Quantum Mechanics, Metaphysics, and Bohm's Implicate Order

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Abstract

The persistent interpretation problem for quantum mechanics may indicate an unwillingness to consider unpalatable assumptions that could open the way toward progress. With this in mind, I focus on the work of David Bohm, whose earlier work has been more influential than that of his later. As I'll discuss, I believe two assumptions play a strong role in explaining the disparity: 1) that theories in physics must be grounded in mathematical structure and 2) that consciousness must supervene on material processes. I'll argue that the first assumption appears to lead us toward Everett's many worlds interpretation, which suggests a red flag. I'll also argue that the second assumption is suspect due to the persistent explanatory gap for consciousness. Later, I explore ways that Bohm's later work holds some promise in providing a better fit with our world, both phenomenologically and empirically. Also, I'll address the possible problem of realism.

1 Introduction

The standard or Schrödinger equation of quantum mechanics fits the experimental data remarkably well. However, questions regarding its interpretation persist. The traditional (Copenhagen) framework describes the evolution of the quantum system until a measurement discontinuously triggers the wave function to collapse into the experimental observations. As is well known, this interpretation provides no mechanism or ontology to account for the instantaneous collapse of the wave function. Many physicists and philosophers find this standard framework, which refers to measurement of the system under study within the theory, unsatisfactory. However, currently no consensus favors an alternate interpretation.

While no consensus interpretation exists, movement among some scientists and philosophers has grown toward favoring a removal of the special role of measurement from the theory of quantum mechanics. That is, many realists argue that quantum mechanics is best described in terms of objective entities without reference to a process of measurement or the consciousness of the experimenter. Well-known alternative explanations consistent with this philosophy include objective collapse explanations, relative states (or many worlds) interpretations, and hidden variables. While realist, each of these nevertheless offers a description of reality that strongly differs from the others, as well as more common-sense views, arguably rooted in classical physics. However, each approach is constructed to fit the experimental data; hence without the availability of residual or anomalous data it is difficult to see we can make progress through empirical testing.

Given this state of affairs we might benefit from paying more attention to the metaphysical assumptions associated with each interpretation. That is, we might make progress through inspection of the underlying and untested assumptions surrounding these different theories. Of course, particle physics has historically had a tense relationship with metaphysics. Many followers of Bohr discouraged efforts to describe an underlying ontology beyond the experimental results. And throughout the 20th century, despite the unsatisfactory aspects of the standard framework, a pragmatic attitude of "shut up and calculate" prevailed (Kaiser 2012).

On the other hand, some history illustrates the significant role that assumptions have played in our evolving understanding of quantum mechanics. Einstein, Podolsky, and Rosen (1935) famously argued that the "spooky action at a distance" inherent in quantum mechanics implied that the theory was incomplete. Yet the nonlocality that Einstein and his colleagues considered to be a flaw has been confirmed empirically. Prior to the EPR debate, few sought to question assumptions of locality with respect to how objects or particles interact. A possible lesson that emerges from the EPR debate, in addition to the presence of nonlocality, is that our lack of progress in finding the right explanation may be attributable to resistance to other unpalatable metaphysics.

The shift favoring realism in quantum mechanics has appeared to increase the focus on the unusual features of the wave function within the Schrödinger equation. As is well known, the mathematical space of the wave function requires an extraordinarily high number of dimensions. A key question for quantum realists is how best to understand the high-dimensional space of the wave function. In particular, is this space real in some sense or merely a mathematical convenience? And we might also ask whether tightly held assumptions about reality might be getting in the way of resolving such mysteries.

My central argument here is that progress in quantum mechanics likely requires careful examination of the assumptions we bring to the table. In order to explore this, I believe it will be helpful to compare two of the most well-known interpretations favored by realists: Everett's many worlds interpretation and Bohm's (1952) hidden variables (also known as the de Broglie-Bohm framework). Comparing these two, I'll try to highlight the role that structure explicitly plays in our theories in ways that might hinder our thinking. From there I wish to consider Bohm's later work, which he termed the "implicate order," in order to address another key assumption, which involves the relationship between mind and matter. In this later work, Bohm defended the view that an underlying strata of reality governing quantum systems provides a foundation for both matter and consciousness (Bohm 2002;

Bohm and Hiley 1993). This more speculative proposal, relying heavily on metaphors and descriptions, has not been as influential as his earlier work, perhaps because many believe that taking mentality as fundamental in some sense runs counter to realism. Also, this likely clashes with the view, held by most physicists and philosophers, that consciousness supervenes on purely material processes.

However, I'll argue that conventional assumptions around mentality and consciousness may be more costly than is generally understood. Examining and relaxing these assumptions may provide a way toward testable implications currently lacking from alternate interpretations of quantum mechanics. In addition, I believe Bohm's implicate order provides more interesting phenomenological insights than are found with the other theories. I understand that many will be reluctant to consider whether phenomenal properties exist at the quantum level of our world. However, given the persistent problems of explaining consciousness, we might reconsider some of the conventional assumptions around this. Thus, I'll argue for a number of reasons that Bohm's later work on the implicate order merits consideration.

2 The Quantum Wave Function and Configuration Space

Schrödinger's equation is the basis for all interpretations of quantum mechanics. Within this standard equation (1), the wave function, Ψ, evolves deterministically with time.

$$\hat{H}\Psi = -i\hbar\frac{\partial\Psi}{\partial t} \tag{1}$$

The wave function contains all possible outcomes, weighted by probability, of such things as particle position or spin orientation. According to the standard (Copenhagen) interpretation, the superposition of possible states collapses on measurement into the state that is observed. This textbook interpretation fits the data remarkably well; however, it omits any explanation on why measurement triggers the transformation from superposed possible states to whatever is actually observed.

A concern with this interpretation is that it is often associated with instrumentalist views, arguably favored by Bohr and other pioneers of quantum mechanics. An illustrative quote is provided by Peterson (1963), a former assistant to Bohr:

> There is no quantum world. There is only an abstract physical description. It is wrong to think that the task of physics is to find out how nature is. Physics concerns what we can say about nature. (p.12)

According to this view, quantum mechanics is a theory that tells us what we can say about the world, not a theory to explain the world itself. Heisenberg (1958) appears to have endorsed this veiw:

> We can no longer speak of the behavior of the particle independently of the process of observation. As a final consequence, the natural laws formulated mathematically in quantum theory no longer deal with the elementary particles themselves but with our knowledge of them. Nor is it any longer possible to ask whether or not these particles exist in space and time objectively... (p. 15)

The form of the Copenhagen interpretation, which invokes 'measurement' without defining precisely how it fits into the theory, as well as arguments such as these, seemed to justify anti-realist views that claim nothing can really be said objectively about the behavior of subatomic particles outside of measurement. However, Bohr's philosophy of complementarity was arguably more complex and sophisticated than a purely instrumentalist view. Bohr's complementarity was based on the understanding that the quantum system could not be isolated from the measurement apparatus. Essentially, the system under investigation and the experimental equipment had to be understood as parts of a whole. Complementary experimental designs or approaches would ultimately lead to different outcomes, which could be interpreted as revealing different aspects of the quantum system. d'Espagnat (2006) invoked the term "weak-objectivity" to characterize such an interpretation: "it implies (directly or indirectly) the notion of an observer but is of such a form (or occurs in such a context) that it implicitly claims to be true for any observer" (p.94).

