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RESEARCH ARTICLE

What Can Consciousness Anomalies Tell Us about Quantum Mechanics?

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Abstract—In this paper, I explore the link between consciousness and quantum mechanics. Often explanations that invoke consciousness to help explain some of the most perplexing aspects of quantum mechanics are not given serious attention. However, casual dismissal is perhaps unwarranted, given the persistence of the measurement problem, as well as the mysterious nature of consciousness. Using data accumulated from experiments in parapsychology, I examine what anomalous data with respect to consciousness might tell us about various explanations of quantum mechanics. I examine three categories of quantum mechanics interpretations that have some promise of fitting with this anomalous data. I conclude that explanations that posit a substratum of reality containing pure information or potentia, along the lines proposed by Bohm and Stapp, offer the best fit for various categories of this data.

Keywords: quantum mechanics—consciousness—parapsychology—psi

Introduction

Quantum mechanics is arguably the most successful theory in physics. Yet it remains the most mysterious one as well. The heart of the mystery is the measurement problem, the transition from the evolution of subatomic particles described by the Schrödinger equation to the results observed in experiments. After nearly a century of experimentation and debate, no consensus among physicists has emerged, and virtually all interpretations depart from classical physics, as well as from common sense reality. And yet the standard (Copenhagen) interpretation fits the data so well, with no apparent anomalies, that making a breakthrough in understanding may be very difficult.

One relatively early class of explanation (which never achieved much traction) was that somehow the consciousness of the observer played some role in the transition from the standard waveform to observed results. A number of the early founders of quantum mechanics, including Schrödinger and Pauli, were at various times sympathetic to some view of this sort. This line of thought took a more formal turn through Von Neumann's analysis, and was made more explicit by Wigner (1967). Stapp (2007) is a more recent advocate, building on Von Neumann's framework. Nevertheless, most physicists have been reluctant to embrace this possibility, and the field has continued to search for explanations that can be framed in more objective terms. However, alternative theories, such as Everett's "many worlds" interpretations, also have unattractive features.

Usually the possibility of some link with consciousness is dismissed without much argument or serious consideration. This might seem odd, given the persistence of the measurement problem as well as the radical nature of some of the alternatives. However, one obvious problem is that this explanation, at least in the consciousness collapses the waveform version, implies that distant stars beyond human perception might exist in a superposed state. Thus the theory would predict that there are some waveforms representing objects or systems in our universe that never collapse.

A more fundamental objection is that the word *consciousness* has no precise definition (Albert 1992:p.82). Hence our ability to construct a precise theory of how physical systems behave using a theory of consciousness would appear to be very difficult, if not impossible. Of course, the implications of this argument spill over into areas beyond quantum mechanics. If consciousness cannot be given precise meaning in ordinary language (or formal equations), then how can we have a theory of consciousness at all? This of course is an aspect of the well-known "hard-problem" that currently vexes the philosophy of mind field. We cannot doubt our subjective experience, yet how do we account for it within our current physical laws and frameworks (Nagel 1974, Chalmers 1995). Moreover, the fact that establishing a theory of consciousness is difficult (even impossible) does not eliminate the possibility that consciousness might be involved with quantum mechanics in some subtle way. And given the persistent mystery of quantum mechanics, it might be unwise to simply dismiss out of hand the possibility that something else that is mysterious, such as consciousness, may be involved.

While most scientists embrace the idea that consciousness is solely a product of brain processes, there is currently no consensus theory on how consciousness emerges. Currently, there is nothing we know from classical physics—from Newtonian laws of motion, Maxwell's equations for electromagnetism, to Einstein's laws of relativity—that suggests how complex collections of non-conscious particles can become conscious. Consciousness remains something of an anomaly to classical physics. None of the theories of consciousness currently on the table are in some sense truly grounded within these more basic laws of physics. This being the case, can we truly afford to casually dismiss interpretations that commit the sin of hinting at a link between consciousness and physical systems?

The paradoxical nature of quantum mechanics virtually assures that any explanation invokes a theoretical construction that clashes with our accustomed view of the world. As a result we have Schrödinger's Cat or Everett's interpretation that every possibility implied by the standard waveform is manifested. Against these sorts of alternatives, an explanation that posits links between consciousness and matter may not appear so radical. And while many of the hows and whats of consciousness remain unanswered, it nevertheless possesses a significant virtue that other alternatives lack: It is not merely a theoretical construction. The existence of consciousness, however mysterious, cannot be doubted.

Perhaps most importantly, there is a considerable amount of data that imply the existence of mind–matter links. Some of these data have developed from experiments intimately connected with quantum mechanics, such as the double-slit experiment. There is also a strong literature on other aspects of consciousness anomalies that suggests nonlocal connections between minds. While controversial, the anomalous features of these data provide some interesting possibilities for assessing alternative theories of quantum mechanics that are lacking from more conventional sources of evidence.

Thus closing the door on the possibility that our consciousness is involved in the transition from the standard waveform to observed experimental results might be premature. The primary focus of this paper is to consider which theories or explanations of quantum mechanics are most consistent with the psi data. I begin with a short review of the history of quantum mechanics, which includes a brief review of some of the alternative explanations. Next, I give a brief review of the empirical literature for some categories of psi, including mind–matter interactions. Because of the controversial nature of the psi data, I rely heavily on studies that have been grouped and analyzed in large numbers of experiments via meta-studies. I then examine what these data suggest for the various possible explanations of the measurement problem.

Later in the paper I argue that there are three classes of quantum mechanics explanations that appear to be consistent with at least some of the various psi categories that include telepathy, clairvoyance, precognition, presentiment, and mind–matter interaction. These three classes include

1) the consciousness collapses the waveform theory, usually associated with Wigner, but also recently advocated by Stapp; 2) Hameroff and Penrose's quantum theory of consciousness; and 3) frameworks that posit a fundamental level of reality as potentia or pure information.[1] The key question I pursue is to what degree each of these theories can account for these categories of psi.

A Brief Overview of Quantum Mechanics

Arguably, the various explanations for quantum mechanics can be grouped into three categories: collapse explanations, relative states (or many worlds) interpretations, and theories that depend on hidden variables or orders. The best-known collapse model is the conventional or Copenhagen interpretation, developed primarily by Bohr and Heisenberg. Numerous experiments have confirmed the validity of its mathematical rules. The Copenhagen interpretation frames a given quantum system as a wave function that represents a superposition of possible vector states of the system. Unlike classical systems, quantum systems are essentially probabilistic, with no way to predict which possible state will eventually manifest. According to Copenhagen, the wave function evolves smoothly in time until a measurement leads to the collapse of the waveform into the state that is observed.

