# Free Will from Outside Spacetime? The Role of Observer in Quantum Mechanics

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**ABSTRACT**

We debate, from conceptual point of view, the relationship between the role of observer in quantum mechanics.

**Key Words:** Observer, von Neumann Chain in Quantum Mechanics

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## Introduction

### Fundamental Question

We start with an important quote by John Bell: who ended his Summary of Against measurement by: I mean [...] by serious, that apparatus should not be separated off from the rest of the world into black boxes, as if it were not made of atoms and not ruled by quantum mechanics. In an implicit way, he introduces the hard problem of observer in quantum mechanics. Second, the meausurement process require his preparation, the preparation is a "choice", moreover this choice do not depend from past events. If we have the possibility to choice the preparation process of measurement also we have the possibility to ask this fundamental question: can a purely deterministic quantum theory give rise to at least the illusion of nondeterminism, randomness,probabilities, and ultimately can free will emerge from such a theory? There are many positions about this hard problem, from superdeterminism ( i.e. Gerard of) to radical free will. We retain that position of Suarez is equilibrate and well argumented. In a recent paper Suarez retain that (in his words) quantum and relativistic correlations can be described in a unified way, in that both assume "free will" as an axiom, and happen without any continuous connection in space-time. This description may contribute to a coherent definition of ßpace-time quantization" and highlights the importance of solving the "measurement problem". Standard quantum mechanics assumes that the decision of the outcome happens at the moment of detection (wavefunction collapse). At the 5th Solvay conference (1927) Einstein objected to this assumption by means of a single-particle gedanken-experiment. The quantum collapse, he argued, implies a nonlocal coordi- nation of the detectors, which cannot be explained by influences propagating with velocity v = c; this involves an entirely peculiar mechanism of action at a distance, which [...] implies to my mind a contradiction with the postulate of relativity (Bondoni, 2010). Astonishingly Einstein's gedanken-experiment in 1927 has been first realized in 2012 (Caponigro, 2008). This experiment demon- strates nonlocally coordinated detectors behavior, and also highlights something Einstein did not mention: Non- locality is necessary to preserve such a fundamental principle as energy conservation(Caponigro, 2008). Regarding Einstein's claim that there is a contradiction between quantum nonlocality and relativity, it has been argued that the contradiction exists only in Einstein's mind, that is, in his interpretation of relativity: In fact, quan- tum physics and relativity are confirmed by one and the same experiment, the single-photon



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space-like Michelson- Morley experiment; this experiment demonstrates that quantum physics and relativity imply each other (Stapp, 2003).

Both, quantum nonlocal correlations and relativistic local ones, assume free will on the part of the experimenter, and mean that observed events are cor- related without particles traveling through trajectories in space-time, that is, without continuous connection in between. This may be the very meaning of the space- time quantization. The introduction of the space-time continuum (geometry and real numbers) in physics is a useful idealization, but it should not be considered a real structure underpinning the physical world (ved gisin N. Gisin, Time Really Passes. Science can't deny that. Presentation at Workshop on Time in Physics, ETH Zurich, September 7-11, 2015.)

Suarez and Scarani (Before-Before experiment) showed that for some relative speeds between two observers A and B, observer A could ßee" the measurement of observer B to be in his future, and vice versa. Because the two experiments have a ßpacelike" separation (neither is inside the causal light cone of the other), each observer thinks he does his own measurement before the other. In 2001, Suarez collaborated with Nicolas Gisin on these tests. Suarez and Gisin described the situation as some influence coming "from outside space-time" to cause the 100In his recent essay "Does Free Will Require New Physics," Suarez explores the possibility that the brain contains a generator of the random bits seen in his nonlocality experiments, and that the will might in some way control the order of those bits to make "pieces of information". This resembles the idea of downward causation.

Suarez knows that making a decision is closely related to the problem of measurement in quantum mechanics. In our information physics view, John von Neumann's "cut" or ßchnitt" between the atomic level and the macroscopic measuring apparatus occurs when stable information enter the universe. Stability means the balancing entropy has been carried away (the Ludwig-Landauer principle). Suarez knows that the conscious observer has little to do with it. He says the decision about which detector clicks (in an interference experiment, like that represented in the Figure) does not happen when öne photon encounters a detector" but only subsequently, after a virtual cascade involving billions of electrons has been triggered. Only then an irreversible registration of a result happens and a human observer can become aware of it. An event is "measured", i.e. irreversibly registered, only if it is possible for a human observer to become aware of it. Suarez notes that quantum mechanics may need "new physics" because it cannot explain precisely when a measurement happens. He says Conscious free will implies irreversibility and therefore requires new physics capable of well defining this concept. But quantum mechanics itself requires such a new physics. Quantum theory does not define at all which conditions determine when measurement happens and a result becomes irreversibly registered. This state of affairs clearly shows a point where the theory can and must be completed. We hope that the information physics view of the problem of measurement can help complete that theory. Suarez cites the Free Will Theorem of John Conway and Simon Kochen as making free will an axiom, without which science itself could not proceed. Suarez does not believe that his current movements can be "explained by a chain of temporal cause going back to the Big Bang."

