Quantum mechanics refutes solipsism: A proof of the existence of an external world

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Abstract

Solipsism asserts that only one's mind exists, and everything else in the world is a mere construction of the mind. In this paper, I present a new and more conclusive argument against solipsism based on an ontological analysis of quantum experiments.

Key words: Solipsism; mind; mental state; quantum state; Born's rule

> "it always remains a scandal of philosophy and universal human reason that the existence of things outside us ... should have to be assumed merely on faith, and that if it occurs to anyone to doubt it, we should be unable to answer him with a satisfactory proof" — Immanuel Kant (Kant, 1781/1787 Bxxxix note).

Solipsism, in its strongest form, asserts that only one's mind exists, and everything else in the world is a mere construction of the mind (Honderich, 2005). Although this view is very far removed from common sense and has been widely criticized for its skepticism towards objective reality, it seems irrefutable (see Schwitzgebel and Moore, 2015 and Westerhoff, 2020 for two recent analyses). In this paper, I will present a new and more conclusive argument against solipsism based on an ontological analysis of quantum experiments. The idea is that even though one's mind can construct the classical world in principle, it cannot construct the quantum world even in principle, since the mental states, which are always definite, are not quantum states.

Consider a usual quantum experiment. An ensemble of identical quantum systems is prepared, and quantum mechanics assigns a pure quantum state ψ to each system. Then a projective measurement M is made on each system in the ensemble, and the probability distribution of different results k turns out to be the Born probability $|\langle k|\psi\rangle|^2$. An ontological analysis of this experiment can be given based on the so-called ontological models framework (Harrigan and Spekkens, 2010; Pusey, Barrett and Rudolph, 2012). The framework has two fundamental assumptions. The first assumption is about the existence of the underlying state of reality. It says that if a quantum system is prepared such that quantum mechanics assigns a pure quantum state to it, then after preparation the system has a well-defined set of physical properties or an underlying ontic state, which is usually represented by a mathematical object, λ. The second assumption gives a rule of connecting the underlying ontic states with the results of measurements, which says that when a measurement is performed, the behaviour of the measuring device is only determined by the ontic state of the system, along with the physical properties of the measuring device. More specifically, for a projective measurement M, the ontic state λ of a physical system determines the probability $p(k|\lambda, M)$ of different results k for the measurement M on the system. The consistency with the predictions of quantum mechanics then requires the following relation: $\int d\lambda p(k|\lambda, M)p(\lambda|\psi) = p(k|M, \psi)$, where $p(k|M, \psi) = |\langle k|\psi\rangle|^2$ is the Born probability of k given M and ψ.

It has been known that under certain auxiliary assumptions one can further prove the reality of the quantum state, namely that the quantum state of a physical system directly represents the ontic state of the system, and it does not represent a state of incomplete knowledge – an epistemic state – about the ontic state of the system (Leifer, 2014; Gao, 2017). These results are called ψ-ontology theorems. For example, the PBR theorem shows that in the ontological models framework, when assuming independently prepared systems have independent ontic states, the ontic state of a physical system uniquely determines its quantum state (Pusey, Barrett and Rudolph, 2012). This auxiliary assumption is called preparation independence assumption. In short, a realist explanation of quantum experiments requires the existence of something represented by the quantum state if one accepts certain auxiliary assumptions such as the preparation independence assumption.

Now let's see whether solipsism can provide a realist explanation of quantum experiments. Note that solipsism is still one kind of realism, or it is the minimum form of realism, which aims to use only one's mental state and its dynamics to explain all experiences. Since solipsism only admits the existence of one's mind, and it denies the existence of the external world, for solipsists there are no identically prepared quantum systems and measuring devices, and they are all construction of one's mind. Then, in the consistency relation for a usual quantum experiment $\int d\lambda p(k|\lambda, M)p(\lambda|\psi) = |\langle k|\psi\rangle|^2$, λ represents one's mental state that corresponds to the "preparation of a system", whose content contains the "setting of the preparation apparatus", k is another mental state whose content contains the result of the "measurement on the system", and ψ is still the quantum state assigned by quantum mechanics for "the system".

The question is: can the mental state and its dynamics satisfy the consistency relation? If the answer is no, then solipsism cannot provide a realist explanation of quantum experiments. When assuming, as in the preparation independence assumption for the PBR theorem, that the mental states for the "independent preparation of two systems" are also independent, it can be proved, by the same proof of the PBR theorem, that the mental state uniquely determines the quantum state, or the quantum state directly represents the mental state. However, since the content of the mental state for the "preparation of a system" contains only the "setting of the preparation apparatus", it is obviously not represented by the quantum state. Thus, under an independence assumption one can prove that the mental state and its dynamics cannot satisfy the consistency relation.

Certainly, by dropping the independence assumption as in certain ψ-epistemic models, one can deny the reality of the quantum state and avoid the above result. However, the above result can also be proved without using the PBR theorem. Since the settings of the preparation apparatus for all systems in the ensemble are the same, the content of the mental state for the "preparation of each system" will be the same, which means that λ is the same for each system in the ensemble or $p(\lambda|\psi) = 1$. Then the above consistency relation reduces to $p(k|\lambda, M) = |\langle k|\psi\rangle|^2$. But this relation cannot hold for any k, since the setting of the preparation apparatus is not represented by the quantum state or $\lambda \neq \psi$.[1]

To sum up, I have argued that solipsism cannot explain quantum experiments, and thus it has been refuted by quantum mechanics. The key point is that a realist explanation of quantum experiments requires the existence of something directly represented by the quantum state or something that can simulate the quantum state, while the mental state is a classical state in

[1]It is true that the setting of the preparation apparatus determines the prepared quantum state by the law of quantum mechanics. However, if only $\lambda \neq \psi$, the relation $p(k|\lambda, M) = |\langle k|\psi\rangle|^2$ cannot hold for any k. In fact, if the setting of the preparation apparatus being the ontic state could explain the consistency relation, then the PBR theorem would be wrong.

the sense that it is always definite and its content contains only information about macroscopic systems such as the setting of a preparation apparatus, which is not enough for representing or simulating the quantum state. A positive result of this analysis is that one finds the existence of an external world besides one's mind. This is a quantum leap from Descartes' (1637) "I think, therefore I am". When admitting the reality of the quantum state, there must exist an external world represented by a quantum state.[2] Yet, how one's mind relates to this quantum world and whether there are other minds remains to be a deep mystery.[3]

References

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[2] In order to explain all possible quantum experiments, this wave function must represent the whole universe, and it has been called the wave function of the universe or the universal wave function.

[3] It can be argued that in the many-worlds interpretation of quantum mechanics there must exist other minds in other worlds.

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