Jeffrey A. Barrett

Quantum Mechanics and Dualism

1 Quantum measurement and the temptation of dualism

The quantum measurement problem is arguably the most difficult conceptual problem in the foundations of physics. It is an indication of its difficulty that attempts to solve it have led physicists and philosophers of physics to speculate concerning the relationship between physical and mental states. We will consider the sense in which this relationship provides a degree of freedom that is tempting to use in addressing the measurement problem. We will start with Eugene Wigner's understanding of the standard collapse formulation of quantum mechanics.

Two years prior to being awarded the Nobel Prize in Physics, Wigner published a paper arguing that a consistent formulation of quantum mechanics requires one to endorse a strong variety of mind-body dualism. In particular, he argued:

> Until not many years ago, the 'existence' of a mind or soul would have been passionately denied by most physical scientists. […] There are [however] several reasons for the return, on the part of most physical scientists, to the Spirit of Descartes' 'Cogito ergo sum' […] When the province of physical theory was extended to encompass microscopic phenomena, through the creation of quantum mechanics, the concept of consciousness came to the fore again: it was not possible to formulate the laws of quantum mechanics in a consistent way without reference to consciousness.

And continued:

> It may be premature to believe that the present philosophy of quantum mechanics will remain a permanent feature of future physical theories; it will remain remarkable, in whatever way our future concepts may develop, that the very study of the external world led to the conclusion that the content of the consciousness is an ultimate reality (1961, 168–169).

To see why Wigner believed that quantum mechanics requires a commitment to a strong variety of mind-body dualism for its consistent formulation, one must understand the basic structure of the standard von Neumann-Dirac formulation of quantum mechanics to which he was committed, and the quantum measurement problem.

We will start with the standard theory and the measurement problem, then consider Wigner's argument. We will then consider a fragment of an argument from an earlier letter from Wolfgang Pauli to Max Born. This line of argument will lead us to consider how even a no-collapse formulation of quantum mechanics may commit one to a strong physical-nonphysical dualism on plausible-sounding assumptions. The suggestion, however, will be that while it is tempting to commit to some form of dualism to address the measurement problem, there are viable options for avoiding a commitment to a strong mind-body dualism.

2 The standard formulation of quantum mechanics

The standard-Dirac collapse formulation of quantum mechanics is based on four rules. There are two representational rules (1) *representation of states*: the state of a physical system S is represented by a vector ψ_s of unit length, sometimes called the wave function, in a Hilbert space H and (2) *representation of observables*: every physical observable O is represented by a Hermitian operator $\hat{O}$ on H, and every Hermitian operator on H corresponds to some observable. An interpretational rule (3) *interpretation of states*: a system S has a determinate value for observable O if and only if the system is in an eigenstate of the observable $O\psi_S = \lambda\psi_S$. And two dynamical laws (4a) *deterministic linear dynamics*: if *no measurement* is made, the system S evolves in a deterministic linear way: $\psi(t_1)_S = \hat{U}(t_0,t_1)\ \psi(t0)_S$ and (4b) *random nonlinear collapse dynamics*: if a *measurement* is made, the system S randomly, instantaneously, and nonlinearly jumps to an eigenstate of the observable being measured, where the probability of jumping to φ_S when O is measured is $|\psi\varphi|^2$. The first dynamical law (4a) explains quantum interference effects, and the second (4b) ensures that measurements yield determinate outcomes and explains quantum probabilities.

The problem with this formulation of quantum mechanics is that while *measurement* occurs as an undefined primitive term in the theory, the two dynamical laws typically give different predictions for the post-interaction state of a measuring device and its object system depending on whether one considers the device to be a physical system like any other or a collapse-causing observer. More specifically, if one treats an observer as a physical system like any other, then one should use rule 4a for the interaction between the observer and her object system; but if one takes the observer to be somehow special and capable of causing collapses, then one should use rule 4b for the interaction. And, since the two rules typical predict different states, one gets a logical contradiction if one tries to apply both. Further, and of particular importance to Wigner, there are also empirical consequences for when each rule is taken to apply—a point central to his friend story, which we will consider in the next section. So the standard formulation of quantum mechanics is either (1) *logically inconsistent* if one thinks that observers and other measuring devices are physical systems like any other or (2) *incomplete* in an empirically significant way if one does not know how to identify systems that should count as measuring devices. This is the quantum measurement problem.

3 Wigner's proposal

Wigner's proposal for solving the measurement problem was simple:

> The important point is that the impression which one gains at an interaction may, and generally does, modify the probabilities with which one gains the various possible impressions at later interactions. In other words, the impression one gains at an interaction, called also th*e result of an observation*, modifies the wave function of the system. [...] [I]t is *the entering of an impression into our consciousness which alters the wave function* because it modifies our appraisal of the probabilities for different impressions which we expect to receive in the future. It is at this point that the consciousness enters the theory unavoidably and unalterably (1961, 172–173).