Einstein could not bring himself to believe that "God plays dice with the world," but perhaps we could reconcile him to the idea that "God lets the world run free." ("The Free Will Theorem," Foundations of Physics, Vol. 36, No. 10, October 2006, p.1441) Although Conway and Kochen do not claim to have proven free will in humans, they assert that should such a freedom exist, then the same freedom must apply to the elementary particles.

What Conway and Kochen are really describing is the indeterminism that quantum mechanics has introduced into the world. While indeterminism is a necessary precondition for human freedom, it is insufficient by itself to provide free will. Why do we call this result the Free Will theorem? It is usually tacitly assumed that experimenters have sufficient free will to choose the settings of their apparatus in a way that is not determined by past history. We make this assumption explicit precisely because our theorem deduces from it the more surprising fact that the particles' responses are also not determined by past history. Thus the theorem asserts that if experimenters have a certain property, then spin 1 particles have exactly the same property. Since this property for experimenters is an instance of what is usually called "free will," we find it appropriate to use the same term also for particles. The theorem states that, given the axioms, if the two experimenters in question are free to make choices about what measurements to take, then the results of the measurements cannot be determined by anything previous to the experiments.

Gisin:

Free will Gisin says about free will, Determinsim is a physical hypothesis that denies free will, and it is false I know that I enjoy free will much more than I know anything about physics. Hence, physics will never be able to convince me that free will is an illusion. Quite the contrary, any physical hypothesis incompatible with free will is falsified by the most profound experience I have about free will. So, would I have rejected Newtonian classical mechanics had I lived before quantum physics? Probably not. Indeed, classical physics leaves open the possibility that free will can somehow interface with the deterministic Newtonian equations: free will could set-up some potential that could slightly influence particles's motion. This would be something like Descartes pineal gland. In standard quantum physics such an interface between free will and physics could be even simpler: free will could influence the probabilities of quantum events. This is, admittedly, a vague and not very original idea; but important is that there is no obvious definite contradiction between free will and standard quantum physics.

von Neumann: The Schnitt von Neumann described the collapse of the wave function as requiring a "cut" (Schnitt in German) between the microscopic quantum system and the observer. He said it did not matter where this cut was placed, because the mathematics would produce the same experimental results.

## Measurement process and the von Neumann chain

The introduction of Stapp's book[1] put in evidence the fundamental problems in QM in relation to Mind/Matter problem.

According Stapp, the basic problem in the interpretation of QM is to reconcile the quantum features of the mathematics with the fact that our perceptual experiences are described in the language of classical physics. Observed physical objects appear to us to occupy definite locations, and we use the concepts of everyday life, refined by the ideas of nineteenth-century physics, to describe both our procedures for obtaining information about the systems we are studying, and also the data that we then receive, such as the reading of the position of a pointer on a dial. Yet our instruments, and our physical bodies and brains, are in some sense conglomerates of atoms. The individual atoms appear to obey the laws of QM, and these laws include rules for combining systems of atomic constituents into larger systems. Insofar as experiments have been able to determine, and these experiments examine systems containing tens of billions of electrons, there is no apparent breakdown of the quantum rules. Yet if we assume that these laws hold all the way up to visible objects such as pointers, then difficulties arise. The state of the pointer would, according to the theory, often have parts associated with the pointer's being located in visibly different places. **If we continue to apply the laws right up to, and into, our brains, then our brains, as represented in QM, would have parts corresponding to our seeing the pointer in several visibly different locations.** Inclusion of the effects of the environment does not remove any of these parts, although it does make it effectively impossible to empirically confirm the simultaneous presence of these different parts. **The orthodox solution to this problem is simply to postulate, as a basic precept of the theory, that our observations are classically describable.** This postulate is incorporated into the theory by asserting that any conscious observation will be accompanied by a "collapse of the wave function" or "reduction of the wave packet" that will simply exclude from the prior physically described state all parts that are incompatible with the conscious experience. This prescription works beautifully. When combined with the rule that the probability that this perception will occur is the ratio of the quantum mechanical weighting of the reduced state to the quantum mechanical weighting of the prior state, one gets predictions never known to fail. This ad hoc injection, in association with "consciousness", of "classical" concepts into a theory that is mathematically incompatible with those concepts, is the origin of the mysteriousness of QM. There is mounting evidence from neuroscience that our conscious thoughts are associated with synchronous oscillations in well-separated sites in the brain. This opens the door to a natural way of understanding, simultaneously, both the mind-brain and quantum-classical linkages. Oscillatory motions play a fundamental role in QM, and they embody an extremely tight quantum-classical connection. This connection allows the quantum-classical and mind-brain connections to be

