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# **Apparent Retrocausation As A Consequence of Orthodox Quantum Mechanics Refined To Accommodate The Principle Of Sufficient Reason**

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**Abstract.** The principle of sufficient reason asserts that anything that happens does so for a reason: no definite state of affairs can come into being unless there is a sufficient reason why that particular thing should happen. This principle is usually attributed to Leibniz, although the first recorded Western philosopher to use it was Anaximander of Miletus. The demand that nature be rational, in the sense that it be compatible with the principle of sufficient reason, conflicts with a basic feature of contemporary orthodox physical theory, namely the notion that nature's response to the probing action of an observer is determined by pure chance, and hence on the basis of absolutely no reason at all. This appeal to pure chance can be deemed to have no rational fundamental place in reason-based Western science. It is argued here, on the basis of the other basic principles of quantum physics, that in a world that conforms to the principle of sufficient reason, the usual quantum statistical rules will naturally emerge at the pragmatic level, in cases where the reason behind nature's choice of response is unknown, but that the usual statistics can become biased in an empirically manifest and apparently retrocausal way when the reason for the choice is empirically identifiable. It is shown here that if the statistical laws of quantum mechanics were to be biased in a certain way then the basically forward-in-time unfolding of empirical reality described by orthodox quantum mechanics would generate the appearance of backward-time-causation of the kind that have been reported in the scientific literature.

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# **Apparent Retrocausation As A Consequence of Orthodox Quantum Mechanics Refined To Accommodate The Principle Of Sufficient Reason**

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November 2, 2011*

**Abstract.** The principle of sufficient reason asserts that anything that happens does so for a reason: no definite state of affairs can come into being unless there is a sufficient reason why that particular thing should happen. This principle is usually attributed to Leibniz, although the first recorded Western philosopher to use it was Anaximander of Miletus. The demand that nature be rational, in the sense that it be compatible with the principle of sufficient reason, conflicts with a basic feature of contemporary orthodox physical theory, namely the notion that nature's response to the probing action of an observer is determined by pure chance, and hence on the basis of absolutely no reason at all. This appeal to pure chance can be deemed to have no rational fundamental place in reason-based Western science. It is argued here, on the basis of the other basic principles of quantum physics, that in a world that conforms to the principle of sufficient reason, the usual quantum statistical rules will naturally emerge at the pragmatic level, in cases where the reason behind nature's choice of response is unknown, but that the usual statistics can become biased in an empirically manifest and apparently retrocausal way when the reason for the choice is empirically identifiable. It is shown here that if the statistical laws of quantum mechanics were to be biased in a certain way then the basically forward-in-time unfolding of empirical reality described by orthodox quantum mechanics would generate the appearance of backward-time-causation of the kind that have been reported in the scientific literature.

**Keywords:** Reason, Retrocausation, Orthodox Quantum Mechanics,

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## INTRODUCTION

An article recently published by the Cornell psychologist Daryl J. Bem [1] in a distinguished psychology journal has provoked a heated discussion in the New York Times [2]. Among the discussants was Douglas Hofstadter who wrote that: “If any of his claims were true, then all of the bases underlying contemporary science would be toppled, and we would have to rethink everything about the nature of the universe.”

It is, I believe, an exaggeration to say that if any of Bem’s claims were true then “all of the bases underlying contemporary science would be toppled” and that “we would have to rethink everything about the nature of the universe”. In fact, all that is required is a relatively small change in the rules, and one that seems reasonable and natural in its own right. The major part of the required rethinking was done already by the founders of quantum mechanics, and cast in more rigorous form by John von Neumann [3], more than three quarters of a century ago.

According to the precepts of *classical* mechanics, once the physically described universe is created, it evolves in a deterministic manner that is completely fixed by mathematical laws that depend only on the present values of evolving physically described properties. There are no inputs to the dynamics that go beyond what is specified by those physically described properties. [Here *physically described properties* are properties that are specified by assigning mathematical properties to space-time points, or to very tiny regions.] The increasing knowledge of human beings and other biological agents enters only as an *output* of the physically described evolution of the universe, and even nature itself is not allowed to interfere with the algorithmically determined mechanistic evolution.

