Letter to the Editor

Reply to a Critic: "Mind Efforts, Quantum Zeno Effect and Environmental Decoherence"

Henry P. Stapp

ABSTRACT

The original Copenhagen interpretation of quantum mechanics was offered as a pragmatic methodology for making predictions about future experiences on the basis of knowledge gleaned from past experiences. It was, therefore, fundamentally about mental realities, and refrained from speaking about a more inclusive reality. Von Neumann created, later, what is called the orthodox formulation of quantum mechanics. It incorporates all of the Copenhagen-based predictions about connections between experiences into a rationally coherent conception of a dynamically integrated psychophysical reality. Von Neumann's formulation allows the same laws and concepts that are used to make predictions about atomic phenomena to account for the capacity of our mental intentions to influence our bodily actions. Danko Georgiev claims to have found logical flaws in my use of von Neumann's theory to explain this causal effectiveness of our mental intentions. The bulk of Georgiev's paper gives a detailed discussion of a system with just two base states, up and down. This is not an adequate model of the pertinent physical system, a human brain. Georgiev's attempt to relate his two-state work to the case at hand is flawed by statements such as "…in von Neumann's formulation there are no such things as *minds, spirits, ghosts, or souls*, …" Von Neumann's formulation certainly does involve *minds*. Georgiev's choice of words seems designed to suggest that I am introducing mental qualities and assumptions that go beyond what are already parts of von Neumann's theory. I explain here why these allegations, and all his other allegations of errors, are incorrect.

Key Words: Quantum Zeno effect, mind, brain, Stapp's interactive dualism, decoherence

NeuroQuantology 2012; 4: 601-605

Introduction

The classical-physics approach to our scientific understanding of nature began with the seventeenth century works of Galileo and Newton. It was significantly advanced by the nineteenth contributions of James Clerk Maxwell and by the twentieth century contributions of Albert Einstein. That classical approach is based on mathematically defined physical properties that are localized at points in 3-dimensional space at various instants of time, and that evolve over time according to mathematical laws and that involve only those physically defined properties themselves, not mental things such as our thoughts, ideas, and feelings.

These classical laws are deterministic: they determine the physical properties at all times from the physical properties that existed at the birth of the physical universe. Thus they imply that each human being is a mechanical automaton whose every physical action was predetermined already at the birth of the universe.

The mechanistic precepts of classical mechanics were found during the twentieth century to be incompatible with a growing mass of empirical findings. That theory was replaced at the fundamental level by a new theory, called quantum mechanics. The original Copenhagen interpretation of quantum mechanics was offered to scientists not as a description of reality but rather as a

Corresponding author: Henry P. Stapp
Address: Lawrence Berkeley National Laboratory, USA.
✉ hpstapp@lbl.gov
Received Oct 13, 2012. Revised Oct 14, 2012.
Accepted Nov 2, 2012.
*e*ISSN 1303-5150

methodology for making predictions about future human experiences on the basis of knowledge gleaned from past experiences. Thus Niels Bohr proclaimed at the beginning of his first book on the subject:

The task of science is to extend the range of our experience and reduce it to order…. (Bohr, p.1)

and a little later,

In our description of nature the purpose is not to disclose the real essence of phenomena, but only to track down as far as possible relations between the multifold aspects of our experience. (ibid. p.18)

Einstein confirmed this fundamental shift when he complained that:

> *What I dislike about this kind of argumentation is the basic positivistic attitude, which from my point of view is untenable, and which seems to me to come to the same thing as Berkeley's esse est percipi. [To be is to be perceived.]* (Einstein, p. 669).