Importantly, while one might be tempted to read parts of this passage epistemically, Wigner took the collapse that resulted from the entering of an impression into the observer's consciousness to be a real physical process. As the Wigner's friend story makes clear, he took there to be experiments one might perform, at least in principle, to determine what systems cause collapses. His solution to the measurement problem, then, was to stipulate, as a fundamental principle of quantum mechanics, that a real physical collapse of the state occurs whenever a conscious mind gains the impression of the measurement result.

There is, indeed, a sense in which Wigner's proposal immediately solves the measurement problem by sharpening rules 4a and 4b. The dynamical laws are now (4a′) *deterministic linear dynamics*: if *no conscious mind apprehends its state*, the system S evolves in a deterministic linear way: $\psi(\mathrm{t}_1)_S = \hat{U}(t_0,t_1)\psi(t_0)_S$ and (4b′) *random nonlinear collapse dynamics*: if a *conscious mind apprehends its state*, the system S randomly, instantaneously, and nonlinearly jumps to an eigenstate of the observable being measured, where the probability of jumping to φ_{S} when O is measured is $|\psi\varphi|^2$. If there is a simple determinate matter of fact concerning whether and when an impression enters into a consciousness, these sharpened rules provide a consistent specification for the quantum dynamics.

Wigner believed that this move was “required” for the consistency of the standard collapse theory, and he considered it to be the “simplest way out” of the quantum measurement problem (180). And, again, he took his specification of when collapses occur to have physical and empirical consequences. Namely, the state collapses caused by minds affect the quantum-mechanical states of physical systems and hence objective, observable properties of the physical world.

Wigner illustrated this with his friend story. Wigner’s friend *F* has a measuring device *M* and both are ready to measure the *x*-spin of a spin-1/2 system *S*. The system *S* begins in the state

$$1/\sqrt{2}(|\uparrow_x\rangle_S+|\downarrow_x\rangle_S). \tag{1}$$

If we use the linear dynamics, rule 4a, and assuming ideal correlating interactions, after the measuring device *M* interacts with the object system *S* and after the F looks at the pointer on the *M*, the composite system *F*+*M*+*S* will be in the state

$$1/\sqrt{2}(|\text{"}\uparrow_x\text{"}\rangle_F|\text{"}\uparrow_x\text{"}\rangle_M|\uparrow_x\rangle_S+|\text{"}\downarrow_x\text{"}\rangle_F|\text{"}\downarrow_x\text{"}\rangle_M|\downarrow_x\rangle_S). \tag{2}$$

This state follows directly from the linearity of the dynamical law and the assumption that the interactions perfectly correlate the *x*-spin of *S* and *F*’s measurement record. By rule 3, this is a state where *F* has no determinate measurement record at all—indeed, he is in an entangled state with *M* and *S* here and hence does not even have a proper quantum-mechanical state of his own.

But if we use the nonlinear collapse dynamics, rule 4b, for the interaction between *M* and *S*, or for the interaction between *M* and *F*, or for when *F*’s mind apprehends the state, the composite system *F*+*M*+*S* will either be in the state

$$|\text{"}\uparrow_x\text{"}\rangle_F|\text{"}\uparrow_x\text{"}\rangle_M|\uparrow_x\rangle_S \tag{3}$$

or in the state

$$|\text{"}\downarrow_x\text{"}\rangle_F|\text{"}\downarrow_x\text{"}\rangle_M|\downarrow_x\rangle_S, \tag{4}$$

each with equal probability 1/2. In contrast with state 2 each of these states describe F as having a determinate measurement result on the standard eigenvalue-eigenstate link 3. In the first of these states, F determinately records the result $\text{"}\uparrow_x\text{"}$ and in the second he determinately records the result $\text{"}\downarrow_x\text{"}$.

Wigner argued that the state of the composite system must be either state 3 or state 4. To begin, Wigner believed that were he to ask the friend what the result of his measurement was, then he would hear his friend say something perfectly determinate. Then, after having completed the whole experiment, if he asked his friend, “What did you feel about the result of your measurement before I ask you?”, the friend would certainly reply, “I told you already, I got the result [$"\uparrow_x"$ or $"\downarrow_x"$]” as the case may be. That is, the friend would report that the result of his measurement “was already decided in his mind” before Wigner asked him. He concludes this line of argument:

> If we accept this, we are driven to the conclusion that the proper wave function immediately after the interaction of friend and object was already either [state (3)] or [state (4)] and not the linear combination [state (2)]. [...] It follows that the beating with the consciousness must have a different role in quantum mechanics then inanimate measuring device (1961, 176–177).

