, unchanging physical state. This is no mere exercise in esoteric possibilities; Barbour is convinced that the state of *our* universe is unchanging. He takes this to be a consequence of the Wheeler-DeWitt equation in quantum gravity, which arguably has no place for temporal evolution. Barbour concludes that "time does not exist" (1999, 247). But as in the previous case, this conclusion might be thought to be absurd; don't we know via direct experience that things change over time?

Barbour's solution to this problem, like Barrett's above, is to argue for a reinterpretation of our experience in light of physical theory. That is, he thinks we can use the physical theory behind the Wheeler-DeWitt equation to explain why it might seem to us that we experience the passage of time even though there is no time. The central explanatory concept here is the *time capsule*; a time capsule is "any fixed pattern that creates or encodes the appearance of motion, change or history" (1999, 30). In particular, we can appeal to such patterns in our brains. When I see a kingfisher in flight, the state of my brain contains, "coded in the neuronal patterns, six or seven snapshots of the kingfisher just as they occurred in the flight I thought I saw" (1999, 267). That is, the state of my brain *at an instant* contains the pattern that I take to be the motion of the kingfisher. There is no motion in the pattern itself, but we (mistakenly) interpret it as an experience of motion.

Barbour thinks that time capsules of this kind are ubiquitous in the unchanging physical state of the universe, in particular (but not exclusively) in human brains. They explain why we interpret our experience in dynamic terms—in terms of motion and change. But this interpretation is a mistake, and we need to learn to reinterpret our experience in light of physical theory. The lesson, he suggests, is the inverse of the one we learned from Copernicus, Kepler and Galileo: "They persuaded us, against what seemed to be overwhelming evidence to the contrary, that the Earth moves. They taught us to see motion where none appears. The notion of time capsules may help us to reverse that process—to see perfect stillness as the reality behind the turbulence we experience" (1999, 32). There is no time and no change, but nevertheless the unchanging state of the world manifests itself as experiences that we take to be experiences of time and change.

Barbour's position is prefigured in Bell (1987). Bell is not writing here about quantum gravity per se, but rather about the version of quantum mechanics considered in the previous section—quantum mechanics without hidden variables or collapse. Bell, following Everett (1957), interprets a superposition like $a\left|\uparrow\right\rangle_o\left|\uparrow\right\rangle_m\left|\uparrow\right\rangle_p + b\left|\downarrow\right\rangle_o\left|\downarrow\right\rangle_m\left|\downarrow\right\rangle_p$ not as a state in which the observer has no determinate experience, but as two mutually exclusive experiences, in one of which the observer sees spin-up and in the other of which she sees spin-down. The question Bell addresses is how these experiences are "strung together" over time to produce coherent streams of experience. One could postulate hidden variables to define such trajectories for us, but we are supposing here that there are no hidden variables. The solution he attributes (tentatively, and perhaps erroneously) to Everett is that "if we do not like these trajectories we can simply leave them out" (1987, 98). That is, there is no connection between the observer's experience at one instant and her experience at earlier and later instants; there are instantaneous experiences of observers, but no *streams* of experience. Bell's speculation here is radical, but not as radical as Barbour's; he is not proposing that there is no time, but he is proposing that our experience has no temporal continuity. His explanation of how to reconcile the lack of temporal continuity with our apparent experience of continuity, though, is just like Barbour's; continuity is no part of our experience, but we mistakenly interpret it as temporally continuous: "For we have no access to the past, but only to memories, and these memories are just part of the instantaneous configuration of the world" (1987, 98).

3 The structure of experience

It is natural to think of experience as analogous to a movie; our experience is made of instantaneous frames, each of which is like a snapshot. (Whether it was natural to think of experience in this way before the advent of movies is an interesting historical question!) But as Barbour realizes, the frames of a movie are *stills*; they do not themselves contain movement, and indeed it may be impossible to tell from a still whether a given object is moving or not. Hence his claim that the instantaneous state of my brain contains six or seven images of the speeding kingfisher; the image in my brain is more like a futurist painting than a snapshot.