This one-way causation from the physical aspects of nature to the empirical/epistemological/mental aspects has always been puzzling: Why should “knowledge” exist at all if it cannot influence anything physical, and hence be of no use to the organisms that possess it. And how can something like an “idea”, seemingly so different from physical matter, as matter is conceived of in classical mechanics, be created by, or simply *be*, the motion of physical matter?

The basic precepts of classical mechanics are now known to be fundamentally incorrect: they cannot be reconciled with a plenitude of empirical facts discovered and verified during the twentieth century. Thus there is no reason to demand or believe that those puzzling properties of the classically conceived world must carry over to the actual world, which conforms far better to the radically different precepts of quantum mechanics.

The founders of quantum theory conceived the theory to be a mathematical procedure for making practical predictions about future empirical-experiential findings on the basis of our present knowledge. According to this idea, quantum theory is basically about the evolution of knowledge. This profound shift is proclaimed by Heisenberg’s assertion [4] that the quantum mathematics “represents no longer the behavior of the elementary particles but rather our knowledge of this behavior”, and by Bohr’s statement [5] that “Strictly speaking, the mathematical formalism of quantum mechanics merely offers rules of calculation for the deduction of expectation about observations obtained under conditions defined by classical physics concepts.”

The essential need to bring “observations” into the theoretical structure arises from the fact that evolution via the Schrödinger equation, which is the quantum analog of the classical equations of motion, produces in general not a single evolving physical world that is compatible with human experience and observations, but rather a mathematical structure that corresponds to a smeared out mixture of increasingly many such worlds. Consequently, some additional process, beyond the one generated by Schrödinger equation, is needed to specify what the connection is between the physically described quantum state of the universe and empirical/experiential reality. Epistemological factors must thereby become connected to the mathematically described physical aspects of the quantum mechanical description of nature.

The founders of quantum mechanics achieved an important advance in our understanding of nature when they recognized that the mathematically/physically described universe that appears in our best physical theory represents not the world of material substance contemplated in the classical physics of Isaac Newton and his direct successors, but rather a world of “*potentia*”, or “*weighted possibilities*”, for our future acquisitions of *knowledge* [6]. It is not surprising that a scientific theory designed to allow us to predict correlations between our shared empirical findings should incorporate, as orthodox quantum mechanics does: 1), a natural place for “*our knowledge*”, which is both all that is really known to us, and also the empirical foundation upon which science is based; 2), an account of the process by means of which we acquire our *knowledge* of certain physically described aspects of nature; and 3), a statistical description, at the pragmatic level, of relationships between various features of the growing aspect of nature that constitutes “*our knowledge*”. What is perhaps surprising is the ready acceptance by most western-oriented scientists and philosophers of the notion that the element of chance that enters quite reasonably into the *pragmatic* formulation of physical theory, in a *practical* context where many pertinent things may be unknown to us, stems from an occurrence of raw pure chance at the underlying *ontological* level. Ascribing such capriciousness to nature herself would seem to contradict the rationalist ideals of Western Science. From a strictly rational point of view, it not unreasonable to examine the mathematical impact of accepting, *at the basic ontological level*, Einstein’s dictum that: “God does not play dice with the universe”, and to attribute the effective entry of pure chance at the pragmatic level to our lack of knowledge of the *reasons* for the “choices on the part of nature” to be what they turn out to be.

These “random” quantum choices are key elements of orthodox quantum mechanics, and the origin of these choices is therefore a fundamental issue. Are they really purely random, as contemporary orthodox theory asserts? Or could they stem at the basic ontological level from sufficient reasons?

## **IMPLEMENTING THE PRINCIPLE OF SUFFICIENT REASON**

I make no judgment on the significance of the purported evidence for the existence of various retrocausal phenomena. That I leave to the collective eventual wisdom of the scientific community. I am concerned here rather with essentially logical and mathematical issues, as they relate to the apparent view of some commentators that scholarly articles reporting the existence of retrocausal phenomena should be banned from the scientific literature, essentially for the reason articulated in the New York Times

by Douglas Hofstadter, namely that the actual existence of such phenomena is irreconcilable with what we now (think we) know about the structure of the universe; that the actual existence of such phenomena would require a wholesale abandonment of basic ideas of contemporary physics. That assessment is certainly not valid, as will be shown here. Only a limited, and intrinsically reasonable, modification of the existing orthodox quantum mechanics is needed in order to accommodate the reported data.