After the midpoint of the 20th century, theories of quantum mechanics were developed to explain the experimental results without any reference to measurement. The most well-known alternatives of these realist interpretations include hidden variables, Everett's many worlds, and objective collapse interpretations. All interpretations retain Schrödinger's equation, with some added modification for objective collapse models. However, no realist alternative has attracted a consensus of support. Despite their wildly different ontologies, testing them with the data at hand has proved difficult. Without substantial empirical verification, many physicists prefer to remain with the more traditional interpretation, despite its drawbacks.

However, I propose instead that we focus our attention on the differing ontologies of the alternatives. That is, given the inability of the data to distinguish the best theory (at least thus far), we might examine more closely the assumptions supporting the interpretations. One of the fronts on the debate around the ultimate nature of quantum ontology is the curious subject of the space of the wave function. The wave function inhabits a space with a large number of dimensions. More formally, this is termed configuration space, which has dimension 3 times N, the number of particles in the quantum system.[1] This

[1] Configuration space is a mathematical space that represents the possible configurations or positions of particles. A configuration space representation of two particles existing in 3 dimensional space would be one particle existing in 6 (2 times 3) dimensions.

size of dimension is required because, although the quantum wave function operates on particles that are observed in our familiar three-dimensional physical space, quantum states can be entangled, and this cannot be adequately captured with a wave function in three dimensions. These entanglements, or correlations between different parts of the system, comprise information necessary for the evolution of the quantum mechanical system. Thus, configuration space is required to provide the degrees of freedom necessary to express various entangled states. As Ney (2013) puts it, the entanglement of quantum systems "results in a complex state of the whole system that contains more information than can be inferred from the individual parts" (p.17). Further, since all interpretations of quantum mechanics involve the Schrödinger equation, all interpretations must somehow address this puzzling aspect of the wave function.

The relevant dimensional size, however, is not limited to some local system under study. There are no truly closed systems in quantum mechanics. Entanglement implies that the system under investigation is connected with its environment. Thus, the relevant number of particles, N, is the number of particles in the universe. This very large dimensional space of the quantum wave function has been a point of contention and puzzlement from the earliest days when Schrödinger first introduced his equation. In correspondence to Schrödinger, Lorentz complained that he had difficulty taking the wave function seriously because he could not see how such an abstract, high-dimensional entity could be used to interpret physical things, such as waves (Lorentz in Przibram 1967, p.44). Schrödinger was also unhappy with this aspect of the wave function and sought to find a way of interpreting the wave function as a mathematical entity representing physical processes in three-dimensional space. Eventually, Schrödinger abandoned this project.

3 Bohm's Hidden Variables Approach

The focus on the high-dimensional space of the wave function arguably came into sharper focus as attempts were made to provide an ontology that removed the fundamental role of the observer from interpretations of quantum mechanics. Bell (1987) argued that it was a merit of the de Broglie-Bohm framework that it explicitly embraced the high-dimensional space of the wave function. De Broglie was the first to propose that the wave function was in some sense a "pilot wave" that guided the particles within a quantum system. De Broglie's framework required no wave function collapse or fundamental role of the observer. However he retreated in the face of criticism by Pauli at the Solvay Congress. Bricmont (2016) notes that one reason why de Broglie didn't defend his framework more strongly was that he was also troubled by the high-dimensional space of the wave function.

Later, Bohm (1952) followed up with an approach similar to de Broglie. However, Bohm (1957) also was reluctant to embrace the high-dimensional space of the wave function as more than just a mathematical convenience. As he put it: "While our theory can be extended formally in a logically consistent way by introducing the concept of a wave in 3N-dimensional space, it is evident that this procedure is not really acceptable in a physical theory, and should at least be regarded as an artifice that one uses provisionally until one obtains a better theory in which everything is expressed once more in ordinary three-dimensional space" (Bohm 1957, p. 117). However, Bohm's views on this changed, as I'll discuss below.

According to the Bohm's framework, a guidance equation specifies the velocity of a quantum particle, $\mathrm{Q_i}$, as a function of the wave function, Ψ,[2]

[2] Going forward, I will refer to this theory as Bohm's approach or Bohm's guidance equation, rather that the de-Broglie-Bohm theory that some prefer. Equation (2), which has the virtue of highlighting the configuration space of the wave function, is a simplified version of Bohm's guidance equation taken from Goldstein (1998).

$$\frac{\partial Q_i}{\partial t} = F(\Psi)(Q_1 \cdots Q_N) \quad (2)$$

Combined with the Schrödinger equation (1), this guidance equation (2) suggests a way to determine the positions of particles without assigning a role for measurement in the theory or positing that probability is in some sense intrinsic to the subatomic domain. Thus, subatomic particles such as electrons have definite positions and trajectories, and they behave deterministically. The velocity of particle $\mathrm{Q_i}$ (and thus all future positions of $\mathrm{Q_i}$ as well) can be expressed as a function of Ψ and the initial positions of all system particles. In this approach, the positions of particles are the hidden variables. Bohm also derived the statistical uncertainty observed in experiments from the uncertainty of the particle's position.

Consider, however, its dependence on the configuration (position of all particles) for the system. This removes the necessity of the rather vague reference to mesasurement from the conventional framework; however, the experimental setup is now explicitly linked to the system under investigation. And given that the system under investigation cannot be separated from the measurement apparatus and its environment, Bohm's guidance equation ultimately depends on the configuration of the universe. For many, this is likely a strange and unpalatable feature. But perhaps this feature simply follows from the extraordinary high-dimensional space of the wave function. That is, perhaps a wave function inhabiting a dimensional size of 3N (needed for all possible positions of the N particles) also depends on whatever the current configuration happens to be.[3]

Initially, Bohm's approach struggled to gain acceptance. At a relatively early stage,

[3] We can note that in a classical N body problem such as gravity, the equation of motion for one particle also depends on the positions of all other particles. But classical equations assign parameter values to the other influential bodies in this case. Bohm's guidance equation, however, takes the configuration of the system as a whole. Thus it is impossible to assign parameter values or individual effects of various other particles on one particular particle of interest.

Bohm suggested some hidden fluctuations within the subatomic domain might account for the probabilistic nature of the experimental findings (Bohm, 1957, pp.111-116). However, most physicists were likely influenced by von Neumann's argument that such hidden influences were incompatible with the standard quantum framework. Bell (1964) spelled out a formal argument, which was later supported empirically, that excluded hidden variables or factors from acting locally. Kochen and Specker (1967) arguably raised another hurdle: under deterministic hidden variable theories, experimental outcomes depend to a surprising degree on even minor details of the measurement process. However, advocates for Bohm's approach have argued that his guidance equation can accommodate these challenges. Bell (1967) and Goldstein (2016) have argued, for example, that Bohm's framework has always been consistent with nonlocality. And Kochen and Specker's (1967) argument can be understood as highlighting the holistic nature of quantum mechanics, which Bohm's approach also acknowledges.

