Is Quantum Physics Relevant for the Mind-Brain Problem?

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Abstract

Quantum Mechanics (QM) has been present in the debate on mind-brain relationships from its beginnings, pointing to the limits of a purely deterministic view. Nevertheless, the relevance of QMfor the brain's physics is still to be proven. Detractors of the influence of QM are confident of the role of decoherent processes in order to vindicate a classical description of the brain. In this article, we bring out the philosophical implications behind the usual recourse to decoherence in the transition from the quantum to the classical world, explaining why the mind-brain problem and the measurement paradox of QM cannot be disentangled.

Keywords: Mind-brain problem; Quantum Decoherence; Measurement Paradox; Quantum Consciousness

Introduction

During the last few decades, progress in the field of neuroscience has renewed the interest to understand the relations between mind and human brain. From its very beginnings, Quantum Mechanics (QM) has been present in this issue through the well-known "measurement paradox". Standard QM interpretation assumes the existence of two irreducible processes: (a) the deterministic

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evolution according to Schrödinger equation of the wavefunction representing the system’s physical state (once its initial conditions have been established); and (b) the indeterministic wavefunction’s “collapse” to a physical state compatible with the specific measurement of an observable, following probability rules which can be computed a priori from the wavefunction. Within this framework, QM hintsat the limitations of a purely deterministic view of nature and, in particular, of brains. It should thus be expected that neuroscientific research will encounter quantum phenomenology at some point.

Along these years, different theoretical models have tried to explain the specific manner in which QM should be playing a relevant role in brain physiology. However, such theories have not generally received the esteem of neurologists for lack of scientific plausibility. Before offering a brief description of the models, it should be noted that there is currently research that uses the QM formalism to describe some phenomena of consciousness and human behavior—a list of the most prominent groups can be seen in [1]

Formal characteristics of QM are applied to certain mental phenomena but without going into the underlying physics of these phenomena on which judgment is suspended. Certainly, the direct application of QM formalism to mental states allows setting many valuable empirical data, but says little about the reality that causes them. However, this research could provide a determination of the relevance of QM in the mind-brain problem; insofar as it is able to show the inability of the classical conditional probability models to explain some of the results currently available. QM predicts results that violate the rules of composition of conditional probability and forbids a purely cognitive interpretation of the wavefunction—as if only referred to the observer’s knowledge. In other words, QM gets access to a reality that is not describable by the use of classical statistics and the laws of conditional probability.

Quantum models of consciousness

Throughout the history of QM, many scientists have explored the behavior of the brain at a microscopic scale and at its macroscopic level amplifications in search of a possible substrate of quantum phenomena. Such phenomena could explain the properties of human psychemuch more convincingly than traditional cognitive neuroscience. Among the most active representatives of this line of research we have: (a) Stuart Hameroff and Roger Penrose, for whom consciousness would be closely linked to objective and structured collapse of the wavefunction in the microtubules of neurons, caused by gravitational interaction[2] [3] [4] [5]; (b) Stuart Kauffman, who considers the brain as a system that continuously passes from quantum decoherence to quantum recoherence [6][7]; and (c) the team led by Giuseppe Vitiello, which applies a dissipative formalism of quantum field theory to explain the various patterns of coherent activity that would occur in the human brain in contact with multiple external stimuli[8][9]. The fundamental problem with these theories is that, even if they happen to be successful from an empirical point of view—through explanation and prediction of new phenomena beyond the reach of a classical theory—, they would only provide a small advance in the understanding of the mind-brain problem. Such models donot give an answer yet to how the transition or conversion occurs from the physical to the mental and vice versa.

There are other models that use QM to explain this last transition, considering consciousness and mental activities as primary realities that have manifestations in the physical world understandable only within the QM paradigm. For example, these may be mentioned: (a) Friedrich Beck and John Eccles, who proposed a model of quantum enhancement of communication through synapses[10]; (b) Henry Stapp, which uses the quantum Zeno effect to explain how conscious attention is able to fix relationships between physical and mental states[11][12][13] [14]; and (c) Efstratios Manousakis, for whom the activities of our brain, the perceptual flow of events and the very QM emerge from primary operations of consciousness[15][16]. But how is it possible that certain physical events may have effects on our consciousness remains unexplained in this type of theories, which neither reach to provide an explanation of the QM measurement paradox. A more general discussion of each of these models can be found in [17].