In order for science to be able to confront effectively purported phenomena that violate the prevailing basic theory what is needed is an alternative theory that retains the valid predictions of the currently prevailing theory, yet accommodates in a rationally coherent way the purported new phenomena.

If the example of the transition from classical physics to quantum physics can serve as an illustration, in that case we had a beautiful theory that had worked well for 200 years, but that was incompatible with the new data made available by advances in technology. However, a new theory was devised that was closely connected to the old one, and that allowed us to recapture the old results in the appropriate special cases, where the effects of the nonzero value of Planck's constant could be ignored. The old formalism was by-and-large retained, but readjusted to accommodate the fact that  $pq$ - $qp$  was non-zero. Yet there was also *a rejection of a basic classical presupposition*, namely the idea that a physical theory should properly be exclusively about connections between physically described material events. The founders of quantum theory insisted that their physical theory was a pragmatic theory -- i.e., was directed at predicting practically useful connections between empirical (i.e., experienced) events [7].

This original pragmatic Copenhagen QM was not suited to be an ontological theory, because of the movable boundary between the aspects of nature described in *classical* physical terms and those described in *quantum* physical terms. It is certainly not ontologically realistic to believe that the pointers on observed measuring devices are built out of *classically* conceivable electrons and atoms, etc. The measuring devices, and also the bodies and brains of human observers, must be understood to be built out of quantum mechanically described particles. That is what allows us to understand and describe many observed properties of these physically described systems, such as their rigidity and electrical conductance.

Von Neumann's analysis of the measurement problem allowed the quantum state of the universe to describe the entire physically described universe: everything that we naturally conceive to be built out of atomic constituents and the fields that they generate. This quantum state is described by assigning mathematical properties to spacetime points (or tiny regions). We have a deterministic law, the Schrödinger equation, that specifies the mindless, essentially mechanical, evolution of this quantum state. But this quantum mechanical law of motion generates *a huge continuous smear of worlds of the kind that we actually experience*. For example, as Einstein emphasized, the position of the pointer on a device that is supposed to tell us the *time* of the detection of a particle produced by the decay of a radioactive nucleus, evolves, under the control of the Schrödinger equation, into a *continuous smear of positions corresponding to all the different possible times of detection*; not to a single position, which is what we observe [8]. And the unrestricted validity of the Schrödinger equation would lead, as also emphasized by Einstein, to the conclusion that the moon, as it is represented in the theory, would be smeared out over the entire night sky, until the first observer of it, say a mouse, looked.

How do we understand this huge disparity between the representation of the universe evolving in accordance with the Schrödinger equation and the empirical reality that we experience?

A completely satisfactory physical theory must include a logically coherent explanation of how the mathematical/physical description is connected to the experienced empirical realities. This demands, in the final analysis, a theory of the mind-brain connection: a theory of how our idea-like knowing aspects are connected to our evolving physically described brains.

The micro-macro separation that enters into Copenhagen QM is actually a separation between what is described in quantum mechanical physical terms and what is described in terms of *our experiences* -- expressed in terms of our everyday concepts of the physical world, refined by the concepts of classical physics. ([9], Sec. 3.5.)

To pass from *quantum pragmatism* to *quantum ontology* one can treat all *physically described* aspects quantum mechanically, as Von Neumann did. He effectively transformed the Copenhagen pragmatic version of QM into a potentially ontological version by shifting the brains and bodies of the observers -- and all other physically described aspects of the theory -- into the part described in quantum mechanical language. The entire physically described universe is treated quantum mechanically, and *our knowledge*, and *the process by means of which we acquire our knowledge about the physically described world*, were elevated to essential features of the theory, not merely postponed, or ignored! Thus certain aspects of reality that had been treated superficially in the earlier classical theories -- namely “our knowledge” and “the process by means of which we acquire our knowledge” -- were now incorporated into the theory in a detailed way.