Nevertheless, the debate regarding the ontological status of the wave function's space continues. Bell (1987) advocated a real high dimensional space: "No one can understand this theory until he is willing to think of it as a real objective field . . . Even though it propagates not in 3-space but in 3N-space" (p.128). More recently, Albert (2013, p.53) has argued that a realistic view of quantum mechanics requires an understanding of the world playing out in a "mind-numbingly high-dimensional space" (either configuration space or a space isomorphic to configuration space). According to Albert, our task is to understand how our familiar three-dimensional world and its objects unfold from a more fundamental level of reality, the high-dimensional physical space of the wave function. North (2013) echoes Albert and argues that the wave function space is fundamental to the 3-space where we find our tables and chairs.

However, Allori et al (2008), Dürr et al (1992), and Goldstein (1998) oppose this view and argue that the quantum wave function can best be understood to be functioning in three-space. They establish the notion of primitive ontology as a guide for understanding the dimension of space for the wave function. That is, ultimately the job of any theory is to account for the behavior of entities such as particles inhabiting three-dimensional space. These authors argue that applying this notion in quantum mechanics allows us to establish congruence with theories we have in classical physics, whose primitive ontology also focusses on particles in 3 space. According to these authors, the higher-dimensional properties of configuration space of the wave function might best be interpreted to be something nomological (that is, resembling laws of nature). It is of course unconventional to assign something like laws of nature to something that has 1) such a large number of dimensions and 2) the feature of evolving with time. Ascribing as nomological something with such rich dynamics as the wave function leads these authors to suggest that our reality is not completely physical. That is, quantum mechanics requires something nomological or quasi-nomological.

Perhaps a shortcoming of Bohm's guidance equation is its inherently nonlocal dependence on the configuration of the universe. Such an equation cannot hold explicit parameters that help us understand how a change in the position of a given particle (perhaps in another galaxy) influences another particle under observation. The guidance equation simply depends on the configuration of all particles in the universe as a whole, no matter how far away they might be. Needless to say, this is an unusual (and perhaps unpalatable) property for an equation to have.

4 Everett's Approach and Reality's Mathematical Structure

Let's examine Everett's interpretation, which has no guidance equation, and claims that no equation or factor beyond the standard wave equation is necessary. All versions of Everett's interpretation share the feature of claiming that the standard (Schrödinger) wave function equation provides a complete description of quantum mechanical systems. That the Everett approach requires one less equation arguably counts as a point in its favor. However, the controversial implication is that all possibilities represented within the wave equation are instantiated, which appears to conflict with our observations in our one world.[4] The Everett interpretation thus implies uncountable (and unobservable) worlds existing simultaneously with our own.

This interpretation depends on the view, explicitly articulated by some, that physics is rooted in mathematics. Tegmark (2014), an advocate of Everett's approach, makes such an argument. He describes the role of mathematics in our ability to understand our world as "a natural consequence of the fact that the latter is a mathematical structure, and we're uncovering it bit by bit" (p.355). Sean Carroll (2016), another advocate of Everett's interpretation, simply takes the mathematics of Schrödiner's equation as a description of many universes: "All those other universes are already there, at least potentially, in the formalism" (p.169). These sorts of claims appear to be consistent with ontic structural realism, the view that all that ultimately exists is best characterized solely by structure. This view is not a constructionist view that holds that the mathematical structure is constructed from the mind. Leading advocates of ontic structural realism such as Ladyman, Ross, and their co-authors, argue that our best scientific theories reveal the structure at the base of everything.[5] Following the maxim that that the best metaphysics at time T should be based on the best science at T-1, Ladyman et al. (2009) argue that fundamental physics does not point fundamentally toward a world comprised of tiny particles (such as electrons or strings). Instead, such objects depend on relational structure that ultimately

[4] An advocate for many worlds would note that we also split because we are entangled with any splitting quantum system. Thus the argument that the world is constantly branching can be reconciled with our observations of one stable world.

[5] Ladyman, Ross, and their colleagues also advocates for Everett's interpretation.

comprise the world. Thus, the history of science, and most especially the results of modern physics, suggests that everything is structure in this sense. A key aspect of this structural basis of reality, of course, is the mathematical structure of theories revealed through the process of experimentation. Thus for advocates of the Everett interpretation, we need not go further than the mathematical formalism of the Schrödinger equation, which remains the most successful equation describing quantum mechanics.

The relationship between Everett's interpretation and such a metaphysical argument is straightforward. Given (1) the assumption that all physics is ultimately rooted in structure or mathematical formalism, (2) the wave function and its standard (Schrödinger) equation have been successful in describing quantum phenomena, and (3) no other expressions (or hidden factors) have been found to account for our observations in quantum experiments, it follows that the wave function and its standard equation likely provides us with the entire quantum ontology. That is, if we must expect everything to be explained in terms of mathematical formalism, but have only found a partial (yet highly useful) mathematical description to account for our observations, we are advised to take that mathematical formalism as all we are likely to find and accept it as a complete description of the ontology. For advocates of the Everett approach, this implies that all of the possibilities represented within the wave function exist as real states of the observables, in this or other (unobservable) realities. And the Schrödinger equation becomes a description of how those different states evolve through time.

However there remains considerable debate around claim (1) above. Arguments presented by Van Frassen (2006) demonstrate the extreme difficulty of explaining the concrete objects of our world in purely mathematics terms, whose nature is abstract. The view that physics involves only structure all the way down seems to "yield a world devoid of substance or qualities (Chalmers, 2015: 254). We can also note the argument, often associated with Russell (1927) that while science reveals the structural properties of the world, it leaves out a good deal that cannot be characterized as structural, such as the most basic or intrinsic aspect of matter. I'll take up Russell's arguments in particular a little later.

In addition to such arguments, we may not accept claim (1) above because we believe some undiscovered or poorly understood process plays a role in bridging the possible states represented in the standard wave equation with experimental results. One possibility is that a hidden process that cannot be explicitly depicted mathematically plays a crucial role. Perhaps the inherently nonlocal and holistic aspect of Bohm's guidance equation falls into this category.[6] We might also conceive of alternative non-Bohmian processes that play an essential role in quantum mechanics that nevertheless elude our ability to express on a white-board. As Trigg (2015) has argued, based on what we know today, it's quite possible that many aspects of the universe are simply not comprehensible in mathematical terms. This may not be something that will eventually be remedied through additional scientific progress; the universe has provided no guarantee that the nomological or law-like entities governing our world can be fully characterized through mathematical structure. And if we are sympathetic to this reasoning, then taking the above step (1), which appears to play a crucial role in implying an infinity of unobservable worlds, appears imprudent.

