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The 18-Fold Way *

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Abstract

At least 18 nontrivial correct choices must be made to arrive at a "right understanding" of the world according to quantum theory.

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1. Introduction.

I have sometimes wondered why it took me forty years to arrive at what now seems to me to be the right way to understand the world according to quantum mechanics. Already in 1959 I had read von Neumann's book, had invented on my own the many-minds interpretation, and found its fatal flaw, and had written the first version of "Mind, Matter, and Quantum Mechanics." The answer to my ponderings became evident when I read Ulrich Mohrhoff's article [1] "The world according to quantum mechanics (or the 18 errors of Henry P. Stapp)." 'Right understanding' requires at least 18 nontrivial right answers: the probability of getting things right by chance is less than one in a quarter million. It may be useful to look at these eighteen choices individually. To this end I shall consider in turn each of the eighteen claims made by Mohrhoff, and explain why I chose in each case the option opposite to the one leading to Mohrhoff's way of removing efficacious mind from our understanding of Nature.

2. Mohrhoff's eighteen claims

1: "an algorithm for assigning a probability to a possible outcome of a possible measurement cannot also represent a state of affairs."

But a successful probability algorithm must have a basis in a state of affairs. A theory that provides an explanation of that basis, or at least a rationally coherent possible explanation of that basis, is more satisfactory than just the algorithm alone, because an explanation can point beyond what is currently known. That is why many scientists seek not just algorithms but also explanations and understanding.

2.1: "The introduction of consciousness... [is] gratuitous."

The empirical basis of science consists of relationships between our conscious experiences. Thus an essential part of any physical theory is a description of the connection between the mathematical formulas and the conscious experiences that are both their empirical basis and the link to possible applications. For quantum theory, as formulated by its founders, the most profound departure from prior science was the introduction of 'the observer' into the theory in a nontrivial way. The founders certainly would have avoided this radical innovation if they had been able to conceive of a satisfactory way to do so. But they could not. The introduction into the theory of the experiences of the observer seemed to be needed to define the 'facts' that science had to deal with.

2.2: "Interpretations that grant quantum states the ontological significance of states of affairs do not satisfy this fundamental requirement" (of being consistent with the probabilistic significance of quantum states.)

The theories of von Neumann, Bohm, and Ghirardi-Rimini-Weber-Pearle all grant to quantum states the ontological significance of states of affairs, or at least aspects of states of affairs, and all are constructed to be consistent also with the probabilistic significance of the quantum states.

2.3: "The word that ought to replace 'measurement' in any ontological interpretation of quantum theory is '(property-indicating) fact'. " "dictionar[ies] define 'fact' as a thing that is *known* to have occurred, to exist, or to be true; a datum of *experience*,... Should we conclude from this that the editors of dictionaries are idealists wanting to convince us that the existence of facts presuppose knowledge or experience. Obviously not. The correct conclusion is that 'fact', ... is so fundamental a concept that it simply *cannot be defined*—the factuality of events or states of affairs cannot be accounted for,"

Dictionaries are usually cited as giving the meaning of a word, not as evidence that the concept cannot be defined. The fact that both Bohr and the dictionary editors turned to experience and knowledge in order to characterize 'facts' suggests that facts might indeed have some sort of experiential underpinning. But that conclusion does not entail commitment to idealistic philosophy. It might signal, rather, the failure of both idealistic and materialistic philosophy to adequately come to grips with the nature of 'facts'. That those two extreme positions are both inadequate is not an unreasonable possibility: philosophers have been debating the merits and deficiencies of those two extreme positions since the beginning of philosophy. Thus it could be deeply significant that the founders of quantum theory found it necessary to define the ‘facts’ in a way that was essentially intermediate between the extremes of purely matter-based philosophy and purely mind-based philosphy. Similarly, von Neumann’s attempt to bring rational order to quantum theory, without renouncing the goal of understanding nature, is built squarely on ‘facts’ that are precisely the *psycho-physical events* specified by Process I. Each such fact has both an experiential aspect, which is the very same ‘experience or knowledge of the observer’ upon which the founders of quantum theory built their version, and also a physical aspect, represented by the reduction of the quantum state of the brain (and hence also the universe) to a form compatible with the experiential aspect of that event. This opens the way to a conception of nature that is built directly on the mathematics of contemporary physics, is philosophically intermediate to idealism and materialism, yet is very different from classical dualism, in which the two components are not dynamically bound together by the basic mathematical structure of the scientific theory itself.

