A quantum observer cannot report her observation; otherwise superluminal signaling is possible

Shan Gao
Research Center for Philosophy of Science and Technology,
Shanxi University, Taiyuan 030006, P. R. China
E-mail: gaoshan2017@sxu.edu.cn.

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Abstract

In collapse theories of quantum mechanics, there are observers who are in a superposition of brain states with different perceptions. This paper presents a no-go result for such quantum observers. It is argued that the following three assumptions: (1) quantum observers have minds, (2) quantum observers can report their mental content, and (3) no-signaling are incompatible. Possible implications of this result are also briefly discussed.

Key words: collapse theories; quantum observer; no-signaling theorem

In quantum mechanics, the physical state, which determines the result of a measuring device or the mental state of an observer, may be described by the wave function, or a decoherent branch of the wave function, or additional variables. The first case includes collapse theories (Ghirardi and Bassi, 2020), where there are quantum observers whose physical states are superpositions of brain states with different perceptions.[1] The second case includes the

[1]In standard quantum mechanics, it is postulated that when a quantum system is measured by a measuring device or an observer, its wave function no longer follows the linear Schrödinger equation, but instantaneously collapses to one of the wave functions that correspond to definite measurement results. As a result, there are no observers who are in a quantum superposition of brain states with different records. However, such quantum

many-worlds theory. The third case includes the de Broglie-Bohm theory. The question is: which one, if any, is true? (Gao, 2019)

In the following, I will derive a no-go result for quantum observers. Concretely speaking, I will prove the incompatibility of the following three assumptions:

(A1). Quantum observers have minds: a quantum observer, whose physical state is a superposition of brain states with different perceptions, has a well-defined mental state;

(A2). The mental content of a quantum observer can be output in a physical way, e.g. a quantum observer can report her measurement result;

(A3). No-signaling: superluminal signaling is prohibited.

Consider a quantum observer M being in a post-measurement superposition:

$$\alpha \left|1\right\rangle_P \left|1\right\rangle_M + \beta \left|2\right\rangle_P \left|2\right\rangle_M , \tag{1}$$

where $\left|1\right\rangle_P$ and $\left|2\right\rangle_P$ are the wave functions of a pointer being centered in positions x_1 and x_2, respectively, $\left|1\right\rangle_M$ and $\left|2\right\rangle_M$ are the wave functions of the observer M who observes the pointer being in positions x_1 and x_2, respectively, and α and β, which are nonzero, satisfy the normalization condition $|\alpha|^2 + |\beta|^2 = 1$.

According to (A1), the quantum observer M has a well-defined mental state. The question is: what is her mental content? There are two cases. The first case is that the mental content of M is related to the values of α and β (Gao, 2019). The second case is that the mental content of M is constant for all nonzero values of α and β. Here there are three subcases: (1) The mental content of M is "observing the pointer being in position x_1"; (2) The mental content of M is "observing the pointer being in position x_2"; (3) The mental content of M is constant for all nonzero values of α and β, but it is neither "observing the pointer being in position x_1" nor "observing the pointer being in position x_2".

observers exist in collapse theories, including consciousness-collapse theories (Chalmers and McQueen, 2022). In (existing) collapse theories, due to the imperfectness of wave-function collapse, the post-measurement state of an observer is an entangled superposition of brain states with all possible records, although the modulus squared of the amplitude of one result branch is close to one in general. This leads to the well-known tails problem (McQueen, 2015). Besides, even if the dynamical collapse of the wave function is perfect, since the collapse time of a single superposed state is a random variable, whose value can range between zero and infinity, there always exist certain measurements with a small probability, for which the collapse time is much longer than the normal perception time and the observer can be in a superposition of brain states with different records (Ghirardi et al, 1993).

Now according to (A2), the mental content of M can be output in a physical way, e.g. M can report her mental content about the measurement result. Then, in the first case, the output of M will contain the information about (nonzero) α and β. Then some non-orthogonal states such as $|1\rangle_P |1\rangle_M$ or $|2\rangle_P |2\rangle_M$ and $\alpha |1\rangle_P |1\rangle_M + \beta |2\rangle_P |2\rangle_M$ or $\alpha |1\rangle_P |1\rangle_M - \beta |2\rangle_P |2\rangle_M$ will be distinguishable. For the former, the output of M does not contain the information about α and β, while for the latter, the output of M contains the information about α and β. Once non-orthogonal states can be distinguished, one can further realize superluminal signaling using the EPR-Bell correlations. This contradicts (A3), the no-signaling assumption.

Similarly, in the second case where the mental content of M is constant for all nonzero values of α and β, the non-orthogonal states $|1\rangle_P |1\rangle_M$ or $|2\rangle_P |2\rangle_M$ and $\alpha |1\rangle_P |1\rangle_M + \beta |2\rangle_P |2\rangle_M$ or $\alpha |1\rangle_P |1\rangle_M - \beta |2\rangle_P |2\rangle_M$ can also be distinguished. For example, in the third subcase, the output of M for $|1\rangle_P |1\rangle_M$ or $|2\rangle_P |2\rangle_M$ is either "observing the pointer being in position x_1" or "observing the pointer being in position x_2", while the output of M for $\alpha |1\rangle_P |1\rangle_M + \beta |2\rangle_P |2\rangle_M$ or $\alpha |1\rangle_P |1\rangle_M - \beta |2\rangle_P |2\rangle_M$ is neither "observing the pointer being in position x_1" nor "observing the pointer being in position x_2". Then, superluminal signaling can also be realized, while this contradicts (A3), the no-signaling assumption.

Therefore, I have derived a no-go result for quantum observers, namely that the following three assumptions: (1) quantum observers have minds, (2) quantum observers can report their mental content, and (3) no-signaling are incompatible. In order to avoid this no-go result, we must reject one or more of these assumptions. Rejecting the first assumption will reject collapse theories, a promising alternative to standard quantum mechanics. Rejecting the third assumption will violate the no-signaling theorem of quantum mechanics. It seems that the second assumption is most probably not true. In this case, a quantum observer cannot report her mental content such as her record of a measurement result. This is also an interesting result for the philosophy of mind which deserves a further analysis.[2]

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