The need to shift basic science from the earlier mechanistic matter-based approach to the newer pragmatic knowledge-based approach stems from the incompatibility of the mechanistic precepts with empirical data that emerged during the twentieth century. The basic quantum mechanical equation of motion, the Schrödinger equation, combined with the quantum rules for forming big visible objects out of their atomic constituents, entails that big things are generally represented by a *continuous collection* of possibilities for what we will perceive if we actually look. Thus an added process is needed to pick out, in each actual individual empirical instance, from this continuous mixture of possibilities, the experience that actually occurs in that particular instance

In the original Copenhagen formulation this extra process is initiated by what is called "A free choice on the part of the experimenter." The phrase "free choice" emphasizes the fact that, while a definite particular choice is needed, this choice is not determined by any known law or rule: The purely physical aspects of the theory have, therefore a significant causal gap, which opens the door to a possible causal input from the mentally side of reality.

This "free choice" *feels* like it is coming from some inner realm of values and meaning. According to both the Copenhagen, and von Neumann's orthodox, formulation quantum mechanics, this free choice poses a yes-or-no type question about some particular physical-described property. Nature then delivers an answer, 'Yes' or 'No'. The infamous quantum element of random chance enters only in connection with nature's response, not in connection with the observer's "free choice", which von Neumann calls "Process 1".

Copenhagen quantum mechanics is a hybrid quasi-classical and purely pragmatic theory, whereas orthodox quantum mechanics can be construed to be a fully quantum mechanical theory of a dynamically integrated psychophysical reality that incorporates all of the predictions of the Copenhagen formulation. The essential point is that the Copenhagen approach is tied to the idea of dividing our theoretical description into two parts by a cut called the Heisenberg cut. Below the cut is the "observed" system, which is to be described in terms of the quantum mathematics, and above the cut is the "observing" system, which is to be described in perceptual and mental terms. The descriptions of "small" things are placed below the cut, and the descriptions of "big" things are placed above the cut.

This idea works well in a purely pragmatic context, where the placement of the cut need not be well defined, and can thus depend upon the application. But big things are not really classical: their properties such as rigidity and electrical conductance depend upon their quantum aspects. So the problem of the placement of the cut bars the way to an immediate transformation of the pragmatic Copenhagen quantum mechanics into a rationally coherent theory of reality.

Von Neumann's formulation resolves this problem of the placement of the cut by pushing it all the way up, so that the "observed" system contains all things that, according to classical ideas, are physical things, including the bodies and brains of all observers. These "physical" things are all described in quantum mechanical terms. The classically described features of our perceptions become, then, aspects of the observing mental side of reality.

Thus the shift from the Copenhagen to the orthodox formulation of quantum mechanics converts the Copenhagen "free choice on the part of the experimenter", who has both physical and mental aspects, to a "Process-1 free choice" that comes from the mentally described "observing" part of reality.

Such a mind-based process-1 free choice is able, and is required, in an individual empirical instance, to pick out, from the continuous mixture of possible perceptions generated by the Schrödinger equation, a particular classically describable possibility, which will then be either actualized or rejected by a random choice on the part of nature. This orthodox causal structure allows bodily actions to be instigated by mental intentions.

Von Neumann goes into these matters is great detail. In his chapter VI on the measuring process he says:

> *First, it is entirely correct that the measurement or related process of subjective perception is a new entity relative to the physical environment and is not reducible to the latter. Indeed, subjective perception leads us into the intellectual inner life of the individual.*

He gives an example of measuring temperature by observing the length of a column of mercury in a thermometer. He says:

> *We can calculate its heating, expansion, and the resultant length of the mercury column, and then say: this length is seen by the observer.*

He pushes the cut further and further into the brain, and then concludes:

> *But in any case, no matter how far we calculate – to the mercury vessel, to the scale of the thermometer, to the retina, or into the brain, at some time we must say: and this is perceived by the observer. That is, we must always divide the world into two parts, the one being the observed system, the other the observer.*

He adds still more details and then concludes that:

> *Indeed, experience only makes statements of this type: an observer has made a certain (subjective) observation; and never any like this: a physical quantity has a certain value.*
>
> *Now quantum mechanics describes the events in the world so long as they do not interact with the observing portion, with the aid of process 2 [the Schrödinger equation], but as soon as such as interaction occurs, i.e., a measurement, it requires the application of process 1.*

