Failure of psychophysical supervenience in Everett's theory

Shan Gao[1,2]
[1] Research Center for Philosophy of Science and Technology, Shanxi University, Taiyuan 030006, P. R. China
[2] Department of Philosophy, University of Chinese Academy of Sciences Beijing 100049, P. R. China
E-mail: gaoshan2017@sxu.edu.cn.

April 2, 2017

Abstract

Everett's theory assumes (1) the completeness of the description by the wave function, (2) the linearity of the dynamics for the wave function, and (3) multiplicity. In this paper, I argue that these three assumptions of Everett's theory may lead to the violation of psychophysical supervenience.

Everett's theory assumes that the wave function of a physical system is a complete description of the system, and the wave function always evolves in accord with the linear Schrödinger equation. In order to solve the measurement problem, the theory further assumes that after a measurement with many possible results there appear many equally real worlds, in each of which there is an observer who is aware of a definite result (Everett, 1957; DeWitt and Graham, 1973; Wallace, 2012). In this paper, I will argue that Everett's theory may violate psychophysical supervenience.

Consider a simple spin measurement. First, suppose an observer M measures the x-spin of a spin one-half system S being x-spin up, $|up\rangle_S$. By the Schrödinger equation, the physical state of the composite system after the measurement will evolve into the product state of M recording x-spin up and S being x-spin up:

$$|up\rangle_S \, |up\rangle_M \,. \tag{1}$$

According to Everett's theory, there is still one observer, namely the original observer, after the measurement, and she is consciously aware of a definite record, x-spin up.

Similarly, when the observer M measures the x-spin of a spin one-half system S being x-spin down, $|down\rangle_S$, the physical state of the composite system after the measurement will evolve into the product state of M recording x-spin down and S being x-spin down:

$$|down\rangle_S \, |down\rangle_M \,. \tag{2}$$

Again, according to Everett's theory, there is still one observer, namely the original observer, after the measurement, and she is consciously aware of a definite record, x-spin down.

Now consider a unitary time evolution operator, which changes $|up\rangle_S \, |up\rangle_M$ to $|down\rangle_S \, |down\rangle_M$ and $|down\rangle_S \, |down\rangle_M$ to $|up\rangle_S \, |up\rangle_M$, namely swaps the above two product states. It is similar to the NOT gate for a single q-bit, and is permitted by the Schrödinger equation in principle. Then after the evolution, the composite system being initially in the product state of M recording x-spin up and S being x-spin up will be in the product state of M recording x-spin down and S being x-spin down, namely

$$|up\rangle_S \, |up\rangle_M \rightarrow |down\rangle_S \, |down\rangle_M \,. \tag{3}$$

According to Everett's theory, there is still one observer, namely the original observer, after the unitary time evolution, and her mental state changes from being aware of x-spin up to being aware of x-spin down.

Similarly, after the unitary time evolution, the composite system being initially in the product state of M recording x-spin down and S being x-spin down will be in the product state of M recording x-spin up and S being x-spin up, namely

$$|down\rangle_S \, |down\rangle_M \rightarrow |up\rangle_S \, |up\rangle_M \,. \tag{4}$$

Again, according to Everett's theory, there is still one observer, namely the original observer, after the unitary time evolution, and her mental state changes from being aware of x-spin down to being aware of x-spin up.

These results are plain and familiar. Obviously the above evolution satisfies the principle of psychophysical supervenience. The mental state of the composite system or the mental state of the corresponding observer changes with the change of the physical state of the composite system. Here supervenience is used in its standard definition. A set of properties A supervenes on another set B in case no two things can differ with respect to A-properties without also differing with respect to their B-properties (see McLaughlin and Bennett, 2014). By this definition, psychophysical supervenience requires that the mental properties of a system cannot change without the change of its physical properties.

