A quantum physical argument for panpsychism

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It has been widely thought that consciousness has no causal efficacy in the physical world. However, this may be not the case. In this paper, we show that a conscious being can distinguish definite perceptions and their quantum superpositions, while a physical measuring system without consciousness cannot distinguish such nonorthogonal quantum states. The possible existence of this distinct quantum physical effect of consciousness may have interesting implications for the science of consciousness. In particular, it suggests that consciousness is not emergent but a fundamental feature of the universe. This may provide a possible quantum basis for panpsychism.

Key words: consciousness, causal efficacy, quantum superposition, quantum-to-classical transition, panpsychism

Introduction

The relationship between consciousness and quantum measurement has been studied since the founding of quantum mechanics (von Neumann 1932/1955; London and Bauer 1939; Wigner 1967; Stapp 1993, 2007; Penrose 1989, 1994; Hameroff and Penrose 1996; Hameroff 1998, 2007; Gao 2004, 2006b, 2008). There are two main viewpoints claiming that they are intimately connected. The first one holds that the consciousness of an observer causes the collapse of the wave function and helps to complete the quantum measurement or quantum-to-classical transition in general (von Neumann 1932/1955; London and Bauer 1939; Wigner 1967; Stapp 1993, 2007). The second view holds that consciousness arises from objective wavefunction collapse (Penrose 1989, 1994; Hameroff and Penrose 1996; Hameroff 1998, 2007). Though these two views are obviously contrary, they both insist that there are no quantum superpositions of definite conscious perception states. Different from these seemingly extreme views, it is widely thought that the quantum-to-classical transition and consciousness are essentially independent with each other (see, e.g. Nauenberg (2007) for a recent review). At first sight, this common-sense view seems too evident to be intriguing. However, it has been argued that, by permitting the existence of superpositions of different conscious perception states, this view may lead to an unexpected new result, a quantum physical effect of consciousness (Gao 2004, 2006b, 2008). In this paper, we will analyze this interesting result and discuss its possible implications.

The plan of this paper is as follows. Section 2 presents a general analysis of the role of consciousness in physical measurement. Section 3 gives a detailed argument for the new quantum physical effect of consciousness. It is argued that under some condition a conscious being can distinguish definite perceptions and their quantum superpositions, while a physical measuring system without consciousness cannot distinguish such nonorthogonal quantum states. Section 4 further analyzes the condition required for the existence of the quantum effect of consciousness. It is shown that although the condition is very stringent, it can be met in principle. Section 5 discusses the possible implications of the distinct quantum effect of consciousness. It is argued that if the effect exists, this would suggest that consciousness is not emergent but a fundamental feature of the universe. Conclusions are given in the last section.

A general analysis

A physical measurement generally consists of two processes: (1). the physical interaction between the observed object and the measuring device; (2). the psychophysical interaction between the measuring device and the observer. In some special situations, measurement may be the direct interaction between the observed object and the observer. Even though what physics commonly studies are the insensible objects, the consciousness of the observer must take part in the last phase of measurement. The observer is introspectively aware of his perception of the measurement results. Here consciousness is used to end the infinite chains of measurement. This is one of the main differences between the functions of a physical measuring device and an observer in the measurement process.

In classical mechanics, the influence of the measuring device or the observer on the observed object can be omitted in principle during a measurement process, and the psychophysical interaction between the observer and the measuring device does not influence the reading of the pointer of the measuring device either. Thus measurement is only an ordinary one-to-one mapping from the state of the observed object to the pointer state of the measuring device and then to the perception state of the observer, or a direct one-to-one mapping from the state of the observed object to the perception state of the observer. The consciousness of the observer has no physically identifiable functions that are different from those of the physical measuring device in the classical theory.

However, the measurement process is no longer plain in quantum mechanics. The influence of the measuring device on the observed object cannot be omitted in principle during a quantum measurement owing to the existence of quantum entanglement. It is just this influence that leads to the quantum-to-classical transition and generates the definite measurement result. Since the measuring device has already generated one definite measurement result, the psychophysical interaction between the observer and the measuring device is still an ordinary one-to-one mapping, and the process is the same as that in the classical context. But when the observed object and the observer directly interact, the existence of quantum superposition will introduce a new element to the psychophysical interaction between the observer and the measured object. The interaction will lead to the appearance of a conscious observer in quantum superposition. As we will see in the next section, the consciousness of the observer in a superposition state can have a physically identifiable effect that is lacking for the physical measuring device, which is regarded as being lack of consciousness.

