Consciousness and Quantum Mechanics[1]

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Consciousness and quantum mechanics are two mysteries in our times. It has been conjectured that a deep connection between them may exist (see, e.g. Chalmers, 1996). The connection is bidirectional. On the one hand, an analysis of the conscious mind and psychophysical connection seems indispensable in understanding quantum mechanics and solving the notorious measurement problem (Gao, 2019).[2] Indeed, as Harvey Brown once emphasized, "The issue of psycho-physical parallelism is at the heart of the problem of measurement in quantum mechanics" (Brown, 1996). On the other hand, it seems that in the end quantum mechanics, the most fundamental theory of the physical world, will be relevant to understanding consciousness and even solving the mind-body problem when assuming a naturalist view, even though we are not quite there yet (Atmanspacher, 2019). Therefore, a careful and thorough examination of possible connections between consciousness and quantum mechanics is not only necessary but also even pressing in order to unravel these two mysteries.

This book is the first volume that provides a comprehensive review and thorough analysis of intriguing conjectures about the connection between consciousness and quantum mechanics. It contains seventeen original chapters that are written by leading

[1] This is an Introduction to the forthcoming volume Consciousness and Quantum Mechanics (OUP, 2022). For more information please visit the OUP website.

[2] Quantum mechanics, according to its standard formulation, says that when there is no measurement, the wave function of a physical system evolves in time according to the linear and deterministic Schrödinger equation, while when a measurement is made on the system, its wave function will collapse to one branch that corresponds to the result of the measurement in a nonlinear and stochastic way. The measurement problem of quantum mechanics, in John Bell's words, is then to answer the question: "What exactly qualifies some physical systems to play the role of 'measurer'?" (Bell, 1990). Quantum mechanics is not a precise physical theory without solving the measurement problem. There are also other formulations of the measurement problem that are independent of standard quantum mechanics (see Chapter 8 and references therein), and solving the measurement problem in one way or another such as resorting to consciousness or not, will lead to alternative quantum theories, which will be discussed in several chapters of this volume.

experts in this research field. This book is accessible to graduate students in physics and philosophy of mind. It will be of value to students and researchers in physics with an interest in the meaning of quantum mechanics, as well as to philosophers working on the foundations of quantum mechanics and philosophy of mind.

This book is organized into three parts in order to facilitate reading, although a few chapters do fit into more than one part. Echoing the possible bidirectional connections between consciousness and quantum mechanics, the first two parts are about the possible roles of consciousness in quantum theories. The first part is about the specific consciousness-collapse conjecture, and the second part is about other possible roles of consciousness in quantum theories, and the third part is about the possible roles of quantum mechanics in understanding consciousness.

A more detailed introduction of the three parts of this book is as follows. The first part investigates the relationship between consciousness and the collapse of the wave function. If consciousness really collapses the wave function, then this will provide both a solution to the measurement problem and a potential role for consciousness in the physical world. This well-known consciousness-collapse conjecture has a long history, but it is often dismissed as a very speculative and imprecise idea. Recently, there has been exciting new progress on developing the idea and making it more precise. One main reason is that theories that give precise and mathematically defined conditions for the presence or absence of consciousness have been developed, such as Tononi's (2008) integrated information theory, in which consciousness is quantified with a mathematical measure of integrated information.

In Chapter 1, David Chalmers and Kelvin McQueen give a comprehensive introduction to the consciousness-collapse idea and answer the usual objections to the idea. Moreover, they put forward a way of making the consciousness-collapse idea precise by exploring and evaluating dynamic principles governing how consciousness collapses the wave function. Two models are proposed. The first one is a simple consciousness-collapse model on which consciousness is entirely superposition-resistant. This model is subject to a conclusive objection arising from the quantum Zeno effect. The second model combines integrated information theory with Pearle's continuous-collapse theory, and it is not subject to the objection. The prospects of empirically testing these models and potential philosophical objections to them are also discussed. The authors conclude that the consciousness-collapse idea is a research program worth exploring.

In Chapter 2, Elias Okon and Miguel Ángel Sebastián introduce a consciousness-collapse model called the subjective-objective collapse model, evaluate the virtues of the model, and answer some possible objections and challenges related to it, such as the multiple realizability of conscious states. This model consists of an objective collapse scheme, where the collapse operator is associated with consciousness as a physical property or with a physical property that correlates with consciousness. Like Chalmers and McQueen's models, the advantage of this model is that consciousness is incorporated into quantum mechanics in a well-defined way, both mathematically and conceptually, and in a way that is fully compatible with the truth of physicalism if consciousness is physical.

In Chapter 3, J. Acacio de Barros and Carlos Montemayor investigate the role of consciousness in the consciousness-collapse quantum theories. According to them, the observer in quantum mechanics is an access conscious observer, rather than a phenomenally conscious observer, because measurements are not entirely determined by merely appearance properties of experiences, but rather by concrete interventions in an environment by a rational agent with specific goals that have unique theoretical meaning. Moreover, they argue that an access-consciousness version of panpsychism, which they call "panintentionalism," suffices, and it is better equipped to account for the role of consciousness involved in these theories than the standard one, based on phenomenal consciousness.