Specifically, each acquisition of knowledge was postulated to involve, first, an initiating probing action executed by an “observer”, followed by “a choice on the part of nature” of a response to the agent’s request (demand) for this particular piece of experientially specified information.

This response on the part of nature is asserted by orthodox quantum mechanics to be controlled by *random chance*, by *a throw of nature’s dice*, with the associated probabilities specified purely in terms of physically described properties. These “random” responses create a sequence of collapses of the quantum state of the universe, with the universe created at each stage concordant with the new state of “our knowledge”.

If nature’s choices conform strictly to these orthodox statistical rules then the retrocausal results reported by Bem cannot be accommodated. However, if nature is not capricious -- if God does *not* play dice with the universe -- but nature’s choices have sufficient reasons, then, given the central role of “our knowledge” in quantum mechanics, it becomes reasonable to consider the possibility that nature’s choices are not completely determined in the purely mechanical way specified by the orthodox rules, but can be *biased* away from the orthodox rules in ways that depend upon the character of the knowledge/experiences that these choices are creating. The results reported by Bem can then be explained in simple way, and nature is elevated from a basically physical process to a basically psycho-physical process.

The question is then: What sort of biasing will suffice? One possibly adequate answer is a biasing that favors positive experiences and disfavors negative experiences, where positive means pleasing, or meaningful; and negative is the opposite of positive.

In classical statistical physics such a biasing of the *statistics* would not produce the appearance of *retrocausation*. But in quantum mechanics it does! The way that the biasing of the forward-in-time quantum causal structure leads to *seemingly* “retrocausal” effects will now be explained.

## BACKWARD IN TIME EFFECTS IN QUANTUM MECHANICS

The idea that choices made now can influence what has already happened needs to be clarified, for this idea is, in some basic sense, incompatible with our idea of the meaning of time. Yet the empirical results of Wheeler’s delayed-choice experiments [10], and the more elaborate delayed-choice experiments of Scully and colleagues [11] are saying that, *in some sense*, what we choose to investigate now can influence what happened in the past. This backward-in-time aspect of QM is neatly captured by an assertion made in the recent book “The Grand Design” by Hawking and Mlodinow: “We create history by our observations, history does not create us” [12].

How can one make rationally coherent sense out of this strange feature of QM?

I believe that the most satisfactory way is to introduce the concept of “process time”. This is a “time” that is different from the “Einstein time” of classical deterministic physics. That classical time is the time that is joined to physically described space to give classical Einstein space-time. (For more details, see my chapter in “Physics and the Ultimate Significance of Time” SUNY, 1986, Ed. David Ray Griffiths. In this book three physicists, D. Bohm, I. Prigogine, and I, set forth basic ideas pertaining to time. [13])

Orthodox quantum mechanics features the phenomena of collapses (or reductions) of the evolving quantum mechanical state. In orthodox Tomonaga-Schwinger relativistic quantum field theory [14,15,16], the quantum state collapses not on an advancing sequence of constant time surfaces (lying at a sequence of times  $t(n)$ , with  $t(n+1) > t(n)$ , as in nonrelativistic QM), but rather on an advancing sequence of *space-like surfaces*  $\Sigma(n)$ . (For each  $n$ , every point on the spacelike surface  $\Sigma(n)$  is spacelike displaced from every other point on  $\Sigma(n)$ , and every point on  $\Sigma(n+1)$  either coincides with a point on  $\Sigma(n)$ , or lies in the open future light-cone of some points on  $\Sigma(n)$ , but not in the open backward light-cone of any point of  $\Sigma(n)$ .)

At each surface  $\Sigma(n)$  a projection operator  $P(n)$ , or its complement  $P'(n) = I - P(n)$ , acts to reduce the quantum state to some part of its former self!

For each surface  $\Sigma(n)$  there is an associated “block universe”, which is defined by extending the quantum state on  $\Sigma(n)$  both forward and backward in time via the unitary time evolution operator generated by the Schrödinger equation. Let the index  $n$  that labels the surfaces  $\Sigma(n)$  be called “process time”. Then for each instant  $n$  of process time a “new history” is defined by the backward-in-time evolution from the newly created state on  $\Sigma(n)$ .