This standard interpretation has been successful in describing the behavior of subatomic particles, but it remains unpalatable in a number of respects. The superposition of vector states suggests an ontology radically different from our common sense view of the world, as Schrödinger famously illustrated with his theoretical cat that is simultaneously alive and dead. Another problem is that a measurement changes the state of a system in a way that is not described by the theory itself. Because whatever measuring apparatus we choose is also composed of particles like those within the system under investigation, there is nothing to suggest how a physical measuring apparatus can somehow instigate a collapse of the wave function.

However, the special role that measurement plays in quantum theory has opened the door to an interesting, albeit controversial possibility: that the consciousness of the observer plays a role in the collapse. Marin (2009) describes that as early as the 1927 Solvay Congress, the early pioneers of quantum mechanics discussed ideas about quantum theory, mysticism, and consciousness. While Bohr was sympathetic to the need for quantum mechanics to accommodate additional laws that might accommodate consciousness, he nevertheless distanced himself from views that consciousness played an operative role in the waveform collapse.

Heisenberg and Pauli, who were influenced by Eastern philosophy, believed that a full understanding of quantum mechanics demanded a pragmatic path between opposing poles of rational science and mysticism. Schrödinger was also influenced by Eastern views and at a later point in his life appeared to embrace a view that consciousness had some influence on the quantum mechanical results. However, Einstein and Planck remained strongly critical of arguments that invoked consciousness involved in transition from waveform to experimental results.

Von Neumann's (1932) formal analysis of the measurement problem acknowledged the crucial role that the observer played with the waveform collapse. More explicit arguments that consciousness itself causes the waveform collapse were made by Wigner (1967). Stapp (1993) invoked Von Neumann's framework to investigate waveform collapse within the brain. Stapp proposed that the microscopic dimensions within neurons create quantum uncertainty, leading to a cloud of possible neurological states within the brain. According to Stapp, consciousness selects from possible brain states the one that is congruent with personal experience.

However, attempts have been made to remove the special role measurement has in the waveform collapse. Ghirardi, Rimini, and Weber (1986) attempted to achieve this by introducing nonlinear terms to the Schrödinger equation in a manner to help the waveform collapse spontaneously. The model specifies probabilities such that collapses are rare events for individual subatomic particles; however, objects with large numbers of particles undergo collapse very quickly. Overall, their rather ad hoc approach has led to other technical difficulties because the nature of the designed collapses does not provide a good match for the type of collapses implied by the data (Albert 1992:92–111).

Penrose (1989, 1994) also explores a theory of objective collapse, which in this case requires substantial innovation across a number of challenging areas, including quantum gravity, consciousness, and the neurological structures within the brain. Collaborations with Hameroff have led to a proposed model (Hameroff & Penrose 1996) in which conscious experience emerges from a sort of quantum computing within the brain's microtubules. That is, the brain's microtubules sustain coherent superposition of quantum states. Consciousness results through the gravitation-induced collapse of these states. Tegmark (2000) has argued that the brain's warm temperatures do not allow a sustained quantum collapse for the duration of time required for neural processing. However, Hagan, Hameroff, and Tuszynski (2002) have replied that under reasonable conditions, the superposition within microtubules might be sustained within the brain. In addition, theoretical arguments have been introduced that describe conditions where entanglement is supported in relatively warm and noisy environments (Hartman, Düer, & Briegel 2006, Li & Paraoanu 2009). Further, recent observations within the light-harvesting processes of photosynthesis have demonstrated quantum coherence between molecular structures (Hildner et al. 2013, Chin et al. 2013).

The second category of quantum mechanical explanation is generally associated with Everett (1957), whose interpretation dispenses with the collapse of the waveform altogether. That is, Everett argued that the standard wave function provides a complete description of the physical state of the world. The considerable appeal for many is to obtain a theory of quantum mechanics that is consistent and complete, without ill-defined notions of measurement or observers outside of the quantum system. However, the implication this raises is that the world is in a superposed state, even at the macroscopic level. Thus Everett's many-worlds proposal postulates that the world is in a superposition of states that are continuously evolving in different ways. The natural objection is that a theory that uses multiple worlds, rather than one world, to account for experimental observations is "ontologically extravagant." In addition, since all states are assumed to continue to exist and evolve simultaneously, it is unclear how to interpret the probabilities associated with the standard waveform.

The last category of quantum mechanics interpretations also attempts to avoid the superposition and waveform collapse style interpretation, however using an approach that has the appearance of greater congruence with our more familiar ontology. This includes hidden variables or processes that invoke deeper realities comprising information. Bohm (1952) followed up on De Broglie's pilot wave theory to provide a deterministic theory of quantum mechanics. Within this framework, subatomic particles such as electrons have definite positions and trajectories and are guided by a quantum potential function in a way that conforms to the statistical predictions of the standard theory. Thus the Schrödinger's Cat paradox is avoided and a more classical ontology is retained. Bohm derived the statistical uncertainty observed in experiments from the uncertainty of the particle's position. Despite its attractive features, Bohm's hidden variables theory has not developed traction, perhaps due to Von Neumann's argument that hidden variables is incompatible with quantum mechanics.[2]

Bohm and Hiley (1993) expanded on Bohm's earlier work with the quantum potential function. They argued that the quantum potential, as well as the Schrödinger equation, functioned in a higher-dimensional reality, which was responsible for the nonlocal and holistic features of quantum mechanics. Instead of a waveform collapse, Bohm and Hiley described how "active information" guides subatomic particles to "select" various possible states or events over others. Further, this "active information" depends on the features of the whole system, which encompasses both the measuring apparatus and the object under study, and cannot therefore be analyzed in terms of individual particles. Thus the system of observation and the objects under investigation compose an undivided whole, which simply cannot be reduced to an analysis of component parts.

Bohm and Hiley (1993) also incorporated what Bohm (1980) termed the "implicate order," an enfolded or hidden, organizing source of information existing within a higher dimensional "space" through which the physical world emerges. Bohm described the implicate order as the source of the "active information" for the quantum potential function and thus may be understood as the ground of all existence. According to Bohm, everything in our physical world (what he terms the explicate order) emerges from this underlying ground, which provides the bridge between mind and matter. Bohm and Hiley (1993) conjectured that mind and matter are two sides of an overall process:

> Active information can serve as a kind of bridge between these two sides. These latter are however inseparable, in the sense, for example, that information contained in thought, which we feel to be on the mental side, is at the same time a related neurophysiologic, chemical, and physical activity. (Bohm & Hiley 1993:384)

Aspects of this later work retain a deterministic flavor through his choice of metaphors to describe the implicate order.[3] However, in other work, Bohm clarifies that the implicate order was a realm of possibility:

> we are saying that the implicate order will have to contain within itself all possible features of the explicate order as potentialities, along with the principles determining which of these features will become actual. (Bohm 1987:41)

Bohm has not always been consistent in whether or not probability within quantum systems can be understood in some sense to be intrinsic or fundamental. Reflecting Bohm's earlier work, Bohm and Hiley (1993) state that probability is "clearly not essentially different from that used in statistical ensembles. Thus in no sense is probability being regarded as a fundamental concept." (p. 42) However, in his later work, Bohm appears to seek a flexible framework that can accommodate both deterministic and indeterministic processes, and his notion of the implicate order certainly appears to embrace potential at a metaphysical level. As Pylkkänen (2007) notes, "Bohm assumes in an Aristotelian fashion that there exist potentialities in the holomovements (implicate order) . . . that 'actualizes' when it unfolds to the explicate order." (p. 26). Of course, any bridge between mind and matter must in some sense possess intrinsic probability if mind possesses free agency.