While Wigner recognized that it is not logically inconsistent to deny that the friend is right in reporting that he already had a determinate measurement result before he was asked, Wigner took such an option to be unacceptable. He argued that to deny that the friend has the same sort of determinate experiences that we do and hence causes collapses of systems to determinate property states “is surely an unnatural attitude, approaching solipsism, and few people, in their hearts, will go along with it” (1961, 177–178). So it is when the friend apprehends the state, and not when Wigner asks him what his result was, that the composite system collapses to a state where the friend has a determinate and now accurate measurement record.

The precise sense in which such collapses involve a real physical process that produces in principle observable results was important for Wigner’s argument. Consider an observable $\hat{A}$ of the composite system F+M+S that has

$$1/\sqrt{2}\left(|"\uparrow_x"\rangle_F\,|"\uparrow_x"\rangle_M\,|\uparrow_x\rangle_S + |"\downarrow_x"\rangle_F\,|"\downarrow_x"\rangle_M\,|\downarrow_x\rangle_S\right) \tag{5}$$

as an eigenstate with eigenvalue +1, and

$$1/\sqrt{2}\left(|"\uparrow_x"\rangle_F\,|"\uparrow_x"\rangle_M\,|\uparrow_x\rangle_S - |"\downarrow_x"\rangle_F\,|"\downarrow_x"\rangle_M\,|\downarrow_x\rangle_S\right) \tag{6}$$

as an eigenstate with eigenvalue –1. An observation of $\hat{A}$ would yield the result +1 with probability 1 if the interactions between F, M, and S are linear, and it would yield the result +1 with probability 1/2 and the result –1 with probability 1/2 if F’s measurement somehow caused a collapse and state 3 or state 4 obtains. So, while extraordinarily difficult to perform due to the complexity of the object system and the difficulty in controlling for decoherence effects, there are at least in principle experiments that would determine what systems cause collapses, and hence what systems should count as conscious if, as Wigner argued, conscious apprehension causes collapses.

For his part, Wigner took the fact that his proposal had empirical consequences to be a virtue. In particular, it provided one a way, at least in principle, to determine which entities in fact cause collapses of physical states. The thought is that one might then compare this to one's pre-theoretic sense of which entities are conscious to test the theory's novel empirical predictions.

That said, one might naturally wonder whether Wigner was right to believe that a solution to the quantum measurement problem requires one to endorse a strong variety of mind-body dualism. The short answer is that this depends on the background assumptions one finds plausible and on the explanatory demands one places on quantum mechanics. If one believes, with Wigner, that there are collapses of the quantum mechanical state and that there must be a principled distinction between one type of system that always evolves linearly and another, strictly disjoint, type of system that causes collapses, then one might be similarly tempted to endorse quantum mind-body dualism. But very different commitments from Wigner's can also push one toward a commitment to a strong variety of mind-body dualism in the context of quantum mechanics. In particular, some sort of strong dualism may be required on plausible-sounding background assumptions even if one opts for a no-collapse formulation of quantum mechanics.

4 An argument for no-collapse dualism

In March 1954 Wolfgang Pauli wrote Max Born from to explain Einstein's objections to quantum mechanics. Einstein and Born had been debating by post the conceptual foundations of quantum mechanics. During his visit at the Institute for Advanced Study in Princeton, Pauli had read the letters, discussed them with Einstein, and come to believe that Born had completely misunderstood Einstein's position. Pauli wrote Born that "[i]t seemed to me that you had erected some dummy Einstein for yourself, which you then knocked down with great pomp" (1954, 221). Contrary to the popular view, a view also held by Born, that Einstein objected to the statistical nature of quantum mechanics, Pauli explained that Einstein's essential worry was not *determinism* but *realism*. In particular, Pauli reported that Einstein was concerned with how one assigned determinate properties like position to a physical system and, in particular, what happened when one observes a macroscopic object that is initially in a superposition of being at different positions.