This new “effective past” is the past that smoothly evolves *into the future the quantum state (of the universe) that incorporates the effects of the psycho-physical event that just*

*occurred*. As far as current predictions about the future are concerned it is *as if* the past were the “effective past”: the former past is no longer pertinent because it fails to incorporate the effects of the psycho-physical event that just occurred.

In orthodox QM each instant of process time corresponds to an “observation”: the collapse at process time  $n$  reduces the former quantum state to the part of itself that is compatible with the increased knowledge generated by the new observation. This sequential creation of a sequence of new “effective pasts” is perhaps the strangest feature of orthodox quantum mechanics, and the origin of its other strange features.

The *actual* evolving physical universe is generated by the always-forward-moving creative process. It is forward-moving in the sense that the sequence of surfaces  $\Sigma(n)$  advances into the future, and at each instant  $n$  of process time some definite, never-to-be-changed, psycho-physical events happens. But this forward-moving creative process generates in its wake an associated sequence of effective pasts, one for each process time  $n$ . *The conditions that define the effective past associated with process time  $n$  combine the “initial” conditions that came from its own effective past with a “final” condition imposed at process time  $n$ .* It is this effective past that evolves directly into the future, and the past that, from a future perspective, led directly to what exists “now”.

Two key features of von Neumann’s rules are mathematical formalizations of two basic features of the earlier pragmatic Copenhagen interpretation of Bohr, Heisenberg, Pauli, and Dirac. Associated with each observation there is an initial “choice on the part of the observer” of what aspect of nature will be probed, linked to an empirically recognizable possible outcome “Yes”, and an associated projection operator  $P(n)$  that, if it acts on the prior quantum state  $\rho$ , reduces that prior state to the part of itself compatible with the knowledge gleaned from the experiencing of the specified outcome “Yes”.

The process that generates the observer’s choice of the probing action is not specified by contemporary quantum mechanics: this choice is, *in this very specific sense*, a “free choice on the part of the experimenter.” Once this choice of probing action is made and executed, then, in Dirac’s words, there is “a choice on the part of *nature*”: nature randomly selects the outcome, “Yes” or “No” in accordance with the statistical rule specified by quantum theory. If nature’s choice is “Yes” then  $P(n)$  acts on the prior quantum state  $\rho$ , and if nature’s answer is “No” then the complementary projection operator  $P'(n) = I - P(n)$  acts on the prior state. Multiple-choice observations are accommodated by decomposing the possibility “No” into sub-possibilities “Yes” and “No”.

## MATHEMATICAL DETAILS

The description of orthodox quantum mechanics given above is a didactic equation-free account of what follows from the equations of quantum measurement theory. The basic mathematical details are given in this section.

The mathematical representation of the dynamical process of measurement is expressed by the two basic formulas of quantum measurement theory:

$$\rho(n+1)_Y = \frac{P(n+1)\rho(n)P(n+1)}{\text{Tr}(P(n+1)\rho(n)P(n+1))} ,$$

and

$$\langle P(n+1) \rangle_Y = \text{Tr}(P(n+1)\rho(n)P(n+1)) = \text{Tr}(P(n+1)\rho(n)).$$

Here the integer “ $n$ ” identifies an element in the global sequence of probing “measurement” actions. The symbol  $\rho(n)$  represents the quantum state (density matrix) of the observed physical system (ultimately the entire physically described universe, here assumed closed) immediately *after* the  $n$ th measurement action;  $P(n)$  is the (projection) operator associated with answer “Yes” to the question posed by the  $n$ th measurement action, and  $P'(n) = I - P(n)$  is analogous projection operator associated in the same way with the answer “No” to that question, with “ $I$ ” the unit matrix. The formulas have been reduced to their essences by ignoring the unitary evolution *between* measurements, which is governed by the Schrödinger equation.

The expectation value  $\langle P(n+1) \rangle_Y$  is the normal orthodox probability that nature’s response to the question associated with  $P(n+1)$  will be “Yes”, and hence that  $\rho(n+1)$  will be  $\rho(n+1)_Y$ . In the second equation I have used the defining property of projection operators,  $PP=P$ , and the general property of the trace operator: for any  $X$  and  $Y$ ,  $\text{Tr}(XY) = \text{Tr}(YX)$ . (The trace operation  $\text{Tr}$  is defined by:  $\text{Tr}(M)$  = Sum of the diagonal elements of the matrix  $M$ ).