He goes on to deal with the problem of the placement of the cut between the observed part and the observing part. He pushes the cut further and further toward the subjective, and finally reaches the point where the entire body and brain is moved into the quantum mechanically described observed part, so that all that remains in the observing part are the subjective experiences of the observer, which he call the observer's "abstract ego"

In order to obtain a rationally coherent theory of a fully quantum mechanical psychophysical reality I use the final placement of the cut, in which all things that are classically conceived to be physical things, including the bodies and brains of all observers, are placed below the cut, and are described in quantum mechanical terms, and all subjective experience are placed above the cut, with these two parts connected by von Neumann's rules involving processes 1, 2, and 3. Von Neumann's process 3 is what Paul Dirac called "a choice on the part of nature".

This account of what von Neumann actually wrote, and my way of using his work, makes it clear that Georgiev's assertion that:

> *in von Neumann's formulation there are no such things as minds … which do not possess their own wave functions, or density matrices, but can interact with other physical objects.*

is profoundly incorrect.

At the outset of his article Georgiev mentions the possibility of combining quantum mechanics with neuroscience, but says that:

> *The fruitfulness of the latter approach however critically depends on the possibility of the brain to sustain quantum coherence for biologically relevant timescales.*

Georgiev is apparently confusing my approach with the very different approach of Penrose and Hameroff, which does indeed depend upon interference effects between

various superposed states. But a main feature of my approach, which I often strongly contrast with the approach of Penrose and Hameroff, is that it does not use interference effects between superposed states. I recognize from the outset that the very strong environmental decoherence effects in the brain will effectively convert superpositions to *mixtures*, thereby excluding any direct use of interference effects.

The key point here is that the brain density matrix is reduced to near-diagonal form in the coordinate-space basis, and this form represents a large continuous collection of perceivable worlds. In each individual empirical instance some process must pick out the perception that actual occurs from the continuous mixture of possibilities generated by the Schrödinger equation. The orthodox theory specifies how this choice is made by a combination of the observer's process-1 free choice, followed by nature's process-3 random choice. Each such choice picks out what actually occurs from among a *mixture*, not a superposition, of possibilities. This renders Georgiev's opening claim completely incorrect.

Georgiev also claims that I have "introduced two novel postulates (axioms) according to which the metaphysical (phenomenal) mind is given *freedom* to choose *which* questions are put to nature, and when they are asked."

These "postulates" are neither novel nor mine. These choices are what are called "free choices on the part of the experimenter" in the Copenhagen formulation, and "process-1 choices" in orthodox quantum mechanics. These free choices are essential elements of both the pragmatic rules formulated by the founder's of quantum mechanics, and of the orthodox reformulation of those ideas.

The three profound errors reveal major conceptual flaws in Georgiev's understanding of the theory he is criticizing. A main technical flaw is his effective assumption that the human brain can be adequately modeled by a quantum system with just two basis states, say up and down. In my treatment, the density matrix of the brain - in the coordinate basis - has a very high-dimensional continuum of states along the diagonal, not just two. The effect of the very strong environmental decoherence is, in accordance with the seminal works of H. D. Zeh, and of E. Joos and Zeh, is to reduce most of the non-diagonal elements nearly to zero. The elements that differ significantly from zero lie very close to the diagonal. The set of essentially non zero matrix elements is concentrated in long but narrow fuzzy strip centered on the diagonal.

An observation reduces the mixture of possibilities corresponding to the set of possibilities represented by the long strip along the diagonal of the density matrix to a relatively short strip compatible with the outcome of the observation. The subsequent action of the Schrödinger equation associated with the brain tends to cause this short strip spread out, as waves normally do. But a rapid sequence of repetitions of that observation will tend to keep the density matrix confined to the short strip, in accordance with the precepts of QZE, the quantum Zeno effect. Thus the mentally controlled process-1 probing actions become endowed, within the orthodox formulation, with the capacity to influence the evolution of the state of brain, as represented by its evolving density matrix.