Stapp (2007) has also attempted to incorporate a notion of pure potential as an underlying reality within quantum mechanics. To be more precise, using his own terminology, Stapp terms potentia as a domain of "real tendencies" that are associated with subatomic particles and that actualize when observation occurs.[4] He utilizes this concept of potentia within a framework that borrows heavily from Whitehead's process philosophy (Whitehead 1929), which he sees as possessing key parallels with Tomonga–Schwinger's quantum field theory. The foundation of Whitehead's process philosophy consists of the distinction between "continuous potentialities" and "atomic actualities." Stapp proceeds to sketch reality as an unfolding process with physical events interacting with potentia, which in turn causes new events to emerge. In Stapp's words: "This basic autogenetic process creates the new actual entity which, upon the completion of its creation, contributes to the potentialities for the succeeding actual entities" (Stapp 2007:90).

In a number of ways, Stapp's exploration resembles Bohm's (as well as Bohm and Hiley's). Stapp borrows from Whitehead's ontology the notion that reality or "actual occasions" comprise psychological and physical aspects. Like Bohm's implicate order, the potentia which precedes actual occasions is neutral with respect to mind and matter and represents a mode of existence where the two are unseparated. In addition, this potentia possesses nonlocal and wholistic features that provide the foundation of such quantum features as entanglement.

However, unlike Bohm's interpretation, Stapp retains the more traditional interpretation of waveform collapse. Also, according to Stapp, we need not think of this potentia as a substance distinct from mind and matter within this framework of process; thus he argues that dualism suffices, instead of neutral monism or dual aspect, which has been used to characterize Bohm's (1980) work, as well as Bohm and Hiley's (1993).

The Evidence for Psi

Currently psi data remains controversial even though for many cases the evidence meets or exceeds the levels of acceptable statistical significance attained for more conventional subjects (Utts 1991). Meta-analysis, which combines diverse studies from numerous experimenters and laboratories, is available for a number of categories of psi, including telepathy, clairvoyance, precognition, presentiment, and some types of mind–matter interaction. The available meta-analyses strengthen the power of the data at hand for these categories of psi. Here I will give a brief overview of the evidence.[5]

Meta-analysis available on remote viewing as well as various categories of telepathy shows highly significant effects. On surveying the evidence for remote viewing, Utts (1996) concluded that the statistical effects were so overwhelming that the probability that chance alone could account for the effects is 10−20%. The cases for telepathy include J. B. Rhine's method of "forced-choice" card guessing, which employed the earliest uses of statistical analysis on laboratory experiments.[6] In addition, telepathy occurring during the dreaming state was extensively studied by Ullman and Kripner from 1966 to 1972. A meta-analysis by Radin (1997) found an overall success rate at 63% (where chance would be 50%), with odds at 1 in 75 million that the results could be attributable to chance.[7] Perhaps the strongest evidence for telepathy is provided with the ganzfeld method, which uses a technique of inducing a mild altered state of consciousness to facilitate a link between sender and receiver. Tressoldi, Storm, and Radin (2010) recently examined all the ganzfeld evidence reported in 108 publications and conducted from 1974 through 2008 and found an overall hit rate across all of the data of 31.5%, above chance expectation of 25%, with a p value of 1.0×10^{-11}.

Meta-analysis also confirms some forms of precognition and presentiment. Honorton and Ferrari (1989) analyzed forced-choice precognition experiments between 1935 and 1987 and found a small, but highly significant effect ($p = 6.3 \times 10^{-25}$). Bem (2011) conducted nine precognition experiments, which essentially "time-reversed" well-known psychological effects so that the individual's response was obtained before casual stimulus occurred. He reported that all but one of the experiments yielded statistically significant results, and the corresponding statistic across all of the experiments yielded $p = 1.34 \times 10^{-11}$.[8] Another psi effect suggesting sensitivity of future events is presentiment, which focuses on physiological effects indicating emotional arousal. Recently, Mossbridge, Tressoldi, and Utts (2012) conducted a meta-analysis of reports published between 1978 and 2010 and found evidence of shifts in physiological activity prior to stimulus, indicating an "unexplained anticipatory effect."[9]

The possibility that human intention can influence physical processes has been investigated using random number generator (RNG) devices. These devices, which incorporate quantum processes in their design, produce true random streams of 1s and 0s. Recently Bosch, Steinkamp, and Boller (2006) gathered 380 known mind–matter experiments using RNG devices and confirmed small, but statistically significant effects. However, the authors were cautious in drawing their conclusion, highlighting the heterogeneous nature of the studies. After noting the overall high quality of the studies, they suggested that publication bias might be the most plausible explanation. However, Radin et al. (2006) argued that invoking publication bias would require an implausible number (1,500) of unpublished studies.[10]

Another category of experiments considers the influence of group emotions or shared consciousness on RNG devices. Typically, these experiments have tested whether groups of individuals via some sort of shared experience or group emotion can influence RNG devices with no intention or awareness of such devices. Thus shifts in emotions shared across large groups might affect the underlying tendencies governing physical processes in the environment of those populations. Nelson and others have developed the Global Consciousness Project (GCP) to monitor the effects of populations, responding to important world events, affecting a global network of devices. Nelson and Bancel (2008) reported the results of the GCP, recording random streams generated during 256 events in its first nine years of operation. The results strongly support the hypothesis of coherent attention or emotional response corresponding to deviations in network output; the combined statistic exceeds what chance would predict by 4.5 standard deviations, with a corresponding p-value of 3×10^{-6}.

Overall, we have meta-analysis across diverse experimenters and laboratories confirming significant results for telepathy, clairvoyance, precognition, presentiment, and mind–matter interaction. As discussed, this includes two categories of mind–matter experiments: 1) those that test the effects of mental intention on an inherently random process; and 2) those that test the effects of shared experience or group emotion on RNG output. I will proceed to explore what these various psi data might tell us about the competing interpretations of quantum mechanics.