Of course, one cannot know the density matrix  $\rho$  of the entire universe. Thus the orthodox rules tell us to construct a “reduced” density matrix by taking a partial trace over the degrees of freedom about which we are ignorant, and renormalizing. This eliminates from the formulas the degrees of freedom about which we are ignorant.

The trace operation is the quantum counterpart of the classical integration over all of phase space. The classical operation is a summation that gives equal a priori weighting to equal volumes of phase space. That is the weighting that is invariant under canonical transformations, which express physical symmetries. The quantum counterparts of the canonical transformations are the unitary transformations, which leave the trace unchanged. Thus the orthodox trace rules are the rational way to give appropriate weights to properties about which have no knowledge, namely by assuming that properties related by physical symmetries should be assigned equal a priori weights.

All this is just orthodox quantum mechanics, elaborated to give a rationally coherent ontological account compatible with the standard computational rules and predictions. [17].

But the assumption that nature gives equal weights to properties that we, in our current state of scientific development, assume should be given equal weights, does not mean that nature itself must give such properties equal weight. Two states of the brain that are assigned equal statistical weight by the trace rule may be very different in the sense that one corresponds to a positive experience and the other corresponds to a negative experience. Classical mechanics postulates that experiential qualities can make no difference in the flow of physical events. But, since quantum mechanics places experiences in a much more central role than classical mechanics, there is no rationally compelling reason to postulate in quantum mechanics that nature, in the process of choosing outcomes of empirical questions posed by agents, must be oblivious to the experiential aspects of reality. That issue should be settled by empirical studies, not by classical-physics-based prejudice.

Consider a situation in which: (1), an agent (the subject) observes a property that corresponds to a projection operator  $P$ ; and (2), a dynamically independent random number generator (RNG) creates either the property represented by the projection operator  $Q$ , or the property represented by the complementary property  $Q'=(I-Q)$ . Suppose at some time after these properties have been created they are still confined to two different systems that have never interacted, so that  $PQ=QP$ , and  $\rho = \rho(P) \rho(Q)$ . Then the probability of getting the answer (PYes), given that (QYes) occurs, is:

$$\text{Trace } PQ\rho/\text{Trace } Q\rho = \text{Tr } P \rho(P)/\text{Tr } \rho(P),$$

which is independent of  $Q$ : the probability of  $P$  does not depend on what the dynamically independent RNG does.

If the two systems interact later, beginning at time  $t$ , then the propagation to a final later time  $t'$  is represented by the action of a unitary transformation: the quantity upon which the trace operation acts gets multiplied on the right by a unitary  $U(t',t)$ , and on the left by the Hermitian conjugate of  $U(t',t)$ . This action leaves all the relationships intact.

If there is then a final measurement at the later final time  $t'$  of a property represented by a projection operator  $R$ , then there could be a dependence upon whether nature's choice at time  $t'$  actualizes  $R$  or  $R' = (I-R)$ . But if the orthodox random rules are obeyed then the net effect, obtained by averaging over the two properly weighted possibilities, is null – because  $R + R' = I$ : the mere fact that an observation is made at the final time  $t'$  has no effect on the correlation (actually the lack of correlation) between  $P$  and  $Q$ . However, if nature's choices are not weighted in the orthodox way then the contributions from the two “complementary” effective pasts, arising from  $R$  and  $R'$ , respectively, will be unequally weighted, and the sum over the two terms will no longer wipe out the effects of the differing effective pasts: observable effects will arise from an excess of histories/probability corresponding to the option that nature's choice favored, and a deficit of histories/probability corresponding to the option that nature's choice disfavored.