Regarding what happens on observation, Pauli agreed with Einstein that "it is not reasonable to invent a causal mechanism according to which 'looking' fixes the position" (1954, 222). This put both Einstein and Pauli at odds with the dynamical postulates of the standard collapse formulation of quantum mechanics and, more specifically, Wigner's later position. Pauli, however, disagreed with Einstein that "a macro-body must *always* have a quasi-sharply-defined position in the 'objective description of reality'". Since Einstein believed that there was no collapse of the state on observation, if a macro-body is to have a quasi-sharply-defined position, then the standard quantum description had to be incomplete since it typically fails to specify even an approximately determinate position. Pauli, in contrast, accepted the standard quantum-mechanical state as a complete description of the *physical* state of the system.[1]

Pauli explained to Born why he disagreed with Einstein by appealing to the uniformity of nature. He reported, "I believe it to be *untrue* that a macro-body *always* has a quasi-sharply-defined position, as I cannot see any fundamental difference between micro- and macro-bodies". In particular, Pauli took the linear dynamics, rule 4a, always to hold, even during an observation. But since he also held that the quantum state provided a complete physical description and that an observation typically provides an observer with a determinate experience, he concluded that the appearance of the collapse of a system to a definite position during an observation was "a 'creation' existing outside the laws of nature, even though it cannot be influenced by the observer. The natural laws only say something about the *statistics* of these acts of observation" (1954, 223).

In contrast to Wigner's view where minds are responsible for collapses, Pauli's letter to Born suggests a no-collapse formulation of quantum mechanics where the linear dynamics always correctly describes the time-evolution of the state of every physical system but where the determinate mental state of an observer only statistically supervenes on the observer's physical state.[2] It does not take much to get from this fragment of an argument to a full argument for a strong variety of physical-nonphysical dualism if one is committed to no collapse

---

[1] More specifically, as Pauli explained in his 1948 essay "Modern Examples of Background Physics", that the physical state provided by quantum mechanics does not specify the value of an outcome in an individual case "does not mean an incompleteness of quantum theory within physics […] but an incompleteness of physics within the whole of life" (translated and quoted in Enz 2002, 424).

[2] See Atmanspacher, and Primas 2006 for an extended discussion of Pauli's views regarding the relationship between physical and mental states. While Pauli's assumptions support a strong physical-nonphysical dualism, for his part, he wanted to somehow reconcile the nonphysical experience of an observer with the physical world. As he put the goal in a 1952 essay, "[i]t would be most satisfactory if physis and psyche could be conceived as complementary aspects of the same reality" (translated and quoted in Atmanspacher, and Primas 2006, section 5.1).

of the quantum mechanical state and rule 4a always correcting describing the time-evolution of the quantum state.

In particular, the following assumptions are sufficient to commit one to a strong variety of dualism:

- *Assumption 1 (state completeness)*: The standard quantum-mechanical state provides a complete and accurate representation of the physical state.
- *Assumption 2 (no collapse)*: The linear dynamics, rule 4a provides a complete and accurate description of the evolution of the physical state for all systems at all times.
- *Assumption 3 (empirical consistency)*: If a system is initially in a superposition of states corresponding to different eigenvalues of the observable being measured, then it is possible for the measurement to yield a result corresponding to any of those eigenvalues.
- *Assumption 4 (no branching)*: The measurement interaction between an observer and a physical system typically yields a single determinate measurement result.

By assumptions 1 and 2, a typical measurement interaction yields a physical state where the observer records a superposition of mutually incompatible measurement results. However, by assumption 4, the observer nevertheless has a single determinate measurement result. By assumptions 1 and 3, the value of the measurement result cannot supervene on her *physical state*. So, insofar as it supervenes on anything, the observer's measurement result must supervene on her *nonphysical state*. And one is committed to a strong physical-nonphysical dualism.

In order to see more clearly how this argument works, consider the Wigner's friend story again. If the post-measurement state predicted by the linear dynamics, the state described by expression 2, is the observer's complete physical state, then the observer's complete physical state clearly does not determine the result of her measurement. Indeed, since the physical state here is perfectly symmetrical between the two possible results here, there is nothing in the state that could determine one or the other.[3] So if the observer has a single determinate measurement result, it must be determined by something nonphysical, presumably the observer's nonphysical state. And one is hence committed to a strong physical-nonphysical dualism.

---

[3] Note that even if the physical state were not perfectly symmetric, the physical state would not be sufficient to determine the single result of the measurement since, for the theory to be empirically adequate, each result associated with a positive amplitude must be statistically possible, so neither can be determined by the physical state that is predicted by the linear dynamics.

It is sometimes suggested that decoherence considerations might explain why there is a single determinate measurement record when the post-measurement state is one like (2). Note, however, that linear interactions with the environment will simply entangle more systems with the state of the compost system $F+M+S$. Hence such interactions will do nothing whatsoever to produce a physical state that describes a system with a single determinate measurement record. Rather, in order for the observer's complete state to describe a single determinate measurement record when such a post-measurement state obtains, one must add something to the physical description given by (2) that specifies the value of that record. On the assumption that (2) is the *complete physical state*, what one adds to get the observer's complete state all told will be a description of something nonphysical.