The effect

Quantum mechanics is the most fundamental theory of the physical world. Yet as to the measurement process or quantum-to-classical transition process, the standard quantum mechanics provides by no means a complete description, and the collapse postulate is just a makeshift (Bell 1987). Dynamical collapse theories (Ghirardi 2008), the many-worlds interpretation (Everett 1957) and the de Broglie-Bohm theory (Bohm 1952) are the main alternatives to a complete quantum theory. The latter two replace the collapse postulate with some new structures, such as branching worlds and Bohmian trajectories, while the former integrate the collapse postulate with the normal Schrödinger evolution into a unified dynamics. It has been recently argued that the dynamical collapse theories are probably in the right direction by admitting wavefunction collapse (Gao 2011). Here we will mainly discuss the possible quantum effects of consciousness in the framework of dynamical collapse theories, though the conclusion also applies to the other two alternatives (Gao 2004). Our analysis only relies on a common character of the theories, i.e., that the collapse of the wave function is one kind of objective dynamical process, essentially independent of the consciousness of observer, and it takes a finite time to finish.

It is a well-known result that nonorthogonal quantum states cannot be distinguished (by physical measuring device) in both standard quantum mechanics and dynamical collapse theories (see, e.g. Wootters and Zurek 1982; Ghirardi et al 1993; Nielsen and Chuang 2000). However, it has been argued that a conscious being can distinguish his definite perception states and the quantum superpositions of these states, and thus when the physical measuring device is replaced by a conscious observer, the nonorthogonal states can be distinguished in principle in dynamical collapse theories (Gao 2004, 2006b, 2008). The distinguishability of nonorthogonal states will reveal a distinct quantum physical effect of consciousness, which is lacking for a physical measuring system without consciousness. In the following, we will give a full exposition of this result.

Let ψ_1 and ψ_2 be two definite perception states of a conscious being, and $\psi_1+\psi_2$ is the quantum superposition of these two perception states. For example, ψ_1 and ψ_2 are triggered respectively by a small number of photons with a certain frequency entering into the eyes of the conscious being from two directions, and $\psi_1+\psi_2$ is triggered by the superposition of these two input states. Suppose the conscious being satisfies the following slow collapse condition, i.e., that the collapse time of the superposition state $\psi_1+\psi_2$, denoted by *tc*, is longer than the conscious time *tp* of the conscious being for forming the perception ψ_1 or ψ_2, and the time difference is large enough for him to identify[1]. This condition ensures that consciousness can take part in the

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[1] Note that during the process of forming the definite perception ψ_1 or ψ_2 the brain state of an observer may

process of wavefunction collapse; otherwise consciousness can only appear after the collapse and will surely have no influence upon the collapse process. Now we will explain why the conscious being can distinguish the definite perception state ψ_1 or ψ_2 and the superposition state $\psi_1+\psi_2$.

First, we assume that a definite perception appears only after the collapse of the superposition state $\psi_1+\psi_2$. This assumption seems plausible. Then the conscious being can have a definite perception after the conscious time *tp* for the states ψ_1 and ψ_2, but only after the collapse time *tc* can the conscious being have a definite perception for the superposition state $\psi_1+\psi_2$. Since the conscious being satisfies the slow collapse condition and can distinguish the times *tp* and *tc*, he can distinguish the definite perception state ψ_1 or ψ_2 and the superposition state $\psi_1+\psi_2$. Note that a similar argument was first given by Squires (1992).

Next, we assume that the above assumption is not true, i.e., that the conscious being in a superposition state can have a definite perception before the collapse has completed. We will show that the conscious being can also distinguish the states $\psi_1+\psi_2$ and ψ_1 or ψ_2 with non-zero probability.