2.4: “Any attempt to explain the emergence of facts... must therefore be a wholly gratuitous endeavor.”

The “therefore” in this claim rests upon acceptance of the assertion that ‘ “fact” is so fundamental a term that it cannot be defined.’ But if a fact is what is created by a quantum event that contains both experiential and physical aspects, and certain proposed mathematical rules governing the emergence of these facts explains in a concise and parsimonious way all the successes of classical and quantum physics, then that putative explanation of the emergence of facts would not appear to be wholly gratuitous.

2.5: “If the answer (to the question does physics presuppose conscious observers) is negative for classical physics then it is equally negative for quantum physics.”

Our conscious experiences play no dynamical role in classical physics: they enter only as passive witnesses to events that are determined by local physical laws. Whether the same is true in the quantum universe cannot be inferred from analogy to the classical approximation. For there is no analog in the classical approximation to the lack of determination by contemporary laws of quantum theory of which question will be posed, or put to nature. That is, there is in quantum dynamics not only the indeterminateness associated with the familiar stochastic element, but also the need to define, in connection with each actual fact, a particular question that was put to nature. This question is not fixed by the known laws of quantum theory. So this issue of the ontological character of the 'facts', and of the process that fixes them, makes quantum physics potentially ontologically different from classical physics: ideas suggested by the classical approximation need not suffice in the real world.

2.6: "The parameter t on which the probability depends is the specified time of this actually or counterfactually performed position measurement. It refers to the time of a position-indicating state of affairs, the existence of which is *assumed*."

This "assumption" is the exactly whole problem. It presupposes, the existence of an essentially classical fact-defining world. That assumption is exactly what troubles many physicists who seek a rationally coherent theory. How does one reconcile the *assumed* existence of a classical world of devices with the quantum character of the atomic constituents of the devices? Bohr stressed that "in every account of physical experience one must describe both experimental conditions and observations by the same means of communication as the one used in classical physics.[2]" What Bohr and the other founders of quantum theory realized was that the fact that scientists use classical language to describe to their colleagues what they have 'done' and what they have 'learned' does not necessarily entail the existence of an essentially classical-type world of localizable facts that exist and are well defined without any explicit involvement of the experiential aspect of nature. The classical character of the language we use the describe the world in which we live could arise from its utility and survival value, rather than from an actually existing world of well defined localized classical-type facts detemined by purely local physical laws that never need acknowledge the existence of experience.

2.7 "$p(R,t)$ is not associated with the possibility that all of a sudden, at time t, the particle 'materializes' inside R. It is the probability with which the particle is found in R *given* that at time t it is found in one of a set of mutually disjoint regions... [that includes R]."

Yes. But what does "found" mean? What is the condition for a 'fact' to exist at time t when it did not exist slightly earlier. In real life, as in science, what is 'found' depends on what is looked for, and how it is looked for. Quantum theory is naturally concordant with that idea. 'Looking for' becomes a fundamental process that is the proper subject of scientific theory. Why must we stick to extratheoretic facts of an essentially classical type? Must the answer to the basic question of the nature and origin facts rest on ideas drawn classical physics, a theory known to be false, or might it come rather from a rationally coherent conception of nature built directly on the mathematics that correctly and seamlessly accounts for ALL the known empirical data, including those explained by classical physical theory. Must it necessarily remain forever true that "Before the mystery of...the existence of facts ...we are left with nothing but shear dumbfoundment." Or can the effort to bring the mathematical laws of quantum theory into close coordination with a conception of reality give us some toe-hold on a path toward understanding the emergence of facts?

3.1: "A possibility is not the kind of thing that persists and changes in time."

But a propensity, or disposition [my words] can be a function of time. And the propensities for various events to occur can change when some event occurs: the propensity for an earthquake to occur is higher when an earthquake has very recently occurred. In a universe (or theory) with stochastic elements the notion of time-dependent propensities can make sense.

3.2 the "third error... is a category mistake. It consists of ... treating possibilities as if they possessed an actuality of their own."

Sir Karl Popper[3] and Werner Heisenberg[4] both recommended treating quantum probabilities as propensities: i.e., as absolutely existing tendencies or 'potentia' for quantum (actualization) events to occur. This notion has a long history in philosophy that dates back to Aristotle.

4: "the erroneous notion that possibilities are things ("propensities") that exist and evolve in time."