## APPLICATION TO BEM'S EXPERIMENTS

The salient point for us is this. All of Bem's experiments have the following form: First, the participant performs a series of observed and recorded actions that choose between two observables, represented, say, by projection operators  $P$  and  $P'=(I-P)$ . Then a dynamically independent random number generator, RNG, chooses to perform upon the participant either an action A1 (represented by  $Q$ ) or an action A2 (represented by  $Q'=(I-Q)$ ) on a specified subset of the participant's observed and recorded actions. Finally, the participant has an experience. The result of the experiment is that, taken together, the participants' previously observed and recorded actions associated with  $P$  are, *in a predicted way*, significantly more likely to occur in the cases in which A1 was performed later from the cases in which A2 was performed later. It would thus *appear* that the actions, A1 or A2, performed later on the participant, in two different ways (chosen by an

independently operating random number generator), influenced, in a predicted way, the participant's earlier observed and recorded actions.

However, if the actions performed upon the participant influenced the participant's later *mood* in a way that produced a collapse of the quantum state, then the "effective past" -- which is what will, after the experiment, be the past that hooks smoothly onto the present -- be determined by nature's choice of which mood/feeling to actualize. That final mood of the participant would be affected by the actions, A1 or A2, previously performed upon the participant, and hence upon the choice between A1 and A2 made by the random number generator RGN. Thus if the statistical weightings nature's choice between R and R' were biased, relative to the orthodox rules, then the histories that lead to the favored final outcome would become enhanced in the effective past.

For example, in the first Bem experiment the participant is shown two screens, L and R, and is told that behind one screen lies a picture, and behind the other lies an image of a blank wall. S/he is instructed to choose the screen behind which s/he feels the picture lies. That chosen screen, L or R, is then replaced by either a picture or an image of a blank wall. What has happened is this: After the participant's recorded choice, L or R, a first random number generator, RNG1, chooses to display in place of that screen, L or R, either a picture, or an image of a blank wall, and a second random number generator, RNG2, decides, with equal probabilities, whether that picture will be "erotic" or "neutral". Bem's result is that the participants, in the absence of all clues, choose more often the screen behind which *will lie* the erotic picture than at the screen behind which *will lie* the neutral picture.

If the random number generator is working properly then this would appear to be a case of retrocausation: a causal action backward in time -- the choices made by the two RNGs are influencing the subject's earlier choice. An alternative possibility is that RNG2, which chooses between "erotic" and "neutral" is being influenced by the participant's dynamically disconnected choice between L and R, but only if RNG1 chooses "picture" not "blank wall". This would require, as Hofstadter remarked, a very major disruption of contemporary ideas about how nature works.

Bem's results would be naturally explained in rational strictly forward-causal way if nature's choice of the participant's *experiences* favored the occurrence of an erotic experience over a neutral experience. In this case, the greater likelihood of the participants' choosing the screen, L or R, behind which an erotic picture lies would arise from the greater probability that nature will actualize a positive experience rather than a negative one in the subset of cases in which participant choice between L and R is the same as the PRNG choice, L or R, behind which a picture lies.

In Bem's Experiment 2, "Precognitive Avoidance of (Subliminal) Negative Stimuli", a long sequence of pairs of pictures is shown to the subject, who chooses a 'preferred' picture from each pair. After each such choice, a RNG makes a random choice of which picture in the pair to identify as the 'target', and then flashes a positive or negative subliminal picture according to whether this target is the "preferred" or "un-preferred" picture. If this random choice of target, and the associated subliminal stimulus, were to occur *before* the subject's choice of preferred picture, then there would be no problem with the empirical evidence that the positive and negative *prior* stimuli appear to

influence the subject's *later* choice of preference. But the normal idea of forward causation does not allow the targeting and associated stimulations that occur *after* the choice of preference to affect that earlier choice of preference. Yet Bem's result is that the pictures chosen *later* as targets are more likely to be *preferred earlier*, compared to the pictures chosen later to be non-targets.

This apparently retrocausal effect follows automatically from the assumption that nature's choice of which outcome actually occurs has a tendency to accentuate the positive and eliminate the negative: such a putative biasing has the effect of adding to the effective past, after nature's biased choice, an abnormal term that corresponds to the *addition* of extra effective histories that lead to positive feelings, or to the *elimination* of effective histories that lead to negative feelings. These extra effective histories have essentially the same effect on the background state of the subject's brain during the process of his or her choice of positive versus negative as the normal effect of performing the brain-changing action *before* the subject's choice of response. In both cases the effective state of the brain of the subject during his or her process of choosing is changed in essentially the same way: whether the change in the effective underlying background state of the subject's brain comes from changes in earlier or later boundary conditions that define the effective past is not important.