Given the four assumptions above, then, an observer's determinate measurement records must supervene on a nonphysical aspect of the observer's complete state. Further, one might argue, for quantum mechanics to be empirically adequate, this aspect of the complete state must also be something to which the observer has epistemic access. The most direct way to ensure this would be to stipulate that the value of an observer's measurement outcome is determined by the observer's mental state, then make this state determinate. On this line of argument, one again ends up committed to a strong variety of mind-body dualism, strong because since the determinate outcome of the observer's measurement fails to supervene on her physical state.

One might have thought that starting with a no-collapse view would prevent one from having to say when collapses occur, as Wigner was required to do, and hence allow one to avoid a commitment to quantum dualism. But this is one half-right. While one does not have the problem of saying when collapses occur, one does have the problem of saying how an observer can have a determinate measurement outcome without a collapse of the entangled superposition like (2) and providing something in the full state description on which the value of that outcome might supervene. The most direct way to get determinate records that are epistemically accessible is to add them as the experiential state of the observer, but if one one takes the quantum state to provide the observer's complete *physical* state, then one ends up committed to a strong mind-body dualism.[4]

Not only are the reason for the quantum dualisms different, there are also significant differences between the Wigner's type of dualism and the no-collapse

---

[4] Note that even if the physical state were not perfectly symmetric, the physical state would not be sufficient to determine the single result of the measurement since, for the theory to be empirically adequate, each result associated with a positive amplitude must be statistically possible, so neither can be determined by the physical state that is predicted by the linear dynamics.

dualism just described. Perhaps most salient is that, while minds cause collapses on Wigner's view, in the no-collapse dualism described, minds are just there to explain determinate measurement outcomes—they are just something on which determinate outcomes might supervene, and, as such, they need never affect physical states. Indeed, since the evolution of the physical state on a no-collapse theory is always given by the linear dynamics, which depends only on the physical state, there is a clear sense in which mental states cannot cause physical events here. The minds are just along for the ride following their own auxiliary dynamics, a dynamics that will be contingent on the evolution of the physical state.[5]

5 Considering the assumptions

If one does not like the strong variety of physical-nonphysical dualism they entail, and there is much not to like, one must give up one of the assumptions that go into the argument of the last section. Let's consider their relative plausibility.

State completeness is a leading candidate for sacrifice. This is the assumption that the standard quantum-mechanical state provides a complete and accurate representation of the physical state. This can be thought of as the assumption that there are no hidden variables unaccounted for in the standard quantum state. It has a long and distinguished history in the development of quantum mechanics. Taking the standard quantum description to be incomplete, Einstein famously denied this assumption. He believed that standard state was incomplete because it failed to specify the values of the real physical quantities that determined of measurement outcomes. At the time, Einstein was very much in the minority in criticizing this assumption. But, as we have seen here, there can be a significant conceptual cost to assuming that the quantum state provides a complete description of the *physical* state–in particular, one might then end up committed to there also being a *nonphysical* state.[6]

Since the linear dynamics entails post-measurement states like 2 and since such states do not select a single measurement result, if one insists on state completeness, one must either give up that there is a determinate measurement

---

[5] Of course, for a complete no-collapse theory one must clearly specify the dynamics for the evolution of mental states. Albert, and Loewer (1988) provide a concrete example for how to do this. See Barrett 1999 for a discussion of this and other options.

[6] See Einstein, Podolski, and Rosen 1935 for his extended argument that the standard quantum-mechanical state is incomplete.

result[7] or give up that there is just one measurement result[8] or give up on the complete *physical* state being sufficient to determine the measurement outcome.[9] None of these options is particularly attractive, and the last commits one to a physical-nonphysical dualism. But if one is going to add something to the full state description, then one might deny state completeness and make it something physical, but something beyond the standard quantum state, that determines measurement outcomes.

Bohmian mechanics provides a concrete example for how to do precisely this. On Bohm's theory, particle positions are always determinate, so, insofar as physical measurement records are determined by particle positions, measurement results are determinate as well.[10] More specifically, in the context of the Wigner's friend story, the theory explains how the position of the particles that make up the pointer of the measuring device M end up associated with one or the other of the two possible measurement results represented in the state 2 and how this association provides the friend *F* with an effective measurement record that one can expect to be well-correlated with whatever actions *F* makes on the basis of the value of that record. It also explains why one can expect such records to satisfy the standard quantum statistics. This is a long story involving a number of subtleties along the way, but since we know how to tell it, we know at least one concrete way to give up the state completeness assumption.[11]

Giving up the assumption of state completeness by adopting Bohmian mechanics, however, exchanges a strong physical-nonphysical dualism for a strong physical-physical dualism where the evolution of the wave function is described by one dynamical law and the motion of particles by another and where the positions of the particles do not supervene on the standard quantum mechanical state.[12]

---

[7] This is the strategy pursued by the so-called bare theory where one seeks to explain the belief that there is an ordinary determinate measurement outcome as an illusion predicted by the theory. See Albert 1992 or Barrett 1999 for descriptions.