In objective collapse theories of quantum mechanics, the collapse of the wave function is not caused by consciousness. However, the conscious perceptions may also put constraints on these theories. In Chapter 4, Adrian Kent analyzes the perception constraints on mass-dependent collapse models. According to the previous analysis of Bassi et al., the parameters of these models consistent with known experiments imply that when a person observes a superposition of a few photons, a collapse would happen in her eye within the normal perception time of 100 ms, and thus these models are consistent with our conscious perceptions. Kent notes a key problem of this analysis: the relevant processes are assumed to happen in a vacuum, rather than in cytoplasm. Moreover, he argues that when considering the existence of cytoplasm, these collapse models with parameters consistent with known experiments may not satisfy the perception constraints.

The second part of this book is about other possible roles of consciousness in quantum theories. In Chapter 5, Philip Goff argues that the reality of consciousness puts

a constraint on the ontology of quantum mechanics. According to wave function monism, a popular interpretation of the ontology of quantum mechanics, fundamental physical reality consists of a complex-valued field in a high-dimensional space. Goff analyzes the question of whether the reality of consciousness can be accounted for by wave function monism. After criticizing the existing attempts to close the wave function/three-dimensional objects explanatory gap, he argues, based on an analysis of the grounding relationship, that the wave function monist has no way to account for consciousness, at least on the assumption that she can't account for three-dimensional objects. Goff's argument does not assume either a materialist or a non-materialist view of consciousness.

In Chapter 6, Peter J. Lewis argues that the word "experience" should not appear as a primitive in the formulation of quantum theory, just as Bell argues that the word "measurement" should not so appear. The psychophysical connection is not something that philosophers and physicists can posit at their convenience; neuroscience constrains the connections between brain structures and experience, whether or not the latter is reducible to the former. But he cautions that, while it is relatively easy to tell whether a use of "measurement" in a discussion of quantum mechanics is good or bad, it is not so easy to tell whether a use of "experience" is good or bad.

In Chapter 7, Jenann Ismael argues for a division between the aspects of the mind that physics can and must cope with, and the aspects that it can't cope with, but can ignore. This clearly explains why physics should care about the mind, and how to think about it without worrying about the mind-body problem. If consciousness has no functional or causal role of its own in the physical world, then physics will not know the difference between the conscious state and its physical basis, and thus consciousness is irrelevant to physics and we need not worry about the mind-body problem in physics. If consciousness has a causal role in the physical world as in the consciousness-collapse theories, it will indeed become something that matters to physics. But then it also becomes something that is characteriable in terms of its physical role, and thus we still have the closure of the problem space and the mind-body problem can also be ignored. In addition, Ismael also analyses the dispute between dynamical and computational theories of mind and suggests a resolution.

In Chapter 8, Shan Gao defends his new mentalistic formulation of the measurement problem and argues that it is more appropriate than Maudlin's original formulation. Moreover, he argues that the solutions to the measurement problem need

to care about the minds of observers, e.g., assuming a certain form of psychophysical connection, and their validity depends on our scientific and philosophical understandings of the conscious minds.

In Chapter 9, Paul Skokowski examines the role of human belief within an Everett no-collapse version of quantum mechanics. He considers the claim that an observer of a measurement resulting in a superposition ends up being deceived about her own perceptual beliefs. Skokowski argues that, upon examination of the neural vehicles that comprise the belief eigenstates of the observer, and the intentional contents of these states, the observer will not, in fact, have the deceptive belief claimed by this interpretation of quantum mechanics.

In Chapter 10, Michael Silberstein and W. M. Stuckey offer a new realist psi-epistemic, principle-based account of quantum mechanics and a neutral monist account of experience. Recent gedanken experiments and theorems in quantum mechanics, such as new iterations on Wigner's friend and delayed choice, have led many people to claim that quantum mechanics is not compatible with determinate and intersubjectively consistent experience (what some call absoluteness of observed events). They show that jettisoning wavefunction realism in favor of a principle-based account and conceiving of consciousness as qualia in favor of neutral monism, allows one to uphold the absoluteness of observed events, deflate the hard problem of consciousness, and deflate the measurement problem, all without giving up free will (i.e., no superdeterminism), locality, or the completeness of QM. Their account requires no invocation of relative states (e.g., outcomes being relative to branches, conscious observers, etc.) and requires no "hybrid models" such as claims about "subjective collapse." They provide a take on QM that yields a single world wherein all the observers (conscious or otherwise) agree about determinate and definite outcomes.

In Chapter 11, Michel Bitbol argues that phenomenology provides a possible way of understanding quantum mechanics and consciousness and further solving the measurement problem and the mind-body problem. According to phenomenology, a philosophical discipline that favors a first-person approach of any ontological and epistemological issues, consciousness is neither something nor a property of something, but the flux of the self-splitting of what there is into subjective existence and its objective targets, and physical systems and processes are nothing more than objects of consciousness. This supports the neo-Bohrian approaches to quantum mechanics such as QBism and participatory realism, according to which the symbols of quantum

mechanics are primarily used by agents to assign probabilistic weights to the outcomes of experiments so that such agents can make consistent bets, and the insuperable dependence of these symbols on our situation and experience indirectly reveals the nature of reality so that our knowledge of it can only be participatory rather than representational, predictive rather than descriptive.