But does this (somewhat) intuitive picture correspond to what is really going on in our experience and in our brains? There are reasons to be skeptical. At the level of experience, my experience of a moving object doesn't seem to be much like a futurist painting; I experience the kingfisher as a *moving* blue object, not as a set of blue objects at different locations. The futurist technique may be one way of representing motion, but at least superficially it does not appear to be the way motion is presented in experience. Of course, a creature *could* represent motion in experience in the futurist way—as a series of snapshots held simultaneously in the mind. This is a static representation of motion; the representation itself is static, even though it represents the kingfisher as moving. But as the above movie analogy above suggests, motion can also be represented dynamically; there is nothing in a still of a flying kingfisher that represents its motion, but the sequence of stills presented over time does represent the motion. A painter is limited to represent motion statically; hence the rather baroque machinery of multiple images in futurist paintings (and cartoons). But a human brain is not so limited, so there is no a priori reason to think that it must represent motion statically rather than dynamically.[3]

But so much for speculation; how is motion actually represented in the brain? As one might expect, the story is complicated. There are mechanisms that identify motions in the visual field independently of any categorization of the visual input into objects; such mechanisms essentially compute rates of change of light intensity across space and across time (Bruce, Green and

[3] Of course, if Barbour is right, then the brain *is* limited to represent motion statically, or else not at all. But the question I am investigating here is whether, independently of Barbour's proposal, there are reasons to think that the brain represents motion in the way required by his theory.

Georgeson 2003, 218). There are other mechanisms that identify motions by tracking features in the visual representation over time; these mechanisms produce an ongoing comparison between successive images, identifying similar features and inferring motions accordingly (ibid., 254). The representation of motion in each case is essentially static; even within an instantaneous mental "snapshot", some regions of the visual field are labelled as moving. This is entirely consistent with Barbour's time-capsule picture.

However, the foregoing description begs the question in an important way, since I assumed without evidence that the experienced outputs of these motion-detecting systems are themselves instantaneous states. But this may be wrong; at the neuronal level, the structures on which experiences supervene may be essentially *dynamic* structures. There has been a good deal of research recently on the role of synchronized neuronal oscillations in various cognitive functions, including visual perception and memory formation (Bartos, Vida and Jonas 2007). The basic idea is that what underlies a particular perception (for example) is not a spatial pattern of neuron firings at a single time, but a spatio-temporal pattern of oscillatory neuronal firings synchronized between different areas of the brain. In the kingfisher case, these oscillations associate the blueness with the motion to yield the experience of a fast blue streak (Gray and Singer 1989; Csibra et al. 2000). Still other oscillations associate the blue streak with previous experiences to yield a familiar *kind* of experience, namely an experience of a kingfisher (Gruber and Müller 2006). This suggests that a snapshot of the brain at a time would not correspond to any experience of a kingfisher, moving or not, because the structures underlying such experiences are spread across time. If this is right, then ascribing experiences to an instantaneous brain state is a bit like ascribing wetness to a water molecule. Wetness is a macroscopic property that applies to a spatially extended substance, and such properties do not appear if one focuses too narrowly in space. Similarly, experience properties apply to a temporally extended process, and again such properties do not appear if one focuses too narrowly in time.

A tempting line of response is that the *information* required to identify the experience is nevertheless present in a snapshot of the brain. Clearly the oscillations themselves are not present in a snapshot, but from the state of the brain at an instant it should be possible to infer that it is currently undergoing the oscillations that constitute an experience of a moving kingfisher. And in that case the kingfisher-experience is, after all, present in the snapshot. But there are two problems with this line of response; first, it is hard to see in what sense the information is present in the snapshot, and second, even if it were present, information is not the issue. Ordinarily, a snapshot captures a time-slice of a dynamical process, but if the universe is the way Barbour envisions it, there are no dynamical processes. So the state captured in the snapshot does not actually evolve, in an oscillatory manner or otherwise. Rather, the inference from the state in the snapshot to the oscillation must be counterfactual: if the universe were of a fundamentally different physical character, then a snapshot like this would be a time-slice of an oscillating state. But it is far from clear how the information available in a snapshot of a fundamentally different universe is relevant to the information available in this one.

Still, suppose some sense could be made of the claim that the information required to reconstruct the kingfisher-experience is present the snapshot. Even so, it does not follow that the experience itself is present in the snapshot. After all, if one takes a snapshot of a deterministic universe, then the snapshot contains information from which one could reconstruct the entire history of the universe. But a snapshot of a deterministic universe clearly does not contain every experience in the history of that universe; the big bang is not a state in which I am experiencing a kingfisher, even if it contains all the relevant information. If the concern is with empirical adequacy, then the issue has to be which experiences are actually grounded by the instantaneous state, not what information about experiences could be extracted from the instantaneous state. And research on the role of neural oscillations suggests that central features of our experience are not grounded by instantaneous states.