What Can the Psi Data Tell Us?

What implications do the psi data have for the various interpretations of quantum mechanics reviewed previously? Let's begin with the theories that appear most at odds with the psi data and then proceed to examine more closely those that hold at least some promise toward fitting the data. The class of explanations influenced by Everett's interpretation of many worlds appears to be the least consistent with the psi data. This is because the implications of the mind–matter data are that, either through mental intentions or through shared emotional resonance, the underlying probabilities governing quantum mechanical systems can be affected. Of course, the role that probabilities play in the Everett world is an unresolved question and problematic even for advocates of that interpretation (Sebens & Carroll 2014). However, if some kind of mental or emotional impulse can affect those probabilities, then the problem grows considerably. Whole parallel realities cannot simply be shifted or made less likely due to the contents of someone's mind.

The results of mind–matter experiments also cast doubt on the GRW (this author) style collapse models, which engineer waveform collapse to be exclusively dependent on the density of subatomic particles. Such models also cannot account for experiments where mental intention can influence quantum-based random number generators. Other collapse models that rely only on physical processes also appear inconsistent with experimental findings that suggest mind has an effect on such quantum processes. This argument also applies to versions of the Copenhagen interpretation, which rely on the measurement apparatus itself rather than a conscious observer. The results of these experiments suggest that consciousness plays some role.

There remain three classes of explanation of quantum mechanics from the ones reviewed previously:

1) the quantum waveform is collapsed somehow as the consciousness of the observer participates in measurement
2) the objective reduction model by Hameroff and Penrose; and
3) hidden variables or hidden order type models.

Each of these allows links with consciousness that the other possible explanations do not. Further, each of these three has already been invoked to explain some aspect of psi phenomenon. It is important to note, however, that none of these are ad hoc constructions developed to explain some aspect of psi. Each is a theory or framework developed to help us account for the measurement problem of quantum mechanics. We'll explore each of these in some depth to determine which one might best provide an understanding of psi.

My strategy in dealing with these three remaining theories is not to focus on whether they supply a satisfactory explanation of the measurement problem. Much has already been written about the relative advantages and shortcomings of these theories. Here, I will instead concentrate on the degree to which these theories or frameworks are consistent with the categories of psi we've reviewed in the previous section.

1) Consciousness Collapses Waveform Theories

Explanations that invoke consciousness as a primary agent that triggers the collapse of the waveform (through some unspecified means) are perhaps the best known of the three classes of explanations that we explore here more fully. This is probably due to its close association with the Copenhagen interpretation, as well as its prominence in popular media. This class of explanation has been cited in the psi literature, especially in association with mind–matter interaction experiments.[11]

The usual idea is that somehow conscious attention on a quantum event triggers a collapse of the standard waveform into the results of the experiments observed. Traditionally, this explanation has been invoked to describe how an observer affects the waveform of a physical process, such as an experiment. As we've discussed, Stapp's framework applies within the neurobiology of the brain. In all cases, the collapse occurs as consciousness or mind interacts with the waveform. This description invokes an explicitly dualistic view of the mind–body question, and advocates may argue that this explanation helps to resolve two problems that confront dualism: 1) how the two disparate substances of mind and matter can possibly interact and 2) how this interaction might occur without committing a violation to the conservation laws of energy and matter.[12]

However, the mind–matter interaction experiments reviewed in the previous section require something else: that a conscious intention directs the collapse in a particular direction. This would imply that a conscious intention might bias the Born probabilities associated with the waveform in the direction congruent with the intention.[13] Thus a waveform collapse theory that incorporates consciousness might provide a serviceable explanation for such mind–matter experiments as Radin et al. (2013) and Jahn et. al. (1997). What exactly this implies when conscious attention is present but without a particular intention is unclear. Presumably, such a condition would lead to a collapse without biasing the probabilities for certain outcomes in a particular direction.

This theory does have the unpalatable shortcoming that it inherits from all versions of collapse stories, which invoke an observer. That is, what are we to make of events such as distant galaxies? Are such objects in a state of quantum superposition? Do they require an observer to have the definite, tangible features that objects we perceive typically have? This undesirable feature of collapse theories is likely an important factor in why cosmological physicists are drawn to the Everett framework, which avoids invoking waveform collapse.

A puzzling characteristic of this explanation is that while consciousness appears to have considerable power in collapsing the waveform, its corresponding ability to bias the underlying probabilities within the waveform is rather weak. That is, the ability of consciousness to reduce the wave packet to observable particles is very substantial, to say the least, since for this class of explanation, no object or event remains in quantum superposition once it is observed, no matter how far away. However, our review of the accumulated evidence on mind–matter experiments suggests that mental intention affects random outcomes with a much smaller effect. This curious feature is not necessarily fatal to the case for this type of explanation, but such observational styled theories must evolve to explain the disparity between the two effects.

In addition to mind–matter interaction, this class of explanation, with its dualistic framework, suggests how anomalous transfers of information might occur in ganzfeld and other telepathy experiments. Dualism suggests that mind is not simply a product of physical processes within the brain. If we take another step and conjecture that consciousness possesses a nonlocal aspect (as quantum mechanics appears to exhibit), then we may have a framework that supports some anomalous communication between minds.

However, clairvoyance, the ability for minds to access anomalous information from the environment, is more problematic. Examples in remote viewing suggest that minds can perceive representations of the environment, even at great distances. Do we count such anomalous transfers of information as observations that are inducing the collapse of a waveform associated with some distant object? If so, how do we interpret misses that also occur in the experiments? Counting misses as some type of observation would seem nonsensical. Perhaps we should not treat anything regarding clairvoyance as an observation, hits or misses. But the evidence does suggest anomalous information transfer at a rate above chance (Bem & Honorton 1994). Is it reasonable to think that accessing information in the form of clairvoyance should be associated with some sort of waveform collapse?

It might seem curious that clairvoyance appears to be a harder fit in this quantum mechanical framework than telepathy is. Telepathy and clairvoyance appear to have a close relationship to one another. Disentangling the effects of clairvoyance from telepathy has proven to be very difficult (Radin 1997:93). The problematic differences that this explanation has in accounting for telepathy and clairvoyance can be attributed to the asymmetric relationship between mind and matter posited by this framework: The physical world remains in quantum superposition until it is observed by a mind.

Precognition and presentiment also present difficulties for this interpretation. One challenge here is that these categories of psi imply a flow of information backward in time, which has troublesome implications for causality. For example, suppose I have precognition of a future event where my front tire blows out on a long trip away from home. Using this information, I replace my worn out tire with a new one and prevent the blowout from occurring. But now my precognition has no basis.