5 Bohm's Implicate Order

In later work, Bohm explored an interpretation of his hidden variables framework that suggested a deeper aspect of reality based in a real (not merely mathematical) high-dimensional space of the wave function, which he termed the "implicate order." According to Bohm (2002), "various particles have to be taken literally as projections of a higher-dimensional

[6] Arguably, Bohm's guidance equation provides an alternate interpretation but with a different structure. However, the inherently holistic dependence of the guidance equation of the configuration of the universe arguably is a departure from the sort of structure favored by ontic structural realism.

reality which cannot be accounted for in terms of any force of interaction between them" (p.237). As projections from this higher-dimensional reality, particles share both nonlocal and non-causal correlations. He characterized this high-dimensional reality as an unbroken whole of pure information and the source of the entanglement within quantum systems. He also argued that its inherently holistic nature represented a break from mechanistic characterizations, rooted in what he suggested as outdated Newtonian views. This new quantum wholeness implied that the world cannot be analyzed in terms of separate and independent parts. Rather the world is a holistic flux of constant unfoldment and re-enfoldment: all physical particles are the results of unfoldments from potentialities (within the implicate order) which in turn enfold back into the high-dimensional ground.

Also, Bohm, with his co-worker Basil Hiley, developed the notion of "active information" which linked the guidance equation from his earlier work with this deeper high-dimensional field (Bohm and Hiley 1993). This active information, according to Bohm and Hiley, captured the information of the quantum system as a whole as it influenced particles through the quantum potential.[7] Bohm and Hiley stressed the importance of the overall form of the system which exerts an influence on a given particle via active information no matter the distance. Thus active information is a way of describing a kind of action from an underlying field which in turn depends on the entire system's configuration. But despite the intriguing nature of this deeper ontology, the theory offered little in the way of additional mathematical structure (equations). Thus, we might understand active information as supporting the inherently holistic processes driving the behavior of quantum systems. In contrast to the more explicitly structural equations that we're familiar with, Bohm's active information represents a different kind of nomological or law-like aspect of quantum mechanics, one that cannot be written down in terms of variables and parameters.

[7] Bohm's quantum potential emerges as a term in his (1952) guidance equation, which has the wave function expressed in polar form.

At first glance, Bohm's description of a world comprised of objects constantly unfolding and re-enfolding back into a more foundational aspect of reality appears absurd. The world around us exhibits considerable stability. On the other hand, Schrödinger equation appears to describe subatomic systems in terms of probability flux. Bohm compares the stable objects in our world to stable vortices or whirlpools in a stream of moving water. The vortices are relatively stable, however there are no sharp boundaries that divides them, and they cannot be understood as separate entities (Bohm 2002, p.12). The stream's moving water, which is informed by the stream's overall shape (form), represents active information, which also supports the structures of the vortices.

Bohm also took a bold, additional step by arguing that this high-dimensional space is foundational to both matter and consciousness. Bohm (2002) described his implicate order as a version of neutral monism, which takes the fundamental basis for both consciousness and matter as neutral, neither mind-like nor material: "So we are led to propose further that the more comprehensive, deeper, and more inward actuality is neither mind nor body but rather a yet higher-dimensional actuality, which is their common ground and which is of a nature beyond both" (p.265). And therefore active information, based in the implicate order, could also be seen as an important link or bridge between mind and matter. Thus the flow of our thoughts and feelings can also be characterized as a continuing of unfoldment and enfoldment from the implicate order. Bohm (1990) also noted that "the implicate order may serve as a means of expressing consistently the actual relationship between mind and matter, without introducing something like the Cartesian duality between them" (p.273).

5.1 Information and the Intrinsic Aspect of Matter

But Bohm (and Hiley's) implicate order proposal has not attracted many followers in physics, even among advocates of Bohm's earlier, hidden variables framework. Bohm's extension from his earlier work deviates sharply from other alternative interpretations in two ways. First, as I noted earlier, Bohm's implicate order provides no additional mathematical structure to his guidance equation; there is only description, which includes inventive use of metaphor. As I've discussed, many generally assume that it is the business of physicists to describe all processes of interest solely with mathematical equations. But perhaps a greater objection to Bohm's latter proposal may be his speculation that the high-dimensional field of the wave function is the foundation for both matter and consciousness. This conflicts with the presumption by many that consciousness supervenes on purely physical processes. In addition, establishing the high-dimensional quantum field as a base for both consciousness and matter may present problems for realism. I'll address the first two concerns here, but I'll take up the issue of realism in a later section.

As I've argued, a requirement that a theory must be accompanied by mathematical structure may create obstacles to progress. We just might not be able to capture some aspects of our physical world with explicit equations one might write on a whiteboard. Also, Russell's argument on the intrinsic aspect of matter claims that the structural or relational properties that physics provides to us is an incomplete description of reality. Alter and Nagasawa (2015) provide a useful characterization of Russell's structuralism argument: "...physics describes the structure of the universe in great detail but is silent on what, if anything, has the structure in itself. That is, physics does not characterize the intrinsic nature of basic physical entities–the relata that stand in basic physical relations" (p.424). Thus our methods of science that reveals an elegant mathematical structure in our world has little to say about the basic, bottom level stuff that grounds our world.

Regarding the second objection, let us acknowledge that consciousness remains a stubborn mystery. There is nothing in the laws of physics as we currently understand them that remotely suggest how consciousness might emerge from collections of non-conscious particles. And thus many philosophers who accept Chalmers (1995) arguments on the hard problem of consciousness suggest that we explore how consciousness may be in some sense fundamental (not emergent from matter). As it turns out, Russell's argument on the intrinsic aspect of matter suggests a promising direction here also. Russell noted that our only acquaintance with something intrinsic is the direct, raw perceptions of our world. Our concrete experiences, which require no theoretical abstraction, remains our only access to anything that might be characterized as intrinsic. This suggested to Russell that conscious experience is likely grounded or based in the intrinsic aspect of the world.

Thus Russell's arguments suggest that the intrinsic aspect of the physical world may take us in a similar direction as Bohm's implicate order. It might also be worth noting that Russell, like Bohm, favored neutral monism. Russell suggested that the raw feels of perception were intimately linked with some neutral foundation. However most philosophers currently exploring alternatives to physicalism do not favor this view. A key problem for neutral monism is how to address what exactly is a neutral element. That is, what is it that is neither mental or physical? Advocates of neutral monism in the early part of the 20th century, which included Russell and William James, had a difficult time describing this neutral element without attributing to it some degree of mentality. A closely related problem is how mentality arises at all from something devoid of mental properties. Thus many advocates of Russellian monism today tend to favor panpsychism, the view that "mentality is fundamental and ubiquitous in the natural world" (Goff et al., 2017).[8]

Recently, Seager (1995) has explored similar ground by examining the informational aspects of quantum mechanics. Young's double slit experiment, he argues, illustrates something interesting regarding information within a quantum system. Any attempt to gain information about the state of a particle, even though it is otherwise left undisturbed, will

[8] Chalmers (1997) coined the term Russellian monism to express the view linked with Russell's arguments we've been discussing. Alter and Nagasawa (2015) provide a good recent discussion on Russellian monism.

inevitably alter the quantum system and measurement outcomes.[9] This example of how quantum systems form distinctive wholes that cannot be reduced to their parts suggests to Seager that such systems are better characterized with a 'semantic' notion of information, rather than the more familiar Shannon notion, based on bit capacity.