Let us consider a more interesting case. Suppose an observer M measures the x-spin of a spin one-half system S that is in a superposition of two different x-spins, $\frac{1}{\sqrt{2}}(|up\rangle_S + |down\rangle_S)$. By the linear Schrödinger equation, the physical state of the composite system after the measurement will evolve into the superposition of M recording x-spin up and S being x-spin up and M recording x-spin down and S being x-spin down:

$$\frac{1}{\sqrt{2}}(|up\rangle_S\,|up\rangle_M + |down\rangle_S\,|down\rangle_M). \tag{5}$$

According to Everett's theory, this post-measurement state (5) corresponds to two observers, each of who is consciously aware of a definite record, either x-spin up or x-spin down.[1]

There are in general three ways of understanding the notion of multiplicity in Everett's theory: (1) measurements lead to multiple worlds at the fundamental level (DeWitt and Graham, 1973), (2) measurements lead to multiple worlds only at the non-fundamental "emergent" level (Wallace, 2012), and (3) measurements only lead to multiple minds (Zeh, 1981; Albert and Loewer, 1988). In either case, for the above post-measurement state (5), the mental state of each observer is not uniquely determined by her whole wave function, and it supervenes on one branch of the wave function.[2]

Now consider again the above unitary time evolution operator, which changes the first branch of the superposition to its second branch and the second branch to the first branch:

$$\frac{1}{\sqrt{2}}(|up\rangle_S\,|up\rangle_M + |down\rangle_S\,|down\rangle_M) \to \frac{1}{\sqrt{2}}(|down\rangle_S\,|down\rangle_M + |up\rangle_S\,|up\rangle_M). \tag{6}$$

Then, like the product state cases, after the evolution the mental state of each observer, which supervenes on the corresponding branch of the superposition, will change; the mental state supervening on the first branch will change from being aware of x-spin up to being aware of x-spin down, and the mental state supervening on the second branch will change from being aware of x-spin down to being aware of x-spin up.[3] On the other hand, it can be seen that after the evolution the whole superposition does not change.

According to Everett's theory, the wave function of a physical system is a complete description of the system. Therefore, after the above unitary time evolution the physical state of the composite system does not change. However, the mental states of the two involved observers both change after

[1] Note that in Wallace's (2012) formulation of Everett's theory the number of the emergent observers after the measurement is not definite due to the imperfectness of decoherence. My following analysis also applies to this formulation.

[2] It is worth noting that if the mental state of each observer does not supervene on or covary with the corresponding branch of the post-measurement superposition, then the predictions of the theory will be not consistent with the predictions of quantum mechanics and experience for some unitary time evolution of the superposition.

[3] This is required by the linearity of dynamics. See below for further discussion.

the evolution. Therefore, it seems that the psychophysical supervenience is violated by Everett's theory in this example.

There are two possible ways to avoid the violation of psychophysical supervenience in the above example. The first way is to deny that after the evolution the physical state of the composite system has not changed. This requires that the wave function of a system is not a complete description of the physical state of the system. Obviously, this requirement is not consistent with Everett's theory.

The second way is to deny that after the evolution the total mental states of the composite system have changed. For example, one may argue that after the above evolution there remain a mental state corresponding to seeing a spin up result and a mental state corresponding to seeing a spin down result, and thus the total mental states of the composite system have not changed. However, this seems to require that each observer has no trans-temporal identity, while the absence of identities of observers is inconsistent with the predictions of quantum mechanics and experience. If each observer has a trans-temporal identity and her mental state supervenes on the corresponding branch of the superposition, then her mental state will change after the evolution, and thus the total mental states of the composite system, which are composed of the mental states of these observers, also change after the evolution.[4]

In order to avoid the violation of psychophysical supervenience, one may even resort to a more complicated dynamics for the mental state, such as a mental dynamics that keeps the mental state of each observer unchanged or switches the two observers' identities for the above evolution of the superposition (5). Certainly, for the evolution of a product state by the same unitary evolution operator, the mental dynamics must still change the mental state of the observer as usual so that it can be consistent with the predictions of quantum mechanics and experience. Thus, such a dynamics must be nonlinear.[5] Although a nonlinear dynamics for the physical state or the wave function is obviously inconsistent with Everett's theory, a nonlinear dynamics for the mental state is not prohibited by the theory; the many-minds theory is an example (Albert and Loewer, 1988; Barrett, 1999). However,

[4]By comparison, if for the post-measurement superposition (5) there is only one observer whose mental content is composed of seeing a spin up result and seeing a spin down result, then her mental state will not change after the above evolution, and the principle of psychophysical supervenience can be satisfied (see Gao, 2016, 2017 for further discussion).