[8] This is the strategy of the many-worlds interpretation where one has a world with a different measurement outcome corresponding to each term in the final superposition 2 written in the determine record basis. See Barrett 1999.

[9] This is the strategy of the single-mind and many-minds formulation of quantum mechanics. See Albert, and Loewer 1988.

[10] Bohmian mechanics needs the assumption determinate measurement outcomes supervene on determinate particle positions in the theory. While this is a plausible assumption given typical hamiltonians of interaction, it is also easy to say how such an assumption might fail. See, for example, Albert 1992 discussion of John 1 and 2.

[11] To start, see Bohm 1952 and the discussion of Bohmian mechanics in Barrett 1999.

[12] This line of argument is perhaps particularly compelling against Bohmians who are also wave-function realists. See Ney, and Albert 2013 for recent discussions of the metaphysics of

Indeed, one might argue that the wave-function/particle-position dualism of Bohmian mechanics looks very like the mind-body dualism of Albert and Loewer's (1988) single-mind theory. On each of these theories, the quantum-mechanical state evolves linearly and the hidden variable that determines measurement outcomes, particle positions in Bohm's theory and mental states on Albert and Loewer's theory, obey an auxiliary dynamics and remain always determinate.

One might further argue that the strong physical-physical dualism of Bohm's theory has no virtues over a variety of strong-mind body dualism. But I do not think that is right. Rather, it seems to me that there is an important distinction to be made between the two types of theory regarding the sort of account of mental states each allows. In particular, while a strong mind-body dualism of the sort that we have been discussing simply precludes such an explanation, Bohm's theory allows one to continue to seek an explanation of mental states by considering how they might supervene on physical states.

Another candidate one might sacrifice to avoid quantum dualism is the *no-collapse* assumption. This is the assumption that the linear dynamics provides a complete and accurate description of the evolution of the physical state for all systems at all times. This assumption, of course, is violated by the standard collapse formulation of quantum mechanics. Indeed, it is precisely this that leads to the quantum measurement problem in the first place—if the standard theory did not have the two mutually incompatible dynamical laws, one would not face the embarrassment of having to say when each obtains. And, of course, it was in addressing the measurement problem that Wigner argued that a commitment to a strong variety of mind-body dualism is required. Hence, one does not automatically escape a commitment to quantum dualism by allowing for collapses.

That said, we do know how to allow for collapses of the state without committing to a physical-nonphysical dualism. Collapse formulations of quantum mechanics like GRW (1986) provide prescriptions for how and when collapses occur without in any way appealing to a physical-nonphysical distinction. The original version of GRW, for example, stipulates that, while each typically obeys the linear dynamics, every particle has a very small, but positive, probability per unit time of collapsing to a state close to an eigenstate of position. The effect of this stochastic term in the dynamics is that while microscopic objects involving few particle will likely behave linearly, macroscopic objects involving many particles whose positions are strongly correlated will likely have an approximately determinate center of mass and behave quasi-classically. There perhaps a sort of dualism at work here, but it is purely physical and involves only the dynamics.

Bohmian mechanics and varieties of wave function realism in particular.

That said, there are good reasons not to like collapse theories at all, and hence to keep the no-collapse assumption. To begin, there is strong empirical support for the linear dynamics insofar it has always made the right empirical predictions whenever we have been able to isolate and control a physical system well enough to test it. Further, since it predicts the instantaneous collapse of specially extended systems, the collapse dynamics, as it stands, is incompatible with relativistic constraints.[13]

Concerning the *empirical consistency* assumption, it is unclear, at least to me, how one might sacrifice this on any empirically adequate formulation of quantum mechanics. This is the assumption that if a system is initially in a superposition of states corresponding to different eigenvalues of the observable being measured, then it is possible for the measurement to yield a result corresponding to any of those eigenvalues. The thought is that this is simply required by our experience given the way that we assign quantum-mechanical states. Even in Bohmian mechanics, where one has a fully deterministic theory and particle position as the only observable non-contextual property, if a system is initially represented by an effective wave function corresponding to different eigenvalues of the (possibly contextual) observable being measured, then there is a positive epistemic probability of the measurement yielding the (possibly contextual) result corresponding to any of those eigenvalues. The upshot is that it is difficult to see how one could given this up and still have something that is recognizable as quantum mechanics. If one gives a concrete proposal for how to do it, then one might consider the potential costs and benefits of sacrificing it.