All this is not to say that the situation envisioned by Barbour is unimaginable. There could be creatures whose experience is constructed out of instantaneous time-slices, and for those creatures Barbour's theory would be empirically adequate. That is, such creatures might mistake an unchanging instantaneous state for a genuinely dynamical one. But these creatures would have to differ from us in the way they are physically constructed; the brain structures underlying their experiences would have to be very different from those underlying our own experiences. At least, so I have argued. If these arguments are correct, then the only way that Barbour's time-capsule theory could be empirically adequate for creatures like us is via some kind of error theory of our own experience; we simply do not have experiences of moving objects, despite the fact that we might think we have them. This, of course, brings us right back to the tenability of the bare theory.

4 Skepticism and empirical adequacy

The bare theory entails that I might have no determinate experience right now and yet believe that I do have some determinate experience. This is possible, according to the bare theory, because when entangled in a superposition state, I will respond "Yes" when asked if I have some determinate experience, even though there is no determinate experience I am having. The obvious response to the bare theorist is that this account misrepresents my experience. I do not believe merely that I am having some determinate experience or other (I might insist); I believe I am experiencing the measuring device pointing to spin-up, and not to spin-down. But the bare theorist will reply that my objection here is not what I think it is, because it fails to constitute a determinate utterance at all. In fact my utterance was a superposition of "I believe I am experiencing the measuring device pointing to spin-up, and not to spin-down" and the utterance "I believe I am experiencing the measuring device pointing to spin-down, and not to spin-up". Nevertheless, I took myself to have made a determinate utterance for the reasons already rehearsed; if asked "Did you utter a determinate sentence?" I would respond "Yes". But in fact I made no determinate objection to the bare theory.

This is exasperating. Is there no way out? Albert (1992, 124) and Barrett (1999, 116) each eventually reject the bare theory, not because they think it is inadequate to our experience, but because acceptance of it would be empirically self-defeating; "the truth of the bare theory would undermine whatever empirical justification one may have thought one had for accepting it in the first place" (Barrett 1999, 116). The bare theory is introduced as an interpretation of quantum mechanics, and quantum mechanics was adopted one the basis of empirical evidence. But if the bare theory is correct, we did not in fact have the determinate experiences that we took to be the evidence for quantum mechanics. The bare theory pulls away its own empirical support.

But this does not seem like a sufficient reason to dismiss the bare theory. As Barrett notes, "such a theory might be true—it is just that if it were true, then one would never know that it was" (1999, 117). If we admit that the bare theory as an option, then skepticism threatens. But the bare theory is a well-motivated form of skepticism. I have no reason to think that I am a brain in a vat; I do not find myself in a world where human brains are extracted and wired to computers. If I did find myself in such a world, then I would have reason to take seriously the theory that I am a brain in a vat, even though this theory undermines my evidence for thinking that I am a brain in a vat in the first place. By contrast, I do have good reason to take the bare theory seriously; the evidence supports quantum mechanics, quantum mechanics requires the existence of superposition states, and the bare theory provides a way to understand the relation between superpositions and measurement outcomes. So I should take the bare theory seriously, even though it undermines the evidence that led to my taking it seriously in the first place.

So is there no way to reject the bare theory? I think that the right response is that a principled appeal to the primacy of experience is available. There are limits to how far one can deny what one apparently experiences, even if that denial is motivated by a scientific theory, and the bare theory crosses the line. The worry here, raised earlier, is that insisting on the primacy of experience is inimical to scientific progress. But note that the examples on which this worry is based do not really threaten the primacy of experience. Consider the case of the motion of the Earth. One might insist that one experiences the Earth as stationary, but this is shorthand; one's experience standing on solid ground is not like one's experience sitting on a speeding horse. Heliocentric astronomy can explain these aspects of experience; standing on solid ground doesn't create wind in your face because the air is moving with you and the ground. Similarly for Barrett's example of the spoon sticking out of a glass of water (1999, 112). One might insist that it is a fact of experience that the spoon is bent, but of course the fact of experience is that the spoon *appears* bent; the handle appears to make an angle where it come through the surface of the water. Classical optics can explain this experience. In neither case am I required to modify the experiences I attribute to myself; I simply explain my existing experiences in a new way.