(1). If the definite perception of the conscious being in the superposed state $\psi_1+\psi_2$ is

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also undergo certain collapse process. As we think, the process does not influence the slow collapse condition and the following argument. First of all, this collapse is independent of the collapse of the superposition $\psi_1+\psi_2$, and thus it does not influence the collapse time *tc* for the superposition. Next, since the definite conscious perception ψ_1 or ψ_2 appears after this collapse finishes in general, the collapse time for ψ_1 or ψ_2, denoted by *te*, will be shorter than the conscious time *tp*. Therefore, the slow collapse condition, which requires that *tc* is longer than *tp*, is not influenced. In fact, even if the collapse time *te* is longer than the conscious time *tp*, the following argument will not be influenced either, because the relevant conditions used in the argument are only the conscious time *tp* and the collapse time *tc*. Besides, it is worth stressing that the conscious time *tp* is for the normal perception ψ_1 or ψ_2, not for their quantum superposition $\psi_1+\psi_2$. For example, the normal conscious time *tp* of a human being is at the level of several hundred milliseconds, but the conscious time for the quantum superposition of normal perceptions may be different as we will argue below. It is generally thought that a normal perception state as a definite macroscopic state is a coherent state in which the position spread and momentum spread are both narrow due to environmental decoherence.

neither ψ_1 nor ψ_2 (e.g. the perception is some sort of mixture of the perceptions ψ_1 and ψ_2), then obviously the conscious being can directly distinguish the states $\psi_1+\psi_2$ and ψ_1 or ψ_2.

(2). If the definite perception of the conscious being in the superposed state $\psi_1+\psi_2$ is always ψ_1, then the conscious being can directly distinguish the states $\psi_1+\psi_2$ and ψ_2. Besides, the conscious being can also distinguish the states $\psi_1+\psi_2$ and ψ_1 with probability 1/2. The superposition state $\psi_1+\psi_2$ will become ψ_2 with probability 1/2 after the collapse, and the definite perception of the conscious being will change from ψ_1 to ψ_2 accordingly. But for the state ψ_1, the perception of the conscious being has no such change.

(3). If the definite perception of the conscious being in the superposed state $\psi_1+\psi_2$ is always ψ_2, the proof is similar to (2).

(4). If the definite perception of the conscious being in the superposed state $\psi_1+\psi_2$ is random, e.g., one time it is ψ_1, and another time it is ψ_2, then the conscious being can still distinguish the states $\psi_1+\psi_2$ and ψ_1 or ψ_2 with non-zero probability. For the definite perception states ψ_1 or ψ_2, the perception of the conscious being does not change. For the superposition state $\psi_1+\psi_2$, the perception of the conscious being will change from ψ_1 to ψ_2 or from ψ_2 to ψ_1 with non-zero probability during the collapse process.

In fact, we can also give a compact proof by reduction to absurdity. Assume that a conscious being cannot distinguish the definite perception states ψ_1 or ψ_2 and the superposition state $\psi_1+\psi_2$. This requires that for the superposition state $\psi_1+\psi_2$ the conscious being must have the perception ψ_1 or ψ_2 immediately after the conscious time *tp*, and moreover, the perception must be exactly the same as his perception after the collapse of the superposition state $\psi_1+\psi_2$.

Otherwise he will be able to distinguish the superposition state $\psi_1 + \psi_2$ from the definite state ψ_1 or ψ_2. Since the conscious time t_p is shorter than the collapse time t_c, the requirement means that the conscious being knows the collapse result *beforehand*. This is impossible due to the essential randomness of the collapse process. Note that even if this is possible, the conscious being also has a distinct quantum physical effect, i.e., that he can know the random collapse result beforehand.

To sum up, we have shown that if a conscious being satisfies the slow collapse condition, he can readily distinguish the nonorthogonal states $\psi_1 + \psi_2$ (or $\psi_1 - \psi_2$) and ψ_1 or ψ_2, which is an impossible task for a physical measuring system without consciousness.

The condition

The above quantum physical effect of consciousness depends on the slow collapse condition, which says that for a conscious being the collapse time of a superposition of his definite conscious perceptions is longer than his normal conscious time. Whether this condition is available for human brains depends on concrete models of consciousness and wavefunction collapse. For example, if a definite conscious perception involves less neurons such as several thousand neurons, then the collapse time of the superposition of such perceptions will be at the same level as the normal conscious time (several hundred milliseconds) according to a dynamical collapse model (Gao 2006a, 2006b, 2008). Let us give a more detailed analysis.