In a later paper, Seager (2013) explored this notion of semantic information in conjunction with Bohm and Hiley's active information. He also reasoned that this active information is likely intimately linked with Russell's intrinsic aspect of matter. That is, he notes that all the relational and structural properties we discover through science arguably requires some intrinsic nature as a basic ground. And these relational aspects can be adequately captured by a Shannon notion of information. However, active information, within the high-dimensional space of the wave function, represents the deeper, intrinsic reality. And given its more semantic, holistic characterization, Seager argues that Bohm is justified in suggesting that this deeper, ground of reality, possesses mental properties. "It is tempting to link active information with consciousness, if only for the reason that conscious states seem to carry meaning intrinsically (as intentional content), and nothing else we know of does so." (p.564)

5.2 Linking Bohm's Implicate Order with the Brain

If processes in quantum mechanics are somehow linked with consciousness, we might ask whether quantum processes are playing a pivotal role in the brain. Curiously, Seager (2013) casts doubt on this prospect. That is, while he seems to identify our mental features with Bohm's active information (which expresses itself through Bohm's quantum potential function), he nevertheless argues that this Russellian grounding of consciousness can support a completely classical view of the brain, understandable through classical information and

[9]This is an aspect of the strong contextuality implied by Kocken and Specker (1967) that quantum systems require.

computation theory. In this way, our analysis of the brain as a vast network or complex computer can separated from the more radical quantum processes underpinning the classical level. Thus "we will not have to posit any special, distinctively quantum but macroscopically significant processes" (p.564). Seager maintains that such a view can accommodate mental causation; however, he offers no hint on what the relationship might be between the mind, grounded in non-classical quantum processes and the more classical brain.

Thus, Seager criticizes Hiley and Pylkkänen (2005) for incorporating Bohm (and Hiley's) active information within brain functioning, however using a model that gives a stronger (more macroscopic) role for quantum processes. Hiley and Pylkkänen (2005) build on the work by Eccles (1986) and Beck and Eccles's (1992), who proposed a dualistic framework for understanding the brain in which a non-material "mind-field" triggers neural processes via quantum mechanics. In their approach, Hiley and Pylkkänen avoid dualism (as well as quantum indeterminacy) through Bohm's interpretation of quantum mechanics that supports active information. They retain the notion of a mind-like field, which via active information, influences the quantum transitions of neural junctions. However, Hiley and Pylkkänen (2005) are ambiguous on the mental properties of this "field," and refer the reader to discussions from Bohm and Hiley (1993).[10]

Seager characterizes their approach using such phrases as "mysterious downward causation" and "bizarre interpositions of non-physical effects" (p.564). However, it is difficult for me to see a meaningful distinction between what Seager suggests and Hiley and Pylkkänen's proposal. Both seek to establish that mind in some sense is grounded in the higher-dimensional quantum field that is a source of active information. Hiley and Pylkkänen's proposal does not appear to be less physical than what Seager has in mind.

[10] As I've mentioned, Bohm (2002) and Bohm and Hiley (1993) advocated neutral monism. My reading of Seager (2013) suggests that he flirts with this view but stops short of a full embrace.

I am also untroubled by the downward causation within Hiley and Pylkkänen (2005), and Seager does not spell out how his view of mental causation would avoid this.

Perhaps Seager wishes to avoid macroscopically important quantum processes within the brain, and his distaste for these may be close to conventional wisdom. Tegmark (2000) has been influential in claiming that the environment within the brain is too warm and noisy to support quantum processes.[11] However, Tegmark's analysis depicts a conventional view of quantum mechanics, with decoherence of superposed states occurring rapidly in the rather warm environment of the brain. The literature he is attacking appears to associate quantum superposed states with consciousness. But as I've discussed, Bohm avoids the need for quantum superpositions. And Bohm's implicate order, the basis for consciousness, resides at a deeper level of reality than the particles that exhibit quantum behavior. In addition, the accumulating evidence in the growing field of quantum biology suggests it is premature to rule out the environments capable of supporting quantum behavior.[12]

That said, I'd like to return to Hiley and Pylkkänen's (2005) framework, but with a slightly modified interpretation. Given the problem that neutral monism has with addressing mentality and consciousness, I propose here that the high-dimensional quantum field, what Bohm called the implicate order, possesses a rudimentary degree of mentality. I do not view this as a significant deviation from Bohm or Hiley and Pylkkänen; these authors have all stated that the quantum level might possess a rudimentary level of mentality. Presumably, the consciousness we and other biological organisms experience in the world result from processes that scale up from this lower degree level of consciousness.[13] Obvi-

[11] Seager (2013) doesn't cite Tegmark (2000), but he does include that paper in his list of references.

[12] McFadden and Al-Khalili (2015) review the evidence of quantum behavior in various biological processes such as photosynthesis, enzymes in respiratory process, mechanisms that guide migratory birds, and olfactory receptors in various animals.

[13] Bohm (1990) suggested that this scaling up from low level mentality to higher states of consciousness takes the form of layers, where each layer could be characterized as possessing a mental and physical aspect, linked together with active information. A rudimentary level of mind might characterize the active information at the level of quantum particles. Our familiar state of consciousness, housed in our brain,

ously, much work is needed to explain how this happens, but I won't address that here. However, arguably this move avoids the more difficult problem of explaining how mentality arises from a neutral foundation in the first place. So I am proposing attaching a more panpsychist flavor to Bohm's implicate order.

I believe this modification can easily fit with Hiley and Pylkkänen's (2005) model with their notion of a field possessing mental properties. Within what I propose, this mind-like field can be characterized as aware potentiality inhabiting a high-dimensional (therefore nonlocal) space that is capable of triggering vast numbers of neural processes within the brain. Thus mental intent can influence collections of neurons within such areas as the motor cortex, as Hiley and Pylkkänen suggest. However, recall that Bohm characterized the quantum relationships between particles as both nonlocal and non-causal. Does this contradict my argument that mental intention might influence quantum processes within neurons? I think the dilemma can be resolved if we understand the intention as enfolding into the potentialities of the implicate order as well as unfolding in a way to influence the relevant quantum processes. Thus causal influence is present in the inherently holistic processes of the implicate order; however direct causal influences between particles is not permitted.

5.3 Linking Bohm's Implicate Order with Structural Information

In exploring how a mind-like field with its holistic, semantic notion of information connects with the brain's vast network of neurons, we might profit from taking a brief look at Tononi's Integrated Information Theory (IIT). Tononi and his colleagues (Tononi et al. 2016) developed IIT as a formal framework for understanding consciousness as integrated information generated by a system of elements, which we can generally take to be a system

is a relatively advanced level. Bohm speculated that these layers might extend indefinitely and include collective minds as well as the mind of humanity as a whole. (Bohm 1990, p. 284) of neurons. Within the IIT framework, consciousness is constituted as qualitative differences in our experience; however, these different qualitative states are integrated into a seamless whole. However, there are some important differences between IIT and Bohm's active information. First, while Tononi argues that consciousness itself is intrinsic, unlike Russell he does not use the term to characterize anything in the physical world. And because IIT does not specify a fundamental substrate (such as an organic nervous system) it conceivably applies to digital systems (advanced computers) as well as biological ones. Perhaps most important, IIT presents a structural (mathematical) framework of causal network elements; however, active information is based in the high-dimensional quantum field and characterizes information of system's configuration that cannot be captured structurally or relationally. Following Seager's argument, active information represents the intrinsic aspect that grounds the relational aspects of a system.