Could we apply this 'consciousness causes the waveform collapse' interpretation against precognition or presentiment so that an observation of a future event collapses the waveform of that event? Recall that this interpretation suggests that the waveform collapse occurs instantaneously. Imposing this condition on future events seems problematic. However, some psi researchers have suggested that the operation of time may be symmetric (that is, time flows both forward and backwards). Bierman (2010, 2015) argues that while we are generally not aware of physical processes that move backward in time, most equations in physics do not impose such constraints as time symmetry. According to Bierman, precognition and presentiment represent cases where consciousness allows awareness of a more symmetric time flow, thus allowing perception of information regarding future events. Perhaps using this argument we might fit precognition and presentiment into a "consciousness collapses the waveform" framework. However, Bierman (2015) acknowledges that such a theory does not yet resolve time paradoxes such as the one I just described. Further, we should note that the collapse of the waveform described in the Copenhagen interpretation does appear to be inherently time-asymmetric (unlike most equations in classical physics). Thus integrating a theory that posits consciousness restoring time symmetry within an explanation where consciousness reduces the wave packet of probabilities for a quantum event appears extremely awkward, to say the least.[14]

Perhaps we might get around the problems raised by clairvoyance and precognition by somehow extending the framework. One way we might proceed is to posit that these types of psi involve accessing some representation of the waveform, some shadow reality that contains information about it and which we can access without triggering a collapse. If somehow our accessing this underlying level of reality meant that we could perceive the probabilities associated with the waveform, we might be able to accommodate such phenomenon as clairvoyance and precognition. In this case, clairvoyance would involve accessing the probabilities about events or facts about the environment, and precognition would involve perceiving current probabilities about future events. Unfortunately, this requires an additional underlying substance or stratum of reality that appears to be outside the dualistic framework of the 'consciousness collapses the waveform' explanation.

One last psi category for us to consider is the effects of group emotion or resonance on random number generators, such as the Global Consciousness Project. This appears to be another psi category that gives a strong challenge to this brand of explanation. The results of these experiments suggest that participants in the experiments (through experiencing common emotions) are influencing changes in random number devices that they have no knowledge of. These experiments are especially relevant for our purposes because the devices used incorporate technology that is based on quantum mechanics. Unlike more conventional mind–matter experiments, direct (or indirect) observation of these devices by the participants plays no role. The ‘consciousness collapses the waveform’ explanation does not appear to provide the right framework for this type of psi phenomenon.

2) Hameroff and Penrose Objective Reduction (OR)

Recall that the theory developed by Hameroff and Penrose builds on Penrose’s earlier work, which conjectures an objective collapse of the waveform, resulting from the interaction of quantum gravity with quantum superposition. A conscious observer plays no role in the waveform collapse. Conscious experience emerges in their model as organized networks of quantum superposition, sustained within microtubules, collapse within the brain.

At the moment, it isn’t clear how the authors would explain psi in their work. However, Hameroff and Penrose (2014) have suggested that their model is consistent with presentiment experiments reported by Bem (2011). The authors have recognized features of quantum mechanics where the quantum state of various particles within a given system depends upon the state of other particles within that system. While not completely understood, such entanglement has been verified empirically and suggests a nonlocal connection between particles within a quantum system. Hameroff has suggested that that their theory is consistent with most kinds of psi phenomenon and that quantum entanglement likely plays a central role, providing a link between their model and anomalous information transfer that psi suggests.[15] Thus the proposal by Hameroff and Penrose that invokes a process of quantum superposition holds a possibility of our minds accessing nonlocal information via quantum entanglement with distant particles in the environment.

It is well established, however, that entanglement between particles cannot be utilized somehow to allow virtually instantaneous transmission of information. This might appear to prevent us from using entanglement as a mechanism for nonlocal transfer of information that psi represents. But given the psi data that we’ve reviewed, let us explore the possibility that entanglement can be used to account for psi.

Perhaps unconscious processes within the brain might access nonlocal correlations between networks of superposed microtubules quantum entangled with other particles in the environment. An explanation for clairvoyance could proceed from such a possibility. Thus nonlocal information, collected within this organized network of structures, and perhaps associated with the unconscious processes within the brain, could become accessible to the mind with orchestrated objective collapse. Remote viewing of a building hundreds of miles away would presumably require quantum entanglement between the particles that compose the building and groupings of mictrotubules in coherent quantum superposition prior to orchestrated objective reduction that leads to the conscious experience of a clairvoyant perception of the building. A central assumption here is that somehow structures within the brain are able to collect, process, and create meaning from this information accessed via entanglement.

However, there are additional problems that invoking entanglement as a theory of psi must address. Perhaps the first one is whether entanglement between particles as we've described can be sustained over long distances in the rather hot and noisy world we inhabit. As I've suggested, some theoretical work suggests that quantum entanglement can persist in relatively warm and noisy environments. However, the authors I've cited above posit conditions that our world outside the laboratory fail to meet. And currently all quantum theory agrees that entanglement between a quantum superposed system with large, macro scale objects in the environment instantly triggers decoherence. Unless such decoherence is accompanied by the nonlocal transfer of information required to explain something like clairvoyance, entanglement as we understand it is unlikely to help us understand psi.

However, let's suppose that entanglement to some degree can be sustained in the warm and noisy environment of our world, and that the decoherence associated with interaction between groupings of superposed microtubules in the brain and the environment is accompanied by some nonlocal transfer of information from which unconscious processes within the brain construct some meaning. Another question that arises is whether entanglement exists in our macro world to such a degree to support something like the ability to remote view a building many miles away. Away from the physics lab, entanglement doesn't appear to play a role in our experience whatsoever. It's difficult to see how Hameroff and Penrose's model, where objective reduction continuously occurs everywhere due to the interaction of quantum superposition with gravity, would provide a sufficient level of quantum superposition to support the necessary entanglement required for psi to operate over large distances.

If we somehow get past this problem, another concern arises: how do we extract meaningful information from such an entangled world? Hameroff and Penrose developed a sophisticated model within the brain describing networks of microtubules in coherent superposition, through which our conscious experience emerges. However, no such coherent control of entangled particles exists outside the brain. The entanglement of the physical world, assuming that a sufficient portion remains in superposition, would presumably entail highly complex relationships across vast numbers of tiny particles. How would the mind sift through this inherently noisy field and access coherent and meaningful information? Further, presumably extracting meaningful information would grow in difficulty with the distance separating minds (objects).[16] However, the experimental data on telepathy and clairvoyance do not show distance effects.