According to the common understanding, the appearance of a conscious perception in human brains involves a large number of neurons changing their states from resting state to activation state. In each neuron, the main difference of activation state and resting state lies in the motion of 10^6 Na^+s passing through the membrane. Since the membrane potential is in the levels of $10^{-2}V$, the energy difference between activation state and resting state is about $10^4 eV$. According to a dynamical collapse model (Gao 2006a, 2006b, 2008), the (average) collapse time of the quantum superposition of activation state and resting state of one neuron is

$$\tau_c \approx \frac{\hbar E_P}{(\Delta E)^2} \approx (\frac{2.8Mev}{0.01MeV})^2 \approx 10^5 s, \qquad (1)$$

where $\hbar$ is the Planck constant divided by 2π, $E_P \approx 10^{19} GeV$ is the Planck energy, and ΔE is the energy difference between the states in the superposition. Since the number of neurons that can form a definite conscious perception is usually of the order of 10^6, the collapse time of the quantum superposition of two different conscious perceptions is

$$\tau_c \approx (\frac{2.8Mev}{10GeV})^2 \approx 10^{-4} ms . \tag{2}$$

The normal conscious time of a human brain is in the levels of several hundred milliseconds. Therefore, the collapse time is much shorter than the normal conscious time, and the slow collapse condition seems unavailable for human brains.

However, there are at least two possible loopholes in the above argument. One is that the estimation of the number of neurons is only for normal conscious states. The number might be much less than the usual level for some special states such as altered conscious states. For example, if the number of neurons that can form a definite conscious perception is of the order of 10^3, the collapse time will be

$$\tau_c \approx (\frac{2.8Mev}{10MeV})^2 \approx 100ms , \tag{3}$$

which is already at the same level as the normal conscious time. The other possible loophole is that the appearance of a conscious perception in human brains might not necessarily involve the state change of a large number of neurons. It may only involve some systems smaller than neurons. For example, in the Penrose-Hameroff orchestrated objective reduction model (Hameroff and Penrose 1996; Hagan, Hameroff and Tuszynski 2002), the appearance of a conscious perception only involves the microtubules inside neurons. If a conscious perception involves about 10^9 participating tubulin, then the collapse time will be several hundred milliseconds and at the level of normal conscious time (Hameroff and Penrose 1996). When assuming that 10% of the tubulin contained becomes involved, the conscious perception only involves about one thousand neurons (there are roughly 10^7 tubulin per neuron). In addition, even though the slow collapse condition is unavailable for human brains, it cannot be in principle excluded that there exist some small brain creatures in the universe who satisfy the slow collapse condition (see also Squires 1992).

We have been discussing the practical availability of the slow collapse condition for human brains, for which the calculated collapse time is the average collapse time for an ensemble composed of identical superposition states. However, it should be pointed out that the collapse time of a single superposition state is an essentially stochastic variable, which value can range between zero and infinity. As a result, the slow collapse condition can always be satisfied in some collapse events with non-zero probability. For these collapse processes, the collapse time of the single superposition state is much longer than the (average) collapse time and the normal conscious time, and thus the conscious being can distinguish the nonorthogonal states and have the distinct quantum physical effect. As we will see in the next section, this ultimate possibility may have important implications for the nature of consciousness.

Implications

Consciousness is the most familiar phenomenon. Yet it is also the hardest to explain. The relationship between objective physical process and subjective conscious experience presents a well-known hard problem for science (Chalmers 1996). It retriggers the recent debate about the long-standing dilemma of panpsychism versus emergentism (Strawson et al 2006). Panpsychism asserts that consciousness (or mind) is a fundamental feature of the world that exists throughout the universe. Emergentism asserts that consciousness appears only as an emerging result of the complex matter process. Though emergentism is currently the most popular solution to the hard problem of consciousness, many doubt that it can bridge the explanation gap ultimately. By comparison, panpsychism may provide an attractive and promising way to solve the hard problem, though it also encounters some serious problems (Seager and Allen-Hermanson 2010). It is widely believed that the physical world is causally closed, i.e., that there is a purely physical explanation for the occurrence of every physical event and the explanation does not refer to any consciousness property (see, e.g. McGinn 1999). But if panpsychism is true, the fundamental consciousness property should take part in the causal chains of the physical world and should present itself in our investigation of the physical world. Then does consciousness have any causal efficacy in the physical world?