Criticisms of the QM relevance for understanding the brain

Major critiques of the application of QM to scientific understanding of the mind-brain problem come from the experimental field.Despite the existence of the aforementioned models and the promising results of the theory of Penrose and Hameroff[5], the main neuroscientists’ criticism is that no experiment hasso far been presented showing unmistakable signs of quantum effects in the brain. One could say that, as a matter of fact, there is no definitive answer about the empirical relevance of QM in the brain and that none of the proposed models seem to enjoy a priori plausibility from the neurobiological perspective. At the same time, coming back to pre-quantum physics in order to physiologically base neural process would not be appropriate to address the mind-brain problem in all its complexity.

Opponents of the QM significance ultimately rely on the effect of decoherent processes at different levels to ensure a classical behavior of brain. Quantum decoherence is currently the most common recourse to try to explain the transition from the world of entangled quantum possibilities into the classic world of real events. Decoherence theory posits that whenever a system interacts with a sufficiently large environment, interference terms in the former’s wavefunction tend to cancel out because of the interaction with the latter. In this situation, quantum interference fails to occur in the system and the classical regime emerges from the various quantum possibilities.

The interaction of the system with its environment resembles the process of a classic measurement, according to QM standard interpretation. The system is partly measured by its environment through a gradual process of decoherence, which brings the system from a coherent superposition of possible states to a “mixed” state, which reflects only the probabilities of each measure—for a review, see [18]. The existence of decoherent processes is to some extent a fact well known experimentally and is one of the major difficulties to build, for example, quantum computers.

Nevertheless, the specific mode of action of decoherent processes in physical and biological systems is only partially understood. On one hand, the theory of decoherence does not provide a consistent ontology of the real world, offering only a process for practical purposes. Decoherence depends on the chosen representation for the wavefunction—of its contextualization according to the preferred observable—so that the reduced density matrix can be diagonal in a representation, but not in another one [19]. On the other hand, the theory of decoherence does not explain how the collapse of the wavefunction occurs in isolated systems or the needed nature of a specific isolation for the environment not being involved. And above all, decoherence does not say anything about which part of a general physical system must be considered as environment and which not—the problem of making "physics in a box" [20]. It therefore provides no well-defined limit of anyphysical variable to ensure classical or quantum behavior of the system.

Conclusions: In which sense is QM relevant for the mind-brain problem?

While neuroscience as such does not need time to deepen these conceptual problems, limiting itself to empirical evidence, philosophers of mind should draw some conclusions. In particular, the mere reference to classical complexity as a would-be explanation of mental phenomena leads to begging the question:QM is the underlying physical theory for the brain physiology. In the latter, classical behavior might be retrieved through decoherence models. But these models claim an ad hoc treatment that makes QM a non-unified theory from the epistemological point of view. One needs to invoke an a priori different treatment of the physical reality's parts in order to get decoherence to work. The system under research has to be divided into a subsystem—the brain or the part of it whose study is considered relevant for consciousness—and a thermal bath—as a mathematical idealization of the environment—, whose degrees of freedom are averaged out and removed from the problem. In this sense, decoherence as final explanation for the emergence of the classical world in the brain and of a mental activity caused by sheer complexity turns out to be an incomplete and essentially dualistic theory.

Moreover, it is notable that decoherence occurs when a physical system is defined a priori to obtain information from it through some action. In other words, the decision about the system under study and the observation to be made is an irreducible part of the measurement process. We must decide a priori what physical subsystem will be relevant and how—under what observable—it will be, since the theory of decoherence involves the selection of subsystems by the observer. Thus, the standard interpretation of QM shows the limit beyond which the separation of nature and human access to it is no longer possible. In QM, logic, knowledge and their neural correlates assume the same importance as the features of what is being described. We face reality levels in which the cognitive statements about dynamic variables of nature become themselves part of the problem.It must be emphasized, therefore, that the philosophical framework of QM is significant for the mind-brain problem not simply because such framework makes randomness versus determinismavailable, but because it supposes an irreducible influence of the choice of relevant information to the viewer in the evolution of physical reality.

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