One line of criticism against IIT is that, as a purely mathematical framework, it does not possess the resources to explain consciousness. Mindt (2017) argues that a primarily structural approach, such as IIT, explains at most structure and function. This is insufficient to explain consciousness. Mindt's argument parallels the arguments made against physicalist explanations of consciousness.[14] But this also echoes the arguments already discussed that claim physics describes only structural or relational properties, leaving out whatever grounds such structural properties. One direction of inquiry appears to be whether something along the lines of Bohm's active information might serve as the appropriate ground for IIT. As Seager pointed out, active information as a semantic information might serve as a ground for more relational (structural) types of information, as well as for conscious states. And since Tononi didn't specify a substrate, we are at liberty to consider whether

[14] In his paper, Mindt (2017) expresses the explanatory gap argument, drawing on Chalmers (2003) and Levine (1983), as 1) physical accounts explain at most structure and function; 2) explaining structure and function does not suffice to explain consciousness; 3) no physical account can explain consciousness.

the arguably most fundamental aspect of the physical world, the quantum field, might provide the missing piece for IIT.

Currently, Tononi views IIT as causally closed. This might discourage us from linking it with something like an implicate order inspired mental field. But such concerns evoke the arguments against dualism; how can a purely mental substance interact with a causally closed physical world? I believe that Bohm's implicate order overcomes this sort of problem. The physical world is comprised of particles that are guided by an underlying field, which we have reason to think supports phenomenal properties. Thus something like a panpsychist version of Hiley and Pylkkänen's model allows a mental field to influence the brain's network of neurons. While IIT currently depicts neural pathways as managing information flow from various parts of the brain, an extension that accommodates this sort of mental field appears to be feasible.

One very intriguing feature of IIT's framework is that it's "qualia space," which is used to analyze different conscious states, requires a very high number of dimensions. That is, IIT analyzes a particular experience as a complex shape within a multi-dimensional qualia space, arising from the informational relationships that link the sets of possible states. However capturing the vast range of possible experience for all creatures, all seamlessly woven together as a whole, requires a mathematical space with an enormously high number of dimensions. Thus the dimensional size of this mathematical space appears to approach the enormity of the wave function's high-dimensional space. Therefore the high-dimensional quantum field (with rudimentary mental properties) appears to indeed by an intriguing candidate for an intrinsic ground for IIT.

This suggests an interesting justification for the wave function's high-dimensional space that has been missing from the debate so far. A high-dimensional space is required to support the wide range of conscious experiences for our reality. Perhaps this requirement is rather startling. We do not perceive a large number of dimensions. However, we do perceive a vast and diverse range of qualia, unified together which, according to IIT, requires a high-dimensional space.

6 Fitting Bohm's Implicate Order into our Reality

To recap, I've argued that the unwillingness to consider unpalatable metaphysical assumptions has possibly hindered progress on our most fundamental understanding of physics. The two assumptions I've discussed are: 1) important aspects or processes of our physical world may not be adequately captured in purely mathematical or structural terms and 2) consciousness may be in some sense fundamental (not supervenient on physical processes). Unlike other explanations on quantum mechanics, Bohm's implicate order proposal appears comfortable with both of these. And we can note with interest that Russell's argument on the intrinsic aspect of matter appears to bring both of these ideas together: 1) there is an intrinsic aspect of our world beyond the purely structural or relational properties that physics delivers and 2) this intrinsic aspect may ground or serve as the basis of our conscious experiences.

6.1 Phenomenology and Bohm's Implicate Order

My primary objective is to argue that venturing into these unpalatable waters may suggest empirical implications that have so far eluded alternative interpretations of quantum mechanics. But Bohm's framework also has interesting phenomenological implications. Before examining how such a framework might be examined empirically, I wish to consider how Bohm's implicate order might fit with our direct experience of the world.[15] Recall that the

[15] As I've argued, I believe a version of Bohm's implicate order that possesses a rudimentary of mentality, even at the level of the wave function, provides a better base for varieties of conscious experience than a neutral element. However I believe the other features of Bohm's implicate order, such as phenomenological

aim of Bohm's (1952) earlier work was to provide an ontology for quantum mechanics that was missing from the standard approach, as well as one that remained within the confines of our one world. In moving forward, Bohm's unconventional approach also has implications for how we experience the world directly. That is, Bohm attempted to advance on the standard wave function equation by incorporating the inherently holistic and constantly changing processes of our experience. His descriptions of the implicate order stem from his aim to understand the more hidden factors of quantum mechanics fundamentally as process. While this approach is short on mathematical structure, it nevertheless attempts to be congruent with our experience and thus inform us about our world.

Bohm's innovative framework leads to some interesting insights around our experience. Recall that Bohm's views of an unfolding and enfolding of active information at the base of our world applies to both the physical world and our conscious experience. An analogy Bohm used to capture this feature is a set of nested cylinders containing viscous fluid. He noted that if a few drops of colored dye are placed within such a cylinder, turning one of the cylinders leads to the colored drops dispersing 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 suggested that hidden orders in our own reality could be compared to various sets of colored drops in the fluid mixed in various degrees within the fluid. Further, he employed this analogy of fluid in nested cylinders as an aid to describe how subatomic particles wink in and out of the fabric of reality as a result of unfolding hidden orders.

Bohm applies this analogy to our own experience using the case of music. Here, Bohm explained that 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

ones, are unaffected by this modification.

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.

Perhaps we can explore such insights of unfolding meaning in other areas. Consider how the author of a novel might foreshadow future events within a narrative. That is, events are not only unfolding as they are presented to the reader, but also in ways that suggest unfolding at a more distant time in the story. This foreshadowing is usually accompanied by an emotional experience (for the reader) suggesting the general direction of the unfolding, rather than specific outcomes. Another example of implicate meaning might include symbolic references that suggest connections between otherwise disparate elements in the novel. Such emotional experiences as these evoke what we might call a sense of deeper meaning arising from a unified, holistic process that link different elements (such as plot and characters).

This sense of literary meaning from a novel of course parallels the issue of existential meaning that has persisted throughout the history of philosophy. Wee don't have space here to adequately deal with such an important subject. Nevertheless, for our limited purposes here, we might say that the issue of existential meaning can be framed as whether our world provides a sense of common meaning or purpose beyond more mundane interpretations or constructions. Scientists and philosophers of the present day, to the degree they weigh in on such matters, usually dismiss the idea that the world possesses meaning in some intrinsic sense. A quote from the physicist Steven Weinberg (1993, p.154) captures the sentiment: "The more the universe seems comprehensible, the more it also seems pointless." But I submit that such positions are rooted in the understandings from physics that leave out Russell's intrinsic aspect. Is there reason to think, perhaps following the reasoning of Seager and Bohm, that we might find meaning in some intrinsic sense in the deeper stuff of reality?