Within von Neumann's formulation of quantum theory the quantum probabilities can be consistently interpreted as propensities that exist and evolve in time.

5: "astronomical data...support the existence of a historically preferred family of hypersurfaces, but not of a dynamically preferred one."

The empirically preferred surfaces are generally believed to be created by 'inflation', which is a dynamical process.

6: "inconsistent combinations of counterfactuals."

The logic is as follows: If getting a certain outcome (-) of a later measurement L1 entails that the outcome of a certain earlier measurement R2 is (+), and if getting outcome (+) of the earlier measurement R2 entails that the outcome of a later measurement L2 would necessarily be (+), and if the last minute choice later choice between L1 and L2 cannot influence the outcome of R2 that has already occurred earlier then one can assert that if R2 is performed earlier then if L1 is performed later and gives outcome (-), then the outcome (+) would necessarily have appeared if the last minute choice of the later measurement had been to perform L2 instead of L1.

After contemplation anyone can then see that this claim is correct. Logicians have examined it and agree that it is correct.

7: "fallacious... proof of... faster-than-light information transfers of information."

This claim is based on denying the validity of my reply to claim 6. That reply stands up under close scrutiny. But Mohrhoff's description of my proof bears little resemblance to my proof itself: there is no butressing: no second proof. There is one concise and rigorous proof [5].

8.1: "granting free will to experimenters" does not lead "to a physical reality inconsistent with the 'block universe' of SR.

By free will I mean the freedom to will ourselves to act 'now' either in some particular way, or not in that way. The existence of freedom in this sense is incompatible with the 'block universe' of SR, which says that the whole universe is laid out for all time in the way that SR (classical special relativity theory) ordains, i.e., such that given the physical state of the universe for very earlier times there is no possibility of choosing now to act in some way or to not act in that way. But the laws of quantum mechanics, being dynamically incomplete, do not entail a block universe in the way that the deterministic and complete laws of SR do. The generally accepted application of the requirements of the theory of relativity to quantum theory is to its *predictions*: **they** must conform to the no-faster-than-light requirements of the theory of relativity. This is exemplified by Tomonaga-Schwinger relativistic quantum field theory, which is completely compatible with instantaneous collapses along spacelike surfaces, and in fact *demands* such collapse to the extent that one accepts the existence of von Neumann's Process I. The laws of quantum theory lack the coersive quality of the classical laws that entail the block universe.

8.2: "if the possibility of foreknowledge does not exist,..I can actually be a free agent."

Not in the sense that I have described, in a universe in which the deterministic laws of SR hold. For being free in that sense means being free to act in either one of two different ways in a universe with a given fixed past. No such freedom exists in a universe that obeys the deterministic laws of special relativity. What the person knows, or does not know, is not pertinent to that conclusion.

8.3 "The fact that the future in a sense 'already' exists is no reason why choices made at an earlier time cannot be partially responsible for it."

The 'choices' actually made at an earlier time can certainly be partially responsible for what happens later. But in a world that conforms to the deterministic laws of classical of SR, and with a fixed early universe, that 'choice' made at the earlier time is not 'free': it could not go in either one of two different ways. "Freedom", in this sense is not compatible with the block universe of SR, but it is compatible with von Neumann quantum theory, due to the indeterminacy within that theory of which question will be put to nature.

9: "the erroneous notion that the experiential now, and the temporal distinctions that we base upon it, have anything to do with the physical world."

In the classical limit the 'experiential now' indeed has no role. But the incompleteness of quantum theory allows the experiential now to enter into the causal structure in ways not allowed in classical limit. Thus arguments based on classical concepts lack conclusiveness.

The 'instantaneous now' plays an essential role in the relativistic quantum field theory of Tomonaga-Schwinger, to the extent that one implements the von Neumann Process I, which ties the instantaneous now of physics to the experiential now of psychology.

10: "There is no such thing as 'an evolving objective physical world'. "

There is such a thing in Tomonaga-Schwinger relativistic quantum field theory if the von Neumann Process I is implemented in it.

11: "There is no such thing as an objectively open future and an objectively closed past."

There is such a thing in Tomonaga-Schwinger relativistic quantum field theory, if the von Neumann process I is implemented in it.

12: The "attempt to involve causality at a more fundamental level" is an error. "While classical physics permits the anthropomorphic projection of causality into the physical world with some measure of consistency quantum physics does not."

