Quantum Theory of Mind

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Abstract: The theory of mind pursued by most neuroscientists has been called "Promissory Materialism" by Karl Popper. It is characterized by a commitment to the view that an understanding of the mind-brain connection will come eventually from dogged adherence to the concepts of classical mechanics. Those concepts are known to be fundamentally false, make no mention of mind, and have been replaced at the fundamental level by those of quantum mechanics. That latter theory, in its orthodox form advanced by von Neumann, is basically a theory of the connection between the minds and the brains of observers, and involves observer free choices that can influence, via the basic quantum laws, an observer's physical actions.

1. Introduction

The great 19th century physicist John Tyndall wrote:

"We can trace the development of a nervous system and correlate it with the parallel phenomena of sensation and thought. We see with undoubting certainty that they go hand in hand. But we try to soar in a vacuum the moment we seek to comprehend the connection between them…" [1] {The Belfast Address, 1874}

And Richard Feynman famously said:

"I think I can safely say that nobody understands quantum mechanics!" [2]{The Character of Physical Law,1965}

In the light of these disclaimers, and the raging controversies among quantum physicists about the nature of the reality that lies behind the successful quantum rules, why should any rational person believe, on the basis of uncontroversial scientific evidence alone, that mind is a quantum effect? Quantum mechanics is, after all, about atoms, whereas the brain is a macroscopic object, and macroscopic things are supposed to be described in terms of the concepts of classical mechanics.

My answer to this query begins with the words of Niels Bohr, who, In his 1934 book *Atomic Theory and the Description of Nature*, says [3]:

"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 the relations between the multifold aspects of our experience."

The positive part of this message is that quantum theory is ultimately about "our experience". Bohr is telling us, obliquely, that the quantum theory of atomic phenomena is, in the end, about our minds. The theory describes empirically validated connections between the quantum mechanical description of atoms and certain happenings in our streams of conscious experiences. In the more mathematically precise and logically coherent orthodox formulation of quantum mechanics developed by John von Neumann[4] the atoms that are directly relevant to the content of a person's stream of consciousness lie in that person's brain (and perhaps other parts of his nervous system). Thus quantum mechanics becomes, in von Neumann's orthodox formulation, directly and explicitly a theory of the mind-brain connection.

Bohr's statement expounds the original, so-called "Copenhagen Interpretation", of quantum mechanics set forth at the 1927 Solvay conference. That approach to atomic theory emphasizes not only that quantum theory connects our ideas about atoms to the structure of our thoughts. It stresses also that the pragmatic quantum understanding of nature is not based on a *prior* understanding or assumption about the underlying real essences. The aim in Copenhagen quantum mechanics is rather to achieve a practically useful understanding of relations between our experiences, without leaning on any prior presumption about the nature of the underlying "real essences".

There has been between 1927 and 2013 a great lifting of the veil that originally blocked a clear understanding of the connection between the pragmatically successful quantum formalism and conceptions about underlying "real essences". Indeed, the core implication of the highly praised 2012 theorem of Pusey, Barrett, and Rudolph [5] {On the reality of the quantum state, Nature Physics, June, 2012} is that the *empirical validity of certain predictions of quantum mechanics* entails that some supposedly mere practical tools (for the calculation of predictions), namely the actualized quantum mechanical states, can rationally be understood to be real essences. Thus a rationally coherent conception of underlying real essences, and of their connection to the structure of our mental lives, emerged from an adequate understanding of the latter; not vice versa.

That is, indeed, the way of science. Isaac Newton himself proceeded in that way -- as he himself emphasized ("I frame no hypotheses") – by deducing from Kepler's understanding of the structure of the astronomical data an idea of the underlying reality. Similarly, John von Neumann deduced, already in 1932, from the Copenhagen understanding of the structure of the (experiential) phenomena a rationally coherent idea of the structure of real essences. That is the scientific method: extract from an adequate understanding of the empirical data a putative understanding of the real essences, and then try to move forward on the basis of that putative deeper understanding.

The salient point here is that the prejudice in the minds of both the founders of quantum mechanics, and -- even more insistently -- of Einstein, that the physical aspects of the pragmatic quantum theory cannot represent real essences, became generally accepted, and that bias threw most physicists and philosophers off course. It caused