In my treatment of the effects of environmental decoherence upon systems possessing continuous coordinate variables – in particular a human brain – I have used the findings of Joos and Zeh. These results follow rationally from the basic precepts of quantum mechanics. The core result is the reduction of the coordinate-space density matrix to near-diagonal form. Georgiev's idiosyncratic treatment of environmental decoherence effects for a system with just two base states has, I believe, no comparable rational connection to the dynamical effects of the physical environment on the state of a human brain.

Georgiev's final and main claim is that the quantum Zeno effect exerted by the mind upon the brain cannot slow down or reverse the effects of environmental decoherence. That claim is certainly correct, but in no way contradicts my model. I do indeed claim that *"the QZE exerted by mind efforts upon brain would work despite the environmental decoherence"*. Indeed, the whole discussion is precisely about that effect. But that does not imply, as Georgiev asserts, that *"the QZE effect exerted by the mind upon the brain can slow down the environmental decoherence of the brain."*

What slows down, and ultimately brings to a halt, the decoherence effect of the environment upon the brain is the Schrödinger equation associated with the brain. The effect of the environment is to reduce the brain density matrix to a continuous collection (mixture) of essentially very narrow Gaussians, which eventually become so narrow in coordinate space that the explosive action produced by the equation of motion balances the narrowing effect of the interaction with the environment. This stalemated state of the brain is the state upon which the mind-based reduction action occurs. This latter action in no way slows down the environmental decoherence effect. Rather, it curtails the effects of the brain Schrödinger equation that are tending to make the state of the brain evolve away from the state to which it was reduced by the physical action associated with the prior process-1 choice. This typical QZE action takes place within a dynamical context in which a strong environmental decoherence action is continuously occurring. The mind-based action does not slow down the environment-based action, but rolls back the brain-based process of evolution. Thus Georgiev's main technical objection to my model is an objection to a feature that my model does not possess.

Georgiev also says:

> *"Stapp investigates a particular case in which the brain is measured by the environment in the very same measurement basis in which the mind makes the wave function collapse."*

Yes, the decoherence basis is the coordinate basis, and the projection operator P might be a projection onto a certain particular interval in coordinate space. But this does not make the latter redundant with the former, as Georgiev claims. The action of the environment reduces the nonzero part of the brain density matrix essentially to the long strip along the diagonal, whereas the action of the mind picks out some particular tiny portion of that strip.

Georgiev says that *"Stapp's main thesis [is] that mind choices are simultaneously effective and absolutely free."* The adverb "absolutely" is not mine. The adjective "free" means only not determined by any known law or rule.

Georgiev keeps bringing up alleged paranormal Psi effects, but he has correctly noted that the orthodox theory under consideration here does not allow any such effects. Thus they are completely irrelevant to the present theoretical discussion, and ought never be mentioned at all, much less be continually referred to.

In the final discussion section Georgiev claims to have rigorously shown that my model cannot have four properties that I do indeed claim my model has. But his proof depends upon a fifth property that my model does not have, and that does not follow from the other four. This fifth property, assumed by Georgiev, but never by me, is that *"the mind action onto the brain density matrix can slow down the environmental decoherence."* Thus Georgiev's entire argument collapses, because it is based on his false assumption that my model has a property that in fact it does not possess, and was never claimed to possess.

References

Bohr N. Atomic theory and the Description of Nature. Cambridge University Press, 1934.

Einstein A. Albert Einstein: Philosopher-Scientist. Tudor, New York, ed, P.A. Schilpp., 1951.

Von Neumann J. Mathematische Grundlagen der Quantenmechanik (Springer, Berlin, 1932): Translated as: Mathematical Foundations of Quantum Mechanics (Princeton University Press, Princeton N.J. 1955)

Georgiev D. Effort, Quantum Zeno Effect and Environmental Decoherence. NeuroQuantology 2012; 10: 324-388.

Joos E and Zeh HD. The Emergence of Classical Properties Through Interaction with the Environment. Z Phys 1985; 59: 223-243.