[1]Mind, Matter and Quantum Mechanics, 2003



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understood together in a relatively simple and direct way.

## von Neumann chain and the Observer

Bondoni (Bondoni,2010) analyze the possible relationship between two fundamental elements, **the measurement process and the von Neumann chain**[2]. We introduce briefly his pathway.

Bondoni start his analysis from the problem nested in Ozawa's effort to block von Neumann's chains and in his attributing the wave-collapse to a interaction between systems. Ozawa's analysis suggests to distinguish (sharply) the mathematical world from the phenomenological one. In Ozawa's own words:

The orthodox view (of the wave-collapse) confuses the time at which the outcome of measurement is obtained and the time at which the object is left in the state determined by the outcome. (…) it confuses the time just after the reading of the outcome and the time just after the interaction between the object and the apparatus. There is no causality relation between the outcome and the state just after measurement.

This analysis according Bondoni is correct, otherwise, he argue, we would have a regress at infinity[3], a sort of hegelian *odd* infinity as von Neumann points out:

we must always divide the world in two parts, the one being the observed system, the other the observer. (…) That this boundary (i.e. between the observed system and the observer) can be pushed *at will* deeply in the interior of the body of the real observer is the content of the principle of the psycho-physical parallelism.

Bondoni, retain that surely the word used ät will" is the source of such problem. This way, the counsciousness can enter in the description of a measurement. O**n the other hand, we must distinguish the *measurement* and the *reading* of this measurement**; i.e. the entanglement of the object with the observer and the reading of this interaction by the experimenter. In this way, we can no longer assert that the mind causes the collapse, as the given collapse is occurred earlier. Moreover Ozawa demonstrates that the wave-collapse occurs in a time interval $t + \Delta t$, while the perception of this collapse is at $t + \Delta t + \tau$, interval in which the two systems (object and observer) can no longer be in a relation.

On the other hand, we can observe that exists only that is perceivable in a *phenomenon*. **A measurement which is not perceived (by a reading) is not a real measurement.** It is a logically possible interaction which doesn't belong to the reality. From the difference between the above mentioned intervals**Ozawa infers a difference between measurement and perceiving of this measurement.** But it is a logical inference. How can someone experience a measurement without interact with it (with a reading)?[4] And if this collapse is not experienceable, then we are making *meta*-physics (we are going *beyond* physics). Therefore, is not usefull putting aside a non physical entity as the mind to leave room for something more abstract, as a measurement without reading, also if this



[2] We recall that von Neumann's quantum theory is a a formulation in which the entire physical universe, including the bodies and brains of the conscious human participant/observers, is represented by the basic quantum state. The dynamics involves three processes. Process 1 is the choice on the part of the experimenter about how he will act. This choice is sometimes called the "Heisenberg choice", because Heisenberg emphasized strongly its crucial role in quantum dynamics. At the pragmatic level it is a "free choice", because it is controlled, at least at the practical level, by the conscious intentions of the experimenter/participant: neither the Copenhagen nor von Neumann formulations specify the causal origins of this choice, apart from the conscious intentions of the human agent.Process 2 is the quantum analog of the equations of motion of classical physics, and like its classical counterpart is local (i.e., via contact between neighbors) and deterministic. This process is constructed from the classical one by a certain quantization procedure, and is reduced back to the classical process by taking the classical approximation. It normally has the effect of expanding the microscopic uncertainties demanded by the Heisenberg uncertainty principle into the macroscopic domain: the centers of large objects are smeared out over large regions of space. This conflict with conscious experience is resolved by invoking Processes 1 and 3. Process 3 is sometimes call the "Dirac choice". Dirac called it a "choice on the part of Nature". It can be regarded as Nature's answer to a question effectively posed by the Process 1 choice made by the experimenter. This posed question is: will the intended consequences of the action that the agent chooses to perform actually be experienced? (e.g.,will the Geiger counter be observed to be placed in the intended place? And, if so, will the specified action of that device be observed to occur?) Processes 1 and 3 act on the variables that specify the body/brain of the agent. According Stapp, the "Yes" answer actualizes the neural correlates of the intended action or associated feedback.