As we have argued in the previous sections, a conscious observer can distinguish two nonorthogonal states, while a measuring system without consciousness cannot. The different conscious perceptions for two nonorthogonal states will correspond to two different brain states of the observer. Especially, the memory content of the observer will be different after he has perceived the two nonorthogonal quantum states; for the definite state ψ_1 or ψ_2 he will remember that he formed a definite perception after the conscious time *tp*, while for the superposition state $\psi_1+\psi_2$, he will remember that he formed a definite perception after the collapse time *tc*. Moreover, the different conscious perceptions of the observer can further lead to different external outputs by his verbal report or physical action. Accordingly, consciousness does have a causal efficacy in the physical world when considering the fundamental quantum processes. This will provide a strong support for panpsychism. In fact, we can further argue that if consciousness has a distinct quantum physical effect, then it cannot be emergent but be a fundamental property of substance. Here is the argument.

If consciousness is emergent, then the conscious beings should also follow the fundamental physical principles such as the principle of energy conservation etc, though they may have some distinct high-level functions. According to the principles of quantum mechanics, two nonorthogonal states cannot be distinguished. However, a conscious being can distinguish the nonorthogonal states in principle. This clearly indicates that consciousness violates the quantum principles, which are the most fundamental physical principles. Therefore, it seems that the conscious property cannot be reducible or emergent but be a fundamental property of substance. It may be not only possessed by the conscious beings, but also possessed by physical measuring devices. Yet the enrichment and complexity of the conscious content and other aspects of consciousness may be different for different systems. The conscious content of a human being can be very rich and complex, while the conscious content of a physical measuring device is probably very simple or even empty. In order to distinguish two nonorthogonal states, the conscious content of a measuring system must at least contain the perceptions of the nonorthogonal states (and probably need to be more complex). Therefore, it is understandable that even although physical measuring devices also have the conscious property, they still cannot distinguish two nonorthogonal states as quantum mechanics predicts and present experiments have confirmed[2].

[2] It is possible that the conscious content of a physical measuring device is too simple to distinguish two nonorthogonal states. It may be also possible that the conscious content of a physical measuring device can be complex enough to distinguish two nonorthogonal states to a certain extent, but the effect is too weak to be detected by present experiments. No doubt, a detailed theory of consciousness and more precise experiments are needed to examine these possibilities.

On the other hand, if the conscious property is a fundamental property of substance, then it is not against expectation that it violates the existing fundamental physical principles, which do not include it at all. Since the distinguishability of nonorthogonal states violates the principle of linear superposition, consciousness will introduce a nonlinear element to the complete evolution of the wave function. The nonlinearity is not stochastic but definite (cf. Wigner 1967). It has been argued that the nonlinear quantum evolution introduced by consciousness has no usual problems of nonlinear quantum mechanics (Gao 2006b). Further implications for quantum mechanics and relativity have also been discussed in Gao (2004, 2006b).

Lastly, it should be noted that the above argument for panpsychism relies on the assumption that the wavefunction collapse is an objective physical process. However, the conclusion is independent of the origin of the wavefunction collapse. If the wavefunction collapse results from the consciousness of observer, then consciousness will also have the distinct quantum effect of collapsing the wave function, and thus the conscious property should be a fundamental property of substance too. In addition, we stress that this conclusion is also independent of the interpretations of quantum mechanics (Gao 2004). It only depends on two firm facts: one is the existence of indefinite quantum superpositions, and the other is the existence of definite conscious perceptions.

Conclusions

Quantum measurement problem is widely acknowledged as one of the hardest problems in modern physics, and the transition from quantum to classical is still a deep mystery. On the other hand, consciousness remains another deep mystery for both philosophy and science, and it is still unknown whether consciousness is emergent or fundamental. Although it seems tempting to conjecture that these two mysteries may have some direct connections, the quantum-to-classical transition and consciousness are generally thought as two essentially independent processes. In this paper, we have argued that this common-sense view will also lead to an unexpected new result, which may help to unveil the nature of consciousness. It is shown that a conscious being can have a distinct quantum physical effect during the quantum-to-classical transition. A conscious system can measure whether he is in a definite perception state or in a quantum superposition of definite perception states, while a system without consciousness cannot distinguish such nonorthogonal states. This result may have interesting implications for the science of consciousness. In particular, it suggests that consciousness is not emergent but a fundamental feature of the universe. This may provide a possible quantum basis for panpsychism.

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