Are there cases where a new scientific theory entails that we are wrong about our own experience? Consider the case of the moon illusion. The moon looks bigger when it is close to the horizon than when it is high in the sky. Does the atmosphere magnify the moon at low elevations? No; one can demonstrate that the moon subtends the same angle on your retina whether it is close to the horizon or high in the sky. Close adherence to the science here might tempt you to say that optics shows that the moon does not appear larger when it is close to the horizon, despite our initial inclination to say that it does appear larger. If the dialectic went this way, it might be a case in which science shows that we are wrong about our experience. But it doesn't go this way; in fact we insist that nevertheless the moon does appear larger, and look for a psychological explanation of the phenomenon rather than a physical one (Kaufman and Kaufman 2000). Indeed, optical illusions of many kinds suggest that we should not let physics alone tell us what we experience.

So we should stand firm; I have determinate experiences of the outcomes of measurements, and I know this directly. A theory that tells me that I have no such experiences is simply telling me something that I know to be false. It makes no difference if the theory tries to explain my conviction by telling me that I would report my experience to be determinate even if it were not; I know that my experience *is* determinate, so the point is moot. The trouble with the bare theory is not that it is skeptical, but that it is empirically inadequate.

5 Significance

Why have I bothered to argue for this? After all, nobody believes in the bare theory; Albert and Barrett reject it, albeit for what I have argued are the wrong reasons. Bell rejects his Everettian version of temporal solipsism for similar reasons: "Solipsism cannot be refuted. But if such a theory were taken seriously it would hardly be possible to take anything else seriously" (1987, 136). And only one person, as far as I know, believes Barbour's time-capsule theory, namely Barbour himself.

However, views with similar but less extreme consequences for experience have gained some currency. The idea that time is emergent rather than fundamental is a common theme in discussions of quantum gravity and string theory (e.g. Seiberg 2007). Of course, to say that time is emergent is not to embrace Barbour's conclusion that there is no time. But insofar as the details of the emergence of time involve the same "time capsule" structure, the arguments above will still apply. That is, to say that time is emergent is to say that at the fundamental level nothing changes, and the most straightforward way one might try to recover the appearance of change in such a universe is to say that the structure of that part of the universe that counts as a later event contains records of the parts of the universe that count as earlier events. This "snapshot" approach to recovering our temporal experience, I have argued, is inadequate. Perhaps some other approach to temporal emergence is possible, but the tenability of temporal emergence certainly cannot be taken for granted.

Second, other interpretations of quantum mechanics can entail a limited degree of indeterminacy in experience. For example, Albert (1992) explores scenarios in which Bohm's hidden variable theory and GRW-type collapse theories might entail that an observer have no determinate experience of the outcome of a measurement. In the case of Bohm's theory, the theory entails that particles always have determinate positions, so as long as an observer's experiences are always encoded in the positions of the particles in her brain, no indeterminacy in experience can arise. But must experiences be encoded in this way? If some of her experiences were encoded in some other properties of particles, such as their energies or spins, then it might be possible for her to have no determinate experience concerning a measurement result and yet report that she does (Albert 1992, 173). In the case of GRW-type theories, the collapses that result in determinate experience are triggered by superpositions in the correlated positions of large numbers of particles, so as long as experiences typically involve large numbers of particles moving together then no indeterminacy can arise. But again, experiences might be encoded in some other way; they might involve relatively few particles, in which case it might be possible for an observer to have no determinate experience of a measurement outcome (Albert 1992, 108).

The chances are good that neither of these possibilities arise for human beings; distinct experiences involve distinct positions of large numbers of particles, so neither of the above sources of indeterminacy poses a problem (Aicardi et al. 1991). But a more recent interpretation of quantum mechanics, flashy GRW (Tumulka 2006), raises the worries anew. According to this interpretation the basic ontology of the world consists of point-like events in spacetime called flashes, and the distribution of these flashes over space and time constitutes the familiar world of experience. But these flashes do not recover the structure of the microscopic world with the detail in which we typically picture it. In particular, the flashes may not recover the structure of our brains to the resolution of the individual molecule, so if brain structure at this level is relevant for experience, our experience might be indeterminate to that extent. Philosophers of quantum mechanics are apt not to worry about such indeterminacy, since the arguments of Albert and Barrett suggest that it is not something we could be aware of. But if the arguments above are correct, then indeterminacy in the content-relevant structure of the brain might render flashy GRW empirically inadequate. I am not suggesting that it *does* have this consequence—that would require far more knowledge of neuroscience than I possess—but merely that it is something that must be born in mind in constructing an interpretation of quantum mechanics. The nature of our experience must inform the physical theory, rather than the physical theory informing the nature of our experience.

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