I believe that meaning in this deeper, existential way might be characterized as the experience of being part of a greater whole, albeit not defined clearly. Common examples might include the raising of our children or the way we provide service to one's community in ways where one feels a greater connection to the other members. Perhaps these are accompanied by a sense of purpose or unfolding meaning in ways we do not fully understand. I suspect such experiences are not uncommon, and extend beyond what we usually characterize as religious or mystical. My main point, however, is that this sort of existential understanding of meaning fits well Bohm's implicate order interpretation. We can also note that Bohm (1990) was sympathetic to Jung's ideas which include synchronicity, meaningful coincidence (p.284). Thus Bohm's interpretation might be important for those inclined to seek unfolding meaning in this deeper sense.

Again, I am only touching on subjects that deserve more space than I am able to provide here. And of course, such considerations are generally outside the bounds of what most physicists consider to be relevant. Nevertheless, we can note that other interpretations on quantum mechanics provide us with highly abstract constructions whose connection with our more concrete world is ambiguous. On such core questions that are intimately linked with our lived experience, Bohm's approach appears to stand alone in providing insight.

6.2 Empirical Implications

I turn now to the case that Bohm's framework has empirical implications that alternative explanations lack. I'll pick up with my panpsychic version of Hiley and Pylkkänen's (2005) model of a mental field influencing nerve junctions within the brain. One interesting area where this proposal might shed some insight is on the recent empirical findings for the relationship between meditation and neuroplasticity in the brain. Specifically, long-term meditation practice appears to be associated with various changes in brain structure. These include a host of regions associated with meta-awareness, introspection, body awareness, memory consolidation, self and emotional regulation, and interhemispheric communication (Fox et al. 2014). Generally, physicalist theories of consciousness hold that there is nothing to explain beyond various functions or mechanisms within the brain. But such theories might have difficulty accounting for such a wide range changes in brain structures resulting from very simple practices involving conscious attention devoid of much sensory stimuli or habitual thought patterns. That is, if consciousness is solely a product of the brain, how does consciousness itself manage to significantly alter the brain's structure over time. It stands to reason, however, that a highly integrated mental field intimately connected with the brain's neural network via quantum processes provides additional avenues to support such neuroplasticity. Perhaps, by virtue of its holistic informational features, we might eventually discover significantly more integration across such the brain structures of long-term meditators than what we would find in the control groups. I might also add that it is not uncommon that experiences of meditation are accompanied by experiences of improved emotional well-being, including having greater sense of meaning (in the sense we touched on above).

Further, we can note that the more radical features of this proposal, regarding consciousness and nonlocality, appear to be broadly consistent with various strands of research on anomalous cognition and psychokinesis. Anomalous cognition includes telepathy (being affected by someone's thoughts or emotions apart from the senses or other conventional modes of contact), clairvoyance or remote-viewing (obtaining information from a distant environment, without the aid of the senses or other conventional sources of gaining information), and precognition or presentiment (being affected by a future event on which one cannot be expected to have knowledge). Psychokinesis or PK refers to affecting an object or (perhaps microscopic) physical process through mental intention.

Of course, such anomalous data remains controversial and unpalatable to many. Be that as it may, studies on such phenomena have been conducted under laboratory conditions for early in the previous century. In recent years, psi research has been published in major psychology journals (Bem, 2011; Storm, Tressoldi and Di Risio, 2010; Cardeña, Etzel, 2018). Cardeña (2018) has provided a recent survey of the meta-analyses on various modes of anomalous cognition and PK, and for the modes of psi I list above finds substantially significant effects. He also reviews various criticisms of the studies and concludes that such data cannot be explained away through such explanations as selective reporting or questionable research practices.

Bohm himself argued that the implicate order is consistent with precognition and presentiment on the grounds that "...the future may be enfolded in the present as possibility" (Bohm 1985, p. 132). Thus precognition might reflect a capacity for one to sense or intuit a deeper or broader level of reality behind the enfolding of events. Thus, perhaps through neural pathways rooted in a mental field also characterized as unfolding potentialities, we have some awareness of the possibilities of future events. As it happens, meta-analyses of extant studies on both precognition and presentiment demonstrate significant effects. Bem, Tressoldi, Rabeyron, and Duggan (2016) provided a meta-analysis of 90 studies for the various precognition experiments first reported by Bem (2011). Mossbridge, Tressoldi, Utts (2012) have provided a meta-analysis of evidence on presentiment across 26 studies.

As I've discussed, Hiley and Pylkkänen's (2005) model suggests how mental intention could trigger quantum processes within the network of nerves of the brain, leading for example to movement directed by motor neurons. However, the high-dimensional quantum field of aware potential at the base of our consciousness implies additional possibilities. The nonlocal nature of this high-dimensional field suggests that mental intention might influence some processes at a distance. In fact, Bohm (1986) has explored a simplified version of this possibility, without Hiley and Pylkkänen's model. However, Bohm noted that quantum behavior is generally difficult to maintain in brain and nervous system. In order to overcome this problem, Bohm proposes nesting various orders of the wave function into one another: "One could go on to suppose a series of wavefunctions of indefinitely many orders, with the wavefunction of each order constituting information that gives form to the activity of the next lower order wave function." (p.130) This nesting scheme most likely fits exactly with Bohm's nesting of implicate orders, which we touched on briefly previously.

However, the recent research showing links between biology and quantum mechanics suggests that this relatively abstract nesting scheme may not be necessary. If quantum biology ultimately reveals important links between quantum physics and the brain, which I suspect will be the case, we may be able to understand the mind-matter link without such an extended version of the wave function (which of course is already quite abstract). Thus, we might understand that within Bohm's (unextended) implicate order, mental intention enfolds into the potentialities of this nonlocal quantum field, ultimately leading to an unfolding that influences the Born probabilities that underlie distant random processes. However, the rather indirect and holistic nature of this influence seems to suggests small effect sizes that can hinge in crucial ways on details around the experimental setup. These features do characterize the empirical research on anomalous microscopic mind-matter interactions. Recently Bösch et al. (2006) gathered 380 mind-matter studies that used random number generator (RNG) devices and confirmed small, but statistically significant effects.[16] They 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) have argued that invoking publication bias would require an implausibly high number of unpublished studies.[17]

Other categories of psi that I believe are consistent with this framework include telepathy and remote viewing. As I've discussed, relying heavily on Bohm's pioneering work, I am proposing that our conscious experience is ultimately rooted in an information rich, nonlocal "space." Thus remote viewing could be attributed to unconscious mechanisms within the brain which are linked with this underlying strata or base of intrinsic information, which in turn is linked with the configuration of the distant physical system of interest. The possibility of telepathy is implied by noting that our minds share this inherently nonlocal space. On the empirical score, meta-analysis indicates small, but highly significant results for both telepathy and clairvoyance. Meta-analysis for two modes of telepathy, ganzfeld method and psi dream studies, are presented in Storm et al. (2010) (108 studies) and Storm et al. (2017) (52 studies), respectively. A recent meta-analysis on remote viewing is presented by Baptista, Derakhshani, and Tressoldi (2015).