I am not projecting the intuition of the causal power of our thoughts into the world to explain the deterministic aspect of nature associated with the Schroedinger equation. I am concerned rather with explaining how our thoughts themselves can be causally efficacious. The mathematical fact is that the quantum laws allow this, by virtue of the indeteminacy associated with von Neumann's Process I, (The freedom of choice in which question to pose—i.e., the basis problem) whereas the classical laws do not provide or allow an analogous causal efficacy. In classical theory the future is determined by the past by LOCAL laws, whereas in quantum theory a present choice of which question to pose is not detemined by the local laws of contemporary physics.

13: "Error 12 depends crucially upon ...[the] erronous view that the factual basis on which quantum probabilities are to be assigned is determined by Nature rather than by us."

One of my very chief points is that quantum theory is incomplete because the equations of quantum theory do not specify which question is put to Nature, i.e., which apparatus is put in place, which 'basis' is used to determine a 'fact'. That role is given to us, the observer/participants, by Copenhagen quantum theory. In von Neumann's formulation this choice is bound up in the psycho-physical event specified by Process I. That this freedom of choice of basis, is given to "us", is the key point that I exploit to explain how mental effort can influence brain activity. Mohrhoff and I seem to be basic agreement on this essential point.

14: "QM [is] inconsistent with a fundamental assumption of field theory."

Mohrhoff's views about quantum field theory are definitely idiosyncratic. I identify contemporary QM with relativistic quantum field theory, and, for the description of brain dynamics, with quantum electrodynamics, supplemented by an external gravitational field to represent the effects of the earth's gravity. I take physical theories to be created by scientists, and to be judged in the end by their predictive and explanatory powers.

15: "freedom to choose is a classical phenomenon."

Mohrhoff's argument is based on his idea that mental choice and effort must be coersive, rather than dispositional. But quantum theory allows dispositional causes. And within classical physical theory there is no possibility of freedom of the kind that I have described above. But von Neumann quantum theory does allow that sort of freedom.

16: It is erroneos to claim that "The objective brain can (sometimes) be described as a decoherent statistical mixture of 'classically described brains' all of which must be regarded as real."

By the objective brain I mean the quantum state defined by taking the trace of the state (density matrix) of the universe over all variable other than those that characterize the brain, and my claim is merely that interaction with the environment converts this state to a form that can be roughly described as a mixture of states each of which approximates a classical state of the brain, in the sense that in the position-basis the states are approximately localized. This mixture includes ALL of these states, not just one of them, or some small subset that are all observationally indistinguishable. There is therefore the problem of relating this state to observation. This is achieved, within the von Neumann formulation, by a psycho-physical event described by Process I. This approach can be described as taking the mathematics of quantum theory to give valid information about the structure of reality, and making our idea of nature, and the facts that define it, conform as closely as possible to that mathematical description.

17: "The metaphor of experimenter as interrogator of Nature [is fitting] within the Copenhagen framework, which accords special status to measuring instruments, [but is not fitting] in Stapp's scenario, which accords special status to neural correlates of mental states."

In the Copenhagen interpretation 'the measuring instruments and the participant/observer' stand outside the system that is described by the quantum mathematics, and they are probing some property of a 'measured system', which is part of an imbedding quantum universe. In the von Neumann formulation the role of 'the measuring instuments and the participant/observer' is transferred to the 'abstract ego', and the measured system whose properties are being probed is the brain of the observer.

The need for the outside 'observer', which includes the measuring devices, is to specify a definite question, which is represented by a projection operator P acting on the state of the 'measured system', even though nothing about that system itself— or even the whole of the quantum-described universe— defines that particular operator P, or specifies *when* that question is 'put to Nature.'

A key technical question now arises: To what extent does the natural Schroedinger evolution of the brain, abetted by the Environment-Induced-Decoherence (EID), already decompose the quantum state of the brain into orthogonal branches that correspond to distinguishable 'facts'? The EID tends to create 'coherent states', which have exponential tails, and are not mutually orthogonal. In fact, it is impossible in principle for a Schroedinger evolution to define the projection operators P that are needed in the von Neumann formulas. That fact is undoubtedly why von Neumann introduced his Process I as a basic process not derivable from the Schroedinger Process II. There is no way to get the needed projection operators out of Process II. A projection operator defines, and is defined by, a *subspace*. That means that the definition of a projection operator P must distinguish every vector in the subspace from vectors that lie outside that subspace and differ from that vector by infinitesimal amounts. The Schroedinger evolution of an isolated system could define and preserve energy eigenstates, but there is no way that the Schroedinger evolution of a brain interacting with its environment could specify subspaces associated with experientially distinct facts without some extra rule or process not specified by the Schroedinger Process II itself. This fact is the technical basis of von Neumann's theory. It is this need for some outside process to fix the content of the facts, and their times of coming into being, that opens the door to the efficacy of experience.