[3]Instead, in this thesis we retain that the infinity regress is not a problem but a resource.

[4]One can interacts with an object *without* knowing the result of this interaction. For example, an observer can know that he is interacting with an object, without knowing the eigenstate in which the object jumped. The observer knows that surely by *this* interaction the system-object jumped in an eigenstate $|\phi_i\rangle$ and that an observable $\mathcal{O}$ must have in $|\phi_i\rangle$ an eigen-value $\lambda_i$. But the observer cannot, without a reading, know in *which* eigenstate the system is. Obviously, knowing the wave-function of the system, he knows too the amplitudes of the probabilities associated to its vectors, but this is only a mathematical (statistic) forecasting, not a perception. In this sense, the fact that at $t + \Delta t$ the system-object is in an eigenstate is only an *inference*.

*something* has a definite grade of mathematical reality. Moreover, Ozawa doesn't answer the main question. The reading of a measurement is invoked to explain the collapse; now, if this cannot be more the cause of the collapse, what is the real cause? Apparently, the interaction between subject and object, but we have no direct experience of it. It is a *perceived* measurement in a given context to determinate the wave-collapse. Von Neumann *seems* adhering to this position, stating:
experience only permits statements of this type: an observer has made a certain (subjective) observation; and never any like this: a physical quantity has a certain value.
Obviously it is higly questionable the *subjective* character of our perception. Our perception is on the contrary *objective* in a phenomenological point of view. What is more objective than the fact that we have in front of us a hgiven and no other experimental set-up, built in a *given* way, with *given* pointers?

*Using Bohr's own words:*
(…) in actual experiments all evidence pertains to observations obtained under reproducible conditions and is expressed by unambiguous statements referring to the *registration* of the point at which an atomic particle arrive on a photographic plate (…).

And:
(…) the problem of explanation that is embodied in the notion of complementarity suggests itself in our position as conscious beings and recalls forcefully the teaching of ancient thinkers that, in the search for a harmonious attitute towards life, it must never be forgotten that we ourselves are both actors and spectators in the drama of existence.

Obviously, it is one thing asserting that reality must be confined to the realm of experience and one other asserting that the cause of the wave-collapse, which oughts to belong to our experience, must coincide with the act of registration of a measure. Ozawa successfully shows that this act cannot cause the collapse. But, where is, then, the real cause of this collapse? If this is the measurement, where is, ontologically speaking, this measurement?

*Quoting Planck:*
it is impossible (…) that the development of the knowledge in Physics until now aimed at a fundamental and radical division between the processes in the external nature and the processes in the human world of feelings.

Being no clear distinction between subject and object, it is best adopting an *holistic* view and consider as fundamental the perceived phenomenon. I.e. there are not in reality subject and object as two clear distinct entities, but a relation which *founds* it. Subject and object are only in a relation, in a totally entangled *Gestalt*. The measurement seen as interaction is such a Gestalt. But not meaning that observer and object *enter* in relation, but that the relation *founds* relate and correlate.

What it is this relation in the measurement? The totality of the experimental arrangement which permits speaking of measurement. A totality which lives in our perception and is made of perceiving devices and tools of measurement. This is the *kantian* position of Bohr which sees in the experiment the real cause of any result: the *a-priori*, a sort of *category* which makes possible speaking of measurements, particles, collapses and so on. A frame in which the observer arranges his experiences. Planck observes:

***what we can measure, that it exists.***
The act of measuring, the registration of measurement, not the measurement without observer. What a measurement could be without observer, Bondoni add: I don't dare to say.
Bondoni, concludes his paper, with two distinct questions:

1. the reading of a measurement cannot be the cause of the wave-collapse
2. attributing the wave-collapse to the interaction observer-object *before* the reading of the measurement stops von Neumann's chain

According Bondoni, Ozawa successfully demonstrates 1. Bondoni, is not sure that stating 1 rules out completely the problem hidden in 1. That is, the rôle of the subject in the act of knowing. In particular, it is not clear the *phenomenological* correlate of the measurement. In absence of a precise phenomenological correlate of a measurement, we can infer that this process amounts to an *observation without observer*. We disagree with this conclusion, **the universality of QM is not a problem but a resource**, to us the real question is: where we can stop the von Neumann chain?

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