Finally, the no branching assumption holds that the measurement interaction between an observer and a physical system typically yields a single determinate measurement result.[14] While this may seem entirely uncontentious, this assumption is famously given up on at least some reconstructions of Everett's pure wave mechanics, theories like the many-worlds interpretation.[15] Giving it up, however, comes with significant costs. Particularly salient among these, if one allows for branching where a copy of the initial observer determinately gets a different measurement outcome on each branch, it is difficult to make sense of the standard quantum probabilities. Indeed, the probability of an observer

---

[13] See Barrett 2014 for a recent discussion.

[14] The *typically* here is just supposed to cover the chance that something goes wrong with the measurement like the pointer breaking during the measurement yielding a state where one piece points at one result and the other at a different result.

[15] See Barrett, and Byrne 2012 for a description of Everett's own views, and Wallace 2012 and Saunders et al. 2010 for a recent discussion of the many-worlds interpretation.

getting each result is one insofar as one understands the observer as surviving the branching process at all, and this is not the statistical prediction one wants from quantum mechanics. Further, concerning the topic at hand, if one allows for branching, one avoids a strong physical-nonphysical dualism only to find oneself with a strong physical-physical pluralism of alternative branches, each with copies of the original observer.[16]

The upshot is that while one would face nontrivial costs giving up any of the assumptions that lead to physical-nonphysical dualism in the no-collapse argument, we know concretely how to give up at least three of the four explicit assumptions. That said, we have also seen that giving up one or more of these assumptions does not automatically prevent one from ending up committed to some variety of dualism by one's favored resolution to the measurement problem. I take strategic considerations regarding theory choice and metaphysical commitment here to be a matter of cost-benefit analysis given one's predictive and explanatory values. The interesting discussion regards the details of the expiatory tradeoffs involved the alternative options.

6 Discussion

On this view, the threat of a commitment to a strong variety of dualism in quantum mechanics ultimately results from competing explanatory demands. The linear dynamics is needed to explain interference effects. But it cannot, by itself, explain how a measurement interaction yields a single determinate measurement record. Hence, if one demands an explanation of determinate measurement records in terms of objective features of the world, then one must add something to the theory. It is this addition that threatens a commitment to some strong variety of dualism or metaphysical pluralism.[17]

---

[16] For discussions of the possible metaphysical commitments of such an approach see Saunders et al. 2010 and the conceptual introduction in Barrett, and Byrne 2012.

[17] Perhaps unsurprisingly, there are approaches to quantum mechanics where one does not make this sort of realist explanatory demand. On Richard Healey's (2012) pragmatist mechanics, for example, state attribution is not directly representational of the physical state of a system, and, hence, one does not require an account of determinate measurement records in terms of attributed states. And one might not worry much about the dynamics since a quantum state represents something more like an agent's epistemic state than the physical state of a system on such a view. There are, of course, significant explanatory costs giving up on direct physical description.

One might add the collapse dynamics to get determinate measurement records. But then one has a theory with two dynamical laws and one must clearly say when each obtains. And, as Wigner argued, given that one only wants, or needs, a system's state to collapse when it is observed, a natural way to accomplish this is to stipulate that conscious observers cause collapses by dint of being conscious. This provided Wigner with principled distinction between systems that cause collapses and those that do not, and the determinateness of the observer's mental state on this view is never threatened by physical superposition. And one ends up committed to a strong variety of mind-body dualism.

But, as we have seen, one can also find oneself committed to a strong variety of mind-body dualism if one takes the standard quantum-mechanical state to provide a complete physical description and denies that there are ever collapses of the quantum mechanical state. If the linear dynamics always obtains but a measurement interaction typically yields just a single measurement result, then, since that single outcome cannot typically be represented by the superposed physical state, it must be represented by a nonphysical state. And since the outcome is meant to explain the observer's experience, it must be a nonphysical state on which the observer's experience supervenes.

The point here is not that quantum mechanics requires a commitment to a strong variety of mind-body dualism. Rather, there remain a number of other options on the table. While quantum mechanics does push toward some variety of pluralism, it need not be a physical-nonphysical dualism. Bohmian mechanics illustrates how one might add something physical to the quantum state to provide something on which determinate measurement records might supervene in a no-collapse theory. One ends up on that account with a strong physical-physical dualism where one must specify both particle positions and the standard quantum state to characterize a physical system. And GRW-type spontaneous collapse theories illustrate how one might specify a single dynamical law that incorporates a sort of physical dualism in its sometimes linear and deterministic and other times nonlinear and stochastic dynamics. And in Bohmian mechanics and GRW, the sort of dualism involved is arguably much more modest than the sort of mind-body dualism required by Wigner's account or something like Albert and Loewer's single-mind theory. While mental states do not typically supervene on physical states in the latter theories, there is nothing in the structure of the former that would prevent this. Such formulations of quantum mechanics, then, exhibit the methodological virtue of not automatically precluding one from explaining mental states by describing how they supervene on physical states.