In Chapter 12, Lucien Hardy investigates the possibility that when humans are used to decide the settings at each end in a Bell experiment, we might expect to see a violation of quantum mechanics in agreement with the relevant Bell inequality. He argues that this result is well motivated when assuming superdeterminism and mind–body dualism, and if it is confirmed, it will be tremendously significant for our understandings of quantum mechanics and consciousness. Moreover, he also discusses in detail how we can perform such a Bell experiment based on current technologies.

The third part of this book is about the quantum approaches to consciousness. In Chapter 13, Roger Penrose argues that the human ability to achieve conscious understanding is a non-computational process, and this requires something beyond current physical theory, an effect of gravitation on quantum mechanics, in supplying a physical basis for "the collapse of the wave function," denoted by OR. OR events are what allow a firm classical reality to arise from a quantum reality having a somewhat weaker ontological status. When appropriately orchestrated, these "proto-conscious" OR events become genuine conscious processes according to the Orch-OR proposal. Moreover, from the principles of relativity theory, it can be deduced that OR, and therefore Orch-OR, can have a certain "retro-active" effect, which may explain how conscious decisions can act within a very small fraction of a second, in contradiction with a conclusion frequently made, on the basis of various experiments, that such acts must be necessarily unconscious. According to Penrose, this provides an explanation for some puzzling related effects found by Benjamin Libet in the 1970s.

In Chapter 14, Stuart Hameroff gives an up-to-date and comprehensive review of the Penrose-Hameroff "Orch OR" theory. The theory attributes consciousness to "orchestrated" quantum computations in microtubules inside brain neurons, which terminate by Penrose objective reduction (OR), a process in the fine scale structure of the universe that introduces phenomenal experience and non-computability. The theory suggests that microtubules (1) encode memory and process information, (2) orchestrate quantum vibrational superpositions (qubits) of pi electron resonance dipoles within tubulin that unify, entangle, and (3) evolve to meet Orch OR threshold for full, rich

conscious experience, most likely (4) in dendrites and soma of cortical layer 5 pyramidal neurons, and (5) selection of microtubule states that regulate axonal firings and behavior, and (6) "retroactivity" inherent in OR and Orch OR can resolve issues in quantum mechanics, free will, and Libet's famous "backward time referral." Hameroff concludes that Orch OR has explanatory power, and is testable and falsifiable.

In Chapter 15, Basil J. Hiley and Paavo Pylkkänen propose that quantum theory implies a radically new notion of matter that has not been properly understood before David Bohm's groundbreaking work. Bohm proposed that the fundamental particles of physics (such as electrons) are not merely pushed around mechanically by classical forces but are also able to respond to information. Information is thus assumed to be an objective commodity that can exist independently of the human mind and that actively guides or instructs physical processes. This notion of active information also applies in computational, biological, and psychological phenomena, thus helping us to understand how the mental and physical sides of reality are related. It may even help us to understand the nature of conscious experience. The latter part of this chapter considers the deeper mathematical and physical background of quantum theory and suggests that we need to revise our basic assumptions about quantum objects, such as the role of the wave function.

In Chapter 16, William Seager argues that the goal of interpretation of a theory such as quantum mechanics is intelligibility, which aims to show how the world described by a theory can be made intuitively clear. He identifies three kinds of intelligibility: mundane, mathematical, and metaphysical, and notes that the mismatch between high mathematical intelligibility and low mundane intelligibility of quantum mechanics motivates the search for its interpretations, which attempt to provide metaphysical intelligibility. Moreover, Seager considers several such interpretations and argues that Bohm's view, which puts mentality or some basic kind of proto-consciousness as the bearer of intrinsic information, as a fundamental feature of the world, may be the best way to provide a metaphysically intelligible basis for quantum mechanics.

In Chapter 17, Lee Smolin proposes an approach to the question of how consciousness fits into the physical world in the context of a relational and realist completion of quantum mechanics called the causal theory of views. In this theory, the "beables" are the information available at each event from its causal past, and a causal universe is composed of a set of partial views of itself. Smolin proposes that conscious

perceptions are aspects of some views. Concretely speaking, only those views that are novel, in the sense that they are not duplicates of the view of any event in the event's own causal past, are the physical correlates of conscious experience, and to be conscious a view must also be maximal, in the sense of being the smallest composite not being part of a larger entangled state. This gives a restricted form of panpsychism defined by a physically based selection principle that selects which views have experiential aspects, and explains why consciousness always involves awareness of a bundled grouping of qualia that define a momentary self.

Notwithstanding these new insightful thoughts about possible deep connections between consciousness and quantum mechanics, maybe we are still far away from the final answer. But this is just the impetus to do the research. I really hope this book will inspire more researchers to join the search for the ultimate reality of the universe.

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