To achieve this explanation one needs to relax the condition that the von Neumann process-1 action of posing a question identifies a property of the brain of the observing system that can be grasped as a high-grade conscious experience. One might replace "high-grade conscious experience" by "experienced mood", which could be generated by the subliminal stimuli. Or high-grade conscious experience could be replaced by a lower-level kind of experience. One actually needs such a relaxing anyway, in order to allow lowly life-forms to enter into the quantum dynamics.

The general proposal that nature's choices arise from reasons should be helpful also to the effort to understand the origin of life. If nature exhibits a slight biasing for positive experiences of individual human beings it would perhaps be natural for it exhibit a large bias in favor of the existence in the universe of systems that can represent meaning or purpose, and act on the basis of such reasons. What is at issue here is the basic nature of the logical break, in the passage to a quantum universe, with the classical-physics conception of a mindless, purposeless, reasonless, purely mechanical universe. Experiments of the kind performed by Bem, and variations thereof, if they stand the test of time, have the potential of shedding important light on this question.

Bem's experiment 3 is "Retrocausal priming I". A sequence of pictures is shown to the subject, who responds to each picture by pressing a first or second button according to whether he or she feels the picture to be pleasing or not. After this timed response of the subject to the picture is recorded, a 'word' is selected by a PRNG, and shown to the subject. This word will be either 'congruent' or 'incongruent' with the picture: it will have either the same or opposite positive or negative valence. Bem reports that the recorded time that it takes for the subject to respond to the question of whether or not the picture is 'pleasing' is shorter or longer according to whether the *subsequently* chosen and displayed 'word' is congruent or not with the previously displayed picture. Again the question is: How can the *recorded facts* about what occurred *earlier* -- in particular the response time -- depend on which word was *later* randomly selected and shown to the subject?

The answer is the same as before: the effective background state of the subject's brain - positive or negative -- in the extra effective histories created by nature's *biased* response to the later priming is similar to the normal forward-in-time effect of the same priming: it matters little whether this influential background state of the brain is produced by an initial or a final boundary condition on the effective past.

All of Bem's reported results would be explained in the same way if nature's choices, rather than being strictly random, in accordance with the rules of contemporary orthodox quantum mechanics, were slightly biased, relative to the predictions of orthodox quantum mechanics, in favor of positive experiences, where "positive" includes pleasurable and meaningful.

In view of this not unreasonable way to accommodate the results of the Bem experiment it is not accurate to claim that: "If any of his claims were true, then all of the bases underlying contemporary science would be toppled, and we would have to rethink everything about the nature of the universe", or to call for the banning of works that run contrary to current mainstream scientific expectations.

The explanation advanced here is "scientific", in the sense that it is easily falsifiable. If the output of the random number generator were to be observed by an independent observer, *before* the chosen action is made on the participant, then the biasing reported by Bem should disappear, because the collapse of the two-branched state generated by the random number generator would then be determined by the experiences of the independent observer rather than by those of the participant.

Such a result would constitute spectacular support of the notion that our observations really do influence the course of physically described events. [ In the above discussion I have considered all of the RNGs to be true (idealized quantum-process-based) random number generators. In some of the experiments the RNG was actually a pseudo-random number generator, a PRNG. In principle a PRNG is, in these experiments, just as good as a true RNG, unless *at the time of its effective action* some actual observer *actually knows* everything needed to know what the pseudo-random choice must necessarily be. Unless the outcome is actually determined by what is actually currently known by observing agents the outcome is, within this framework, still undetermined.]

The same line of argument carries over to all nine of Bem's experiments. Of course, the strength of the effect depends upon the power of the subject's mental state to affect nature's choices, and this power appears to vary greatly among subjects.

## CONCLUSION

Numerous reported seemingly backward-in-time causal effects are naturally explainable within orthodox forward-in-time quantum mechanics, by taking due account of the difference between the actual past and the effective past, which is defined by both an initial and a final boundary condition, and by replacing in the quantum formalism the orthodox input of pure chance by the input of sufficient reason, with two such reasons being the promotion of positive experiences and the suppression of negative experiences.

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