[5]A linear dynamics requires that the evolution of one branch of a superposition is independent of the evolution of other branches, as well as whether or not these branches exist. Thus, by the same unitary evolution operator, the evolution of one branch of the post-measurement superposition (5), such as the branch $|up\rangle_S |up\rangle_M$ in the sperposition, will be the same as the evolution of the post-measurement state containing only this branch, such as the product state $|up\rangle_S |up\rangle_M$. This is true for the evolution of both the physical state and the mental state. Otherwise the linearity of dynamics will be violated, and the resulting dynamics will be nonlinear.

the existence of a nonlinear dynamics for the mental state in Everett's theory already entails dualism. It seems that this is no better than the violation of psychophysical supervenience. Moreover, such a nonlinear dynamics seems very ad hoc, and it is also difficult to determine what the dynamics is for an arbitrary superposition such as $\alpha \left|up\right\rangle_S \left|up\right\rangle_M + \beta \left|down\right\rangle_S \left|down\right\rangle_M$, where α and β are not zero and satisfy the normalization condition $|\alpha|^2 + |\beta|^2 = 1$.

Finally, one may argue that the above superposition (5) is a very special state, and thus the violation of psychophysical supervenience, even if it exists, is not serious for Everett's theory. For other states, the amplitudes of the two branches of the superposition are different, and thus after the above evolution the physical state of the composite system, like the mental states of the system, will also change. Then the psychophysical supervenience will not be violated for these states. However, when the difference of the amplitudes of the two branches of the superposition is very small, the change of the physical state of the composite system is also very small after the evolution. But the change of the mental state of each observer is still very large, e.g. from being aware of x-spin down to being aware of x-spin up. In this case, even if the psychophysical supervenience is not violated in a strict sense, it seems very difficult or even impossible to explain how the mental state supervenes on the physical state.

To sum up, I have argued that Everett's theory may violate psychophysical supervenience. The violation of psychophysical supervenience results from the three key assumptions of the theory: (1) the completeness of the description by the wave function, (2) the linearity of the dynamics for the wave function, and (3) multiplicity. It is well known that the many-minds theory violates psychophysical supervenience, and thus this result is not new for the theory. But for the many-worlds theory, no matter the worlds are at the fundamental level or only at the non-fundamental "emergent" level, this result is new; a many-worlds theory may also violate the psychophysical supervenience.

References

[1] Albert, D. Z. and B. Loewer. (1988). Interpreting the Many Worlds Interpretation, Synthese, 77, 195-213.

[2] Barrett, J. A. (1999). The Quantum Mechanics of Minds and Worlds. Oxford: Oxford University Press.

[3] DeWitt, B. S. and N. Graham (eds.). (1973). The Many-Worlds Interpretation of Quantum Mechanics. Princeton: Princeton University Press.

[4] Everett, H. (1957). 'Relative state' formulation of quantum mechanics. Rev. Mod. Phys. 29, 454-462.

[5] Gao, S. (2016). What does it feel like to be in a quantum superposition? http://philsci-archive.pitt.edu/11811/.

[6] Gao, S. (2017). The Meaning of the Wave Function: In Search of the Ontology of Quantum Mechanics. Cambridge: Cambridge University Press.

[7] McLaughlin, Brian and Bennett, Karen, Supervenience, The Stanford Encyclopedia of Philosophy (Spring 2014 Edition), Edward N. Zalta (ed.), https://plato.stanford.edu/archives/spr2014/entries/supervenience/.

[8] Wallace, D. (2012). The Emergent Multiverse: Quantum Theory according to the Everett Interpretation. Oxford: Oxford University Press.

[9] Zeh, H. D. (1981). The Problem of Conscious Observation in Quantum Mechanical Description, Epistemological Letters of the Ferdinand-Gonseth Association in Biel (Switzerland), 63. Also Published in Foundations of Physics Letters. 13 (2000) 221-233.