17.1: "The questions the mind can put to the brain, by choosing where to fix its attention, are always compatible, for the mind does not have to choose between incompatible experimental arrangements."

But it does have to define an operator P, or, equivalently, a subspace of the Hilbert space associated with the brain, and this subspace is not specified by the prior (quantum) state of the brain or the universe.

17.2 "If attention is drawn to the highest bidder, the highest bidder is not a component of a mixture of CDBs (Classically Described Brains), but one among several neural events or activities competing for attention in one and the same CDB."

The various CDBs are overlapping (non-orthogonal), and the function of Process I is to pick out of this amorphous mass of possible states some well defined subspace associated with a distinct experience. Our ruminations about possible choices can run over various consciously experienced possibilities, but each such experience is associated with a selection of a subspace from the amorphous collection of overlapping possibilities that constitutes the state of the brain at that moment. The Schroedinger Process II cannot by itself unambiguously decompose the state of the brain into well defined orthogonal branches corresponding to distinct CDBs.

18: "The theory Stapp ends up formulating is completely different from the theory that he initially professes to formulate, for in the beginning consciousness is responsible for state vector reduction, whereas in the end a new physical law is responsible, a law that in no wise depends on consciousness."

That example is not my final theory. It was put forward as a simple model to show how one could, within the general von Neumann framework that I have developed, produce a dynamically complete theory. It does this by postulating a new law that resolves in a certain definite way the dynamical freedom that I have used to make consciousness efficacious.

Mohrhoff suggests that this model violates the quantum laws, but that is not true: the extra postulated law controls which questions are asked, and when they are asked, and these are precisely the elements that are not controlled by the standard quantum laws, and whose indeterminacy, with respect to those laws, provides the opening for efficacious minds within contemporary basic physical theory

The essential points are, first, that some rules that go beyond the Schroedinger equation (as expressed within the framework of relativistic quantum field theory developed by Tomonaga and Schwinger), *must* be added to the Schroedinger equation to tie the quantum mathematics to the problem of securing statistical connections between human conscious experiences, and, second, that these added rules are basically nonlocal, because the evaluation of the formula Trace PS(t) is a nonlocal operation. (These extra rules are needed not only in the von Neumann formulation, but in every formulation, including the many minds/worlds theories, where this dynamical gap is known as "the basis problem". This basis problem has *not* been solved within any framework resting solely on the Schroedinger equation alone.)

The key issue is whether consciousness itself enters the dynamics. This devolves to the question: What is the ontological source or basis of the coersive quality of the laws of nature?

My answer is that with respect to the local dynamical process governed by the Schroedinger equation this question is not worth pursuing: it is the *existence* of that mechanical law that matters to us, and inquiry into what gives that law its coersive quality is unduly speculative. But the same question is far from meaningless in connection with the collapse process that is associated with a human conscious experience. This is because the experiences associated with these collapses *are known to us*, and are in fact the only things really known to us. Thus they are proper elements of science, and are, in fact, the basis of science.

I have thus emphasized that the resetting (of the state of the brain) associated with a conscious human experience is mathematically and dynamically different from the local mechanical (Schroedinger) process, and I now suggest that the coersiveness of the laws that govern the creation of a stream of consciousness comes in part from the experiences that constitute that stream: that the experiential realities are actually doing something that is not done by the local mechanical laws. Why else would they exist?

Thus I have noted that some process beyond the local mechanical process described by the Schroedinger equation is needed to complete basic contemporary physical theory, and tie it to the empirical facts, and I am suggesting that the conscious experiences that emerge in this process are essential causal elements of a nonlocal evaluative process that is needed to complete the quantum dynamics.

In summary, local mechanical process alone is logically incapable picking the question (choosing the basis) and fixing the timings of the events in the quantum universe. So there is no rational reason to claim that the experiential reality that constitutes a stream of consciousness is not a causal aspect of the dynamical process that prolongs or extends this reality, yet lies beyond what the local quantum mechanical process is logically able to do.

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