Thus, while their model demonstrates considerable sophistication toward the process of generating and processing meaningful information within the brain, this requires a controlled and coherent collection of superposed structures that does not exist outside the brain. Even allowing for considerable entanglement between brain structures and the environment, it's difficult to see how meaningful and coherent information can be transmitted across great distances. Perhaps Penrose's Platonic world can be used to supplement the role of entanglement and provide a channel for nonlocal information. However, Penrose has not suggested that his conception of a Platonic world allows for this. Overall, the problem of invoking quantum entanglement without some additional modification to their model appears to be a significant hindrance for Hameroff and Penrose to explain psi phenomenon.

3) Theories of Hidden Order or Potentia

The remaining class of explanations includes theories that posit an underlying order or stratum of reality that might be described as potentia or active information. This includes Bohm and Hiley's (1993) framework, which incorporates Bohm's (1980) implicate order, as well as Stapp (2007) invoking a notion of potentia within Whitehead's process reality. Ullman (2006) has speculated that Bohm's implicate order may be useful for explaining his work on dream telepathy. Talbot (1992) has invoked Bohm's implicate order as well as his use of the hologram as a conceptual tool in order to explore an ontology capable of explaining several different psi phenomenon.

We can recall that Bohm (1980) proposed an implicate order functioning in a high dimensional reality and exhibiting nonlocal and holistic features. This underlying ground, the source for what Bohm terms "active information," is the foundation for consciousness as well as subatomic particles composing matter. Departing from mechanistic approaches, Bohm describes a holistic process of unfolding from potentialities of the implicate order to our familiar world (explicate order).

I'll proceed with something close to Bohm's implicate order that emphasizes the notion of a potentia underlying the standard waveform, which therefore incorporates an important element in Stapp's model as well. For our purposes here, I'll attempt a relatively simple framework that incorporates the work of Bohm, Hiley, and Stapp, but which may depart from those frameworks in small ways.[17] For our purposes here, I posit a neutral foundation underlying mind and matter as active information, which possesses the nonlocal and holistic properties exhibited in quantum mechanics. This more fundamental level of reality also possesses the precursors of our consciousness as well as the potentia, the real tendencies or probabilities underlying physical reality, which the standard waveform reflects.

I submit that this framework fits well with the psi categories we've reviewed. First, let's consider telepathy and clairvoyance. As I have proposed, this hidden, foundational level of reality is a realm of information supporting the world we experience. With our minds in contact with this neutral bridge, we can share, to a small or modest degree perhaps, information that influences other minds, as well as features of the environment. The intrinsic probabilistic nature of this foundational level of reality fits well not only with the quantum mechanical literature, but also the psi empirical literature. Probabilities are inextricably linked with all of the psi data obtained through laboratory research. This is usually understood as an inevitable result of extracting information from a noisy process. This framework of active information suggests another interpretation: Probabilities, as quantum mechanics suggests, may be intrinsic to the underlying reality that binds us together.

Recall my effort to solve the problem that the 'collapse the waveform' theory had with clairvoyance (as well as with precognition and presentiment). This involved extending the model to allow for perceiving underlying probabilities about the state of the world (or future events of the world). While the effort floundered with the 'collapse' framework, it fits perfectly well here. What apparently is required is a deeper or more fundamental level of reality comprising information, which includes the probabilities underlying the phenomenon of our experience. Thus precognition and presentiment can be understood as involving a perception of current probabilities of future events. Note that no time or causal paradoxes arise with such an interpretation.

Bohm noted that his framework suggested interesting implications for thinking about time (Bohm 1980:211). That is, time may be understood to be more derivative with respect to the higher-dimensional ground of the implicate order. Thus what we have been describing as active information may be sourced or functioning in an order of reality outside of time in some sense. While this multi-dimensional reality may be difficult for us to comprehend, perhaps some aspect of our perception can access it in ways that result in precognition or presentiment.

We have noted that the nonlocal nature of this foundational stratum supports a mechanism of information flow that does not diminish with distance. The question arises, however, what is different here from the situation of using entangled particles to convey information as we explored with Penrose and Hameroff. In that case, it appears that encounters with unrelated particles is unavoidable, so the level of noise must ultimately overwhelm the information we are attempting to extract. Accounting for the lack of distance effects reported in telepathy and clairvoyance requires something else. I presume a field of pure, nonlocal information provides a better explanation.

This framework suggests that mind–matter interaction can be explained by exploiting the intimate relationship between conscious experience and a nonlocal proto-conscious field containing the probabilities underlying physical systems. The framework suggests that intention can affect those probabilities. Indeed, Jahn and Dunne (2011) explored various experiments that demonstrated such a link between intention and random processes rooted in quantum mechanics. Other random experiments, such as throwing dice, might be explained through intrinsic randomness that is nevertheless involved. Essentially, an individual's intention must be linked with the underlying probabilities residing within the proposed proto-conscious field that is associated with the event. This interpretation linking conscious intention with the probabilistic world of quantum mechanics may help place testable restrictions on observations for future mind–matter experiments.

Let's finally consider the influence on random number devices from group emotions or shared consciousness. Recall the unusual nature of this particular sort of psi: groups of individuals sharing a common emotion influencing the outputs of random number generators with no intention or awareness of such devices. Our framework suggests that changes in emotions shared by relatively large groups may influence the proto-conscious foundation of mind and matter. Thus shifts in emotions shared across large groups might affect the underlying tendencies governing physical processes in the environment of those populations.

Table 1 summarizes my arguments on how well these various explanations of quantum mechanics fit with the categories of psi. The objective collapse theory proposed by Hameroff and Penrose fared worst on this score; the explanation doesn't appear capable of explaining any psi, due to the difficulties we discussed invoking entanglement. Theories

TABLE 1
How Consistent Are the Three Explanations of Quantum Mechanics with the Psi Data?

Psi Category	Consciousness Collapses the Waveform	Hameroff and Penrose Objective Collapse	Theories of Hidden Order or Potentia
Telepathy	X		X
Remote viewing			X
Precognition			X
Mind–matter	X		X
Group resonance			X

that posit that consciousness collapses the waveform perform better. This class of theory holds promise, accounting for telepathy and mind–matter interactions. However, as we discussed, this type of theory appears to be an awkward fit with respect to remote viewing, precognition, and shifts in RNG devices due to group resonance. Explanations such as Bohm's implicate order, which posit an underlying strata of pure information or potentia, appear to hold more promise in accounting for these various categories of psi.

Discussion

One surprising result here is that our arguments regarding these last three explanations ultimately did not depend so much crucially on the mind–matter interaction data often invoked to justify explanations invoking consciousness playing some role in waveform collapse. Once we moved beyond the Everett and GRW objective collapse theories, the evidence from mind–matter experiments does not play such a crucial role. This is a helpful detail to note, given that the mind–matter data is arguably not quite as robust as the other categories of psi. Although I've argued that the mind–matter interaction and group resonance evidence is substantial enough to help us weigh the different interpretations of quantum mechanics, one could put less weight on it and still reach the same conclusion.