Again, I acknowledge the controversial nature of these data. However, the data has held up despite various criticisms. Also, I believe a key obstacle to these results being given wider consideration are various metaphysical assumptions around consciousness and the

[16] These devices, which incorporated quantum processes in their design, produced true random streams of 1s and 0s. Within a binomial distribution where the expected effect is 0.5 (equal probability for 1s and 0's) the estimated effect size, reported from Bosch et al. (2006) was 0.50003.

[17] Stapp (2017) has also recently suggested a framework for understanding a version of psychokenisis, where mental intention might bias the Born probabilities. Stapp argues that his framework is based on a slightly adjusted version of the standard interpretation of quantum mechanics (pp.76-77).

physical world that we may have reason to question. We can note that we are not anywhere close to resolving the hard problem of consciousness. And given the radical nature of most explanations of quantum mechanics, it seems odd to ignore data that surprises us or clashes with our priors. While some may have questioned whether such anomalous data can be accommodated by a theoretical framework, I submit that something along the lines of Bohm's implicate order can indeed accommodate such data.

7 Realism and Bohm's Implicate Order

Nevertheless, arguably Bohm's implicate order (or my panpsychist version), faces the question of scientific realism. Advocates of realism will likely object to any proposal that takes consciousness or some degree of mentality as fundamental (rather than supervening on physical processes). Further, it is generally argued that a core tenet of scientific realism is that the objects we investigate are mind-independent (Chakravartty 2017). The framework I've sketched above appears to violate this tenet. What does this mean, then, for scientific realism?

Chakravartty (2017) notes there is some difficulty in pinning down a precise definition among philosophers of science, but suggests that a shared core of ideas might be expressed as "an epistemically positive attitude toward the output of scientific investigation, regarding both observable and unobservable aspects of the world." As I have discussed, the most relevant area of debate on realism for our purposes unfolded during the advent of quantum mechanics, where for some time a more or less instrumentalist view was adopted. Thus the emphasis remained on the predictions of the conventional framework, but not on the underlying ontology that supported the experimental outsomes. As I've discussed, with measurement and observers understood to play an explicit role, it remained an open question whether obtaining a deeper ontological understanding was even possible. However, under more realist interpretations, a world uninfluenced by the mind could arguably avoid such problems.

Bohm's (1952) intended his hidden variables framework, as well as his later work, to more completely describe an ontology lacking in the Copenhagen approach. Bohm's hidden variables approach can be understood as the first realist interpretation for quantum mechanics. And I submit that his later work (as well as my own modification) arguably respects realism in some sense. Recall that Bohm's hidden variables interpretation removes the need for wave function superposition and collapse, as well as the special role of measurement instrumentation and the observer. Particles inhabit positions even when we don't attempt to measure them, as we might suspect, given the concrete nature of the objects of our world. However, measurement devices and the observer are still important, but Bohm's theory allows for them to be incorporated expllicitly; in Bohm's hidden variables framework, the relevant physical system must include the experimental setup.

One might argue that we have to abandon here a strict form of realism where the quantum system under investigation cannot be isolated from the process of measurement. In this sense, d'Espagnat's characterization of "weak-objectivity" appears to apply to Bohm's hidden variable framework. Thus, while the hidden variable framework may provide something of an advance regarding the underlying ontology of the quantum world, the choices concerning experimental setup as well as various physical characteristics of the experimental environment must be factored into the relevant configuration for Bohm's guidance equation. Thus in some sense the wall of independence between the scientist and the system under study is weakened; nonseparability and contextuality make this necessary. However, the theory accounts for this and the implied constraints appear to be manageable.

It is doubtful that Bohm's implicate order can meet the requirements of scientific realism if, as I've argued, quantum processes may be influenced with mental intention. However, perhaps what we might call weak-realism might apply. Bohm's implicate order framework allows for explicitly including consciousness in its ontology in ways that arguably removes independence between mentality and experimental outcomes, albeit in a manageable way. Bohm's implicate order extends the relevant configuration of the system beyond just the positions of physical particles to include the potentialities of the inherently nonlocal quantum field which are also linked with the conscious observer. An observer may have an effect on distant random physical processes if 1) her intention enfolds into the potentialities underlying the random physical process and 2) the unfoldment that influences the random process reflects that intention to some degree. Of course, the possibility of the observer's intention having this kind of effect adds some difficulty and uncertainty regarding quantum experiments. However, based on the extant mind-matter interaction data (see above), this rather contingent and holistic effect are arguably much smaller in magnitude, and hence more manageable, than the uncertainties already tolerated in association with experimental set-up. Also important, this influence of mental intention does not prevent us from describing the underlying ontology of the system. Thus this notion of weak-realism allows us to move closer to a theoretical structure that is consistent with observable and unobservable (albeit anomalous) processes.

I submit that any departure from a more conventional version of realism is adequately compensated with a more complete understanding of an ontology that is the base of both consciousness and matter. And we must take care that any notion of realism we adopt maintains a respect for conscious experiences. All facts we possess about the world (objective or subjective) arrive to us through our consciousness. Thus, our conscious experience possesses a stronger ontological status than the mathematical abstractions offered by alternative explanations of quantum mechanics. This argument applies to the all of our world's ultimates (electrons, quarks, strings) for which our understanding is still incomplete. To the extent that a metaphysical claim ends up marginalizing that which is most real for us, it imposes an unacceptable cost.

And with that said, we know too far little about consciousness to impose a strict condition against mind-independence. We can note that none of the current physicalist-based theories of consciousness have any real grounding in the laws of physics. There is nothing in all our physical laws that even remotely suggests how collections of non-conscious particles or fields become conscious. We have no theories that close the gap between the laws of physics that describe the physical world and consciousness. And proposals that consciousness is in some sense fundamental, that is, not supervenient on physical processes, is a growing area of research (Alter and Nagasawa 2015; Brüntrup and Jaskolla 2017). Given this persistent mystery of consciousness, as well as its superior ontological status, we are in weak position to dismiss out of hand unconventional proposals on consciousness. It is arguably far from obvious that such proposals are more radical than other more familiar interpretations of quantum mechanics currently on the table.

8 Conclusion

Bohm's implicate order appears to hold some promise toward a greater understanding for both quantum behavior and consciousness, two areas that have been extremely vexing for scientists and philosophers. The reluctance of many to embrace this framework is understandable, given its novel treatment of consciousness and its lack (so far) of additional mathematical structure. On the other hand, its more radical features do suggest some interesting possibilities for empirical testing, which of course is an area where more mainstream approaches continue to struggle. Equally important, Bohm's more phenomenological approach appears to be more congruent with our experience of the world. On the other hand, more standard theories appear to lead us into mathematical abstractions whose relationships with our world are ambiguous. Bohm's implicate order deserves a place at the table among the various explanations for quantum behavior.

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