Whether a satisfactory resolution to the measurement problem should be taken to require some variety of mind-body dualism, physical-nonphysical dualism, or physical-physical dualism depends on the precise explanatory demands one places on quantum mechanics and on the background assumptions one finds plausible. My sense is that if a set of plausible-sounding assumptions commits one to a strong any sort of physical-nonphysical dualism where the nonphysical states do not supervene on the physical states, then one should sacrifice some of the plausible-sounding assumptions. The puzzle is what to sacrifice.

Given the options, I take the least objectionable to be either (1) sacrificing physical state completeness and adopting a hidden-variable theory like Bohmian mechanics hence opting for a physical-physical dualism or (2) sacrificing the requirement that the complete state determine a single measurement outcome and adopting something like Everett's pure wave mechanics. To be sure, each of these options comes with significant explanatory costs.[18] But quantum mechanics should be expected to requires one to sacrifice at least come of one's pre-theoretic intuitions.

---

[18] See the conceptual introduction of Barrett, and Byrne 2012 for a discussion of the conceptual costs of taking pure wave mechanics seriously.

References

Albert, D.Z. 1992, *Quantum Mechanics and Experience*, Cambridge, MA: Harvard University Press.

Albert, D.Z., and Loewer, B. 1988, "Interpreting the Many Worlds Interpretation", *Synthese* 77: 195–213.

Atmanspacher, H., and Primas, H. 2006, "Pauli's Ideas on Mind and Matter in the Context of Contemporary Science", *Journal of Consciousness Studies* 13 (3): 5–50.

Barrett, J.A., and Byrne P. 2012, *The Everett Interpretation of Quantum Mechanics: Collected Works 1955-1980 with Commentary*, Princeton: Princeton University Press.

Barrett, J.A. 1995, "The Single-Mind and Many-Minds Formulations of Quantum Mechanics", *Erkenntnis* 42: 89–105.

Barrett, J.A. 1999, *The Quantum Mechanics of Minds and Worlds*, Oxford: Oxford University Press.

Barrett, J.A. 2006, "A Quantum-Mechanical Argument for Mind-Body Dualism", *Erkenntnis* 65 (1): 97–115.

Bohm, D. 1952, "A Suggested Interpretation of Quantum Theory in Terms of 'Hidden Variables'", Parts I and II, *Physical Review* 85: 166–179, 180–193.

Einstein, A., Podolsky, B., and Rosen N. 1935, "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?", *Physical Review* 47: 777–780.

Enz, C.P. 2002, *No Time to be Brief: a Scientific Biography of Wolfgang Pauli*, Oxford: Oxford University Press.

Ghirardi, G.C., Rimini, A., and Weber, T. 1986, "Unified Dynamics for Microscopic and Macroscopic Systems", *Physical Review*, D 34: 470.

Healey, R. 2012, "Quantum Theory: A Pragmatist Approach", *British Journal for the Philosophy of Science*, 63 (4): 729–771. doi:10.1093/bjps/axr054.

Ney, A., and Albert D.Z. 2013 (eds.), *The Wave Function: Essays on the Metaphysics of Quantum Mechanics,* New York: Oxford University Press.

Neumann, J. von 1932, *Die mathematischen Grundlagen der Quantenmechanik*, Berlin: Springer. English translation: *Mathematical Foundations of Quantum Mechanics,* Princeton, New Jersey: Princeton University Press 1955.

Pauli, W. 1954, "Letter to Born, 31 March 1954", in M. Born (ed.) 1971, *The Born-Einstein Letters*, London: Walker and Co.

Saunders, S., Barrett J., Kent A., and Wallace D. (eds.) 2010, *Many Worlds? Everett, Quantum Theory, and Reality*, Oxford: Oxford University Press.

Wallace, D. 2012, *The Emergent Multiverse: Quantum Theory according to the Everett Interpretation*, Oxford: Oxford University Press.

Wigner, E.P. 1961, "Remarks on the Mind–Body Question", originally published in I.J. Good (ed.) 1961, *The Scientist Speculates*, London: Heinemann, 284–302. Reprinted in J.A. Wheeler, and W.H. Zurek (eds.) 1983, Quantum Theory and Measurement, Princeton: Princeton University Press, 168–181.