Overall, the anomalous data we've discussed appears to best support a framework of active information, which incorporates the probabilities reflected in the waveform, similar to Bohm's implicate order and Stapp's potentia. This underlying strata of pure information possesses a number of key features in both Bohm's and Stapp's frameworks. In addition to containing an intrinsic probabilistic nature, this strata also possesses mind-like or proto-conscious features that support the precursors of consciousness. Also, both Bohm and Stapp highlight nonlocal and holistic attributes. This framework supports an accounting of quantum mechanics that does not require sharp clashes with our sense of reality.

As discussed, this class of model does not currently rank very high on most quantum physicists' list of preferred explanations. This may be due to its radical departure from more conventional and materialistic approaches. However, some radical change from the status quo is likely necessary to explain the two greatest mysteries confronting science: quantum mechanics and the hard problem of consciousness. Using anomalous data involving consciousness that has been subjected to rigorous statistical analysis across diverse laboratories is arguably a fruitful approach.

We might also consider some common threads the three classes of explanations I've discussed in more depth share. First, Plato's argument that underlying our physical world is a realm of forms undeniably still has a strong influence on such classes of explanations. Recall that Penrose argues that something like a Platonic world is the source of mathematical order. Penrose and Hameroff speculate that a Platonic order informs how consciousness emerges through objective reduction. Stapp also has acknowledged that Heisenberg referenced Plato's world of forms in a comment on Stapp's work. And Bohm's implicate order, the source of active information and the potentia underlying quantum processes, may be considered to be a close relative of a Platonic realm.

Another common thread among these works is the process philosophy of Alfred North Whitehead. As I've discussed, Stapp sees direct parallels between Tomanaga–Shwinger relativistic quantum field theory and Whitehead's process philosophy. Hameroff has suggested that their objective reduction framework, which suggests all things undergo something of an alternation between quantum superposition and some degree of consciousness, fits very well into Whitehead's framework. Bohm's implicate order, describing a fundamental folding and unfolding of order, can also be understood as a contribution within process philosophy. As Pylkkänen (2007) notes, Bohm's proposal of a movement underlying dual aspects of mind and matter has close parallels with Aristotle and Spinoza, as well as more recently with Russell (p. 37).

The links with Plato's ideas and Whitehead's process philosophy help to highlight an arguably unpalatable feature: the inherently mysterious and hidden aspect of these theories. This manifests as the inherent holistic and non-reductionist nature of Bohm's implicate order, which undoubtedly hinders its ability to generate experiments.

Bohm's interpretation invoking a hidden stratum of reality as a source of order stems largely from his efforts to interpret quantum mechanics using an ontology that in important ways is congruent with reality as we experience it. Thus, instead of positing our world in quantum superposition or splitting into parallel realities, Bohm sought an interpretation more consistent with our experience by essentially pushing the paradoxical features down into deeper levels of reality. Our physical world, as well as the equations of classical physics that attempt to explain it, exist in 4 dimensions (3 spatial and 1 temporal). However, Bohm recognized that the standard quantum waveform, as well as his proposed guidance equation, required a much larger number of dimensions due to its nonlocal and holistic features. For Bohm, this points to a deeper, higher dimensional reality as the foundation of our world. Thus he believed that conventional mathematical or mechanistic frameworks were probably inadequate for a complete understanding; hence the necessity for using metaphors in exploring the nature of the implicate order.

One example of a metaphor used by Bohm is the hologram, which contains information (through light interference patterns) structured in an inherently holistic way. Each part of the hologram, no matter how small, contains information regarding the whole. With the hologram metaphor, Bohm was attempting to illustrate how it was possible for particles in a quantum system to be connected with a much larger system.

We might consider further what this metaphor might imply for our conscious experiences and the psi data that we have briefly examined. Within a phenomenological framework, we can speculate that our thoughts or moments of experience are part of a whole rooted in a deeper ground of reality. Bohm's implicate order, as well as the available psi data, suggests a nonlocal feature to this ground that connects with each of our individual conscious experiences as well as our environment. Pursuing this rather speculative exercise, we might compare some of the feelings we experience to waves that propagate and connect with a much greater nonlocal field of proto-consciousness. Contrary to conventional theories in psychology, such feelings may be able to access a considerable range of information. While the psi data from controlled experiments suggests small or modest effect sizes, these results may understate the full significance of this nonlocal, proto-conscious field of information if we take into account its inherently holistic aspect. That is, while one's ability to ascertain information from particular subjects or locations may be limited, the holistic nature of Bohm's theory suggests we are likely accessing (albeit subconsciously) information from a wide variety of sources around us.

This possibility that some of our feelings are part of a larger, nonlocal reality suggests an interesting interpretation of other psi data, such as the emotional resonance mind–matter interaction experiments of the GCP. For these cases, the data suggest that groups of individuals sharing certain kinds of powerful emotions may be able to shift the outcomes of random number generator devices. Within the framework considered here, these emotions are perhaps linked with nonlocal fluctuations of information, which in turn may influence the proto-conscious potentia at the base of nearby physical processes, such as the test devices. Thus this interpretation suggests some spectrum of our feelings or emotions may affect the potential random outcomes of quantum processes at some distance away.

Bohm explored how a hidden order can be enfolded into reality through another metaphor where a few drops of colored dye are placed within a cylinder filled with clear viscous liquid. In a particular kind of setup that allows the fluid within the cylinder to be mixed, the mixing leads the colored droplets to expand and dissipate throughout the fluid until they ultimately disappear. However, once the droplets have vanished, turning the cylinder in the opposite direction allows the colored droplets to ultimately reappear in their original form.

Bohm employed this illustration of enfoldment to consider the experience of listening to music. That is, as we listen to the series of notes playing across time, we apprehend a set of co-present elements at different degrees of enfoldment. We listen to one set of notes that suggests or hints at a theme for a future stream of notes. As this first set of notes recedes from our conscious awareness, they are still present to some extent within our subconscious processes. They are thus hidden and enfolded in our awareness in some sense (like the vanished colored droplets), and they mesh to some degree with the next series of notes (or theme that they express) that play through our consciousness. Therefore, while a present stream of notes plays through our conscious awareness, there is a background or subconscious awareness that anticipates the next stream of notes, as well as its relationship to other themes or streams of notes, all in order to experience a greater sense of harmony.

Bohm extended this exploration of music experience to consider how our moments of consciousness may also be sets of co-present elements that are in different degrees of enfoldment. This suggests perhaps an atemporal ordering or harmonizing capacity that manages the flow of our streams of experience. That is, Bohm's implicate order, existing beyond time, manages in some sense conscious and subconscious flows of information, as well as their relationships. This speculation at the least appears congruent with precognition and presentiment data that indicate some degree of perception extending beyond our present moment of awareness.

Of course Bohm's proposal currently remains a radical step for most physicists. Nevertheless, we can note that the psi data we've reviewed also appear to take us in an unconventional direction, and something like a hidden order, containing information and potentia underlying both mind and matter, suits it well. Recall that the alternatives we have explored appear to struggle without this underlying level of information and potentia. The 'consciousness collapses the waveform' explanation appeared to founder in explaining clairvoyance and precognition without including something like the underling probabilities of events within the framework. Quantum entanglement (in the context of Penrose and Hameroff OR) does not seem sufficient for allowing coherent transmission of anomalous information. Something like Bohm's domain of active information underlying subatomic particles appears to be required.[18]

However, while there may well be difficulties obtaining testable mathematical predictions from such a framework, there appear to be significant compensations. The framework appears to be consistent with the quantum mechanical data, and all the psi data we've explored, and appears to hold significant promise toward a better understanding of consciousness. We achieve this without the sharp deviations from our sense of reality that the Copenhagen and Everett interpretations imply. Perhaps accepting the psi data (ironically) moves us in a direction more congruent with our common sense reality.

Conclusion

Nearly a century has passed since the standard or Copenhagen interpretation of quantum mechanics has been established; yet we are arguably no closer to a consensus solution that resolves the measurement problem. Despite its problematic nature, resolving its mysteries or moving toward an alternative explanation may be challenging, given the overall success of the standard interpretation and the lack of anomalies to exploit. And it appears that whatever explanation is ultimately correct, it will likely entail radical departures from a more classical worldview.

I've argued here that we have available anomalous data with respect to consciousness that is worthy of examination toward helping us resolve this conundrum. Of course, anomalous links with consciousness have been invoked from nearly the birth of quantum mechanics, and such avenues have rarely been pursued. A primary point here is that we know far too little about consciousness to dismiss its possible role in those areas of quantum mechanics where we still struggle to understand. With alternative explanations on the table that invoke bifurcating realities and ghost-like quantum superpositions, we are in a poor position to dismiss data that, while controversial, is nevertheless rigorously obtained across diverse laboratories and researchers. Accepting such data may be a necessary step, not only toward progress in quantum mechanics, but for a deeper understanding of consciousness as well.

Notes

1 As I'll discuss later, this includes Bohm's (1980) implicate order framework and Stapp's (2007) theory of potentia.

2 Von Neumann's criticism of hidden variable theories eventually came to be viewed as unnecessarily restrictive (Bell 1966).

3 For example, Bohm (1980) and Bohm and Hiley (1993) describe drops of color embedded in a fluid contained in a cylinder. The drops are invisible until the cylinder is rotated sufficiently to reveal the drops. Another metaphor Bohm uses is the holographic plate that can be used to construct a three-dimensional object. The metaphors are interesting and illuminating but do not suggest an inherently probabilistic reality.

4 According to Stapp (1993), Heisenberg favored this interpretation but reluctantly conformed to the wishes of the Copenhagen school to refrain from talking about a deeper underlying theory behind quantum theory, presumably according to the wishes of Bohr (Stapp 1993:95–96).

5 See Radin (1997, 2006) for more depth and a broader presentation from an advocate of the evidence of psi within the laboratory. Also see Utts (1991), especially for a discussion on the evolution of criteria for evaluating psi. Krippner and Friedman (2010) provide arguments from both skeptics and advocates on the current state of psi.

6 Honorton (1975) reported that Rhine's results demonstrated an astronomically significant psi effect (p. 105).

7 Sherwood and Roe (2003) examined 21 dream-telepathy studies published between 1977 and 2002 and compared them with the Maimonides studies. They found significant results overall, however with smaller effect sizes which they attributed to slightly different methods and protocols.

8 A recent meta-analysis by Bem, Tressoldi, Rabeyron, and Duggan (2014) confirmed these effects with an overall p value of 1.2×10^{-10}.

9 Mossbridge, Tressoldi, and Utts (2012) report $p < 2.7 \times 10^{-12}$ using fixed effects estimation and $p < 5.7 \times 10^{-8}$ using random effects.

10 Another class of mind–matter experiment uses Young's double-slit apparatus, perhaps the best-known experiment showing quantum mechanical effects, as a framework for testing. Radin et al. (2012) used participants who had experience with meditation and found that the meditators performed better than nonmeditators, with odds against chance of 300,000 to one. Control sessions were found to have a non-significant effect. Re-

cently, Radin, Michel, and Delorme (2016) extended the experiment using a double-slit optical system for online users. The results showed that for human observers (1,479 people), the interference pattern deviated from null pattern by 5.72 sigma ($p = 1.05 \times 10^{-8}$).

11 For examples, see Bierman (2003), Houtkooper (2002), and Radin et al. (2012).

12 It's unclear whether Cartesian dualism generally allows for disparate minds to be connected, as we describe here in order to explore telepathy and other forms of psi. Nevertheless, we posit that as a feature here as we investigate the implications for waveform collapse explanations.

13 This is the idea behind Observational theory, through which some parapsychologists explain mind–matter interaction via a "consciousness collapses the waveform" interpretation of quantum mechanics (Houtkooper 2002).

14 Bierman (2010, 2015) bases his argument of time symmetry not on quantum mechanics, but on the time symmetric feature of most classical equations. Thus perhaps his argument is not undone by the inherently time asymmetric feature of the Copenhagen interpretation. My point here is that precognition and presentiment do not fit well within a "consciousness collapses the waveform" style of explanation.

15 At the present time, see this lecture Hameroff presented to the Rhine Center, available at http://vimeo.com/7357010.

16 To be clear, quantum entanglement, according to the experimental evidence at hand, need not suffer distance effects. However, if the number of entangled particles grows exponentially with distance, then presumably the noise to signal ratio will grow at a comparable rate.

17 Bohm (1980) posited a hierarchy of nested implicate orders, while I will try to keep things simpler. Also, as I've discussed, while much of Bohm's work had a determinate flavor, I will emphasize probability as intrinsic. As I'll discuss, the framework I recommend here is neutral monism, which departs from Stapp's dualism.

18 This reasoning suggests a possible direction for development of Hameroff and Penrose OR. Recall that Penrose invokes a Platonic Order, which guides the expression of objective reduction. Perhaps their interpretation of Platonic Order could be extended as a level of reality that supports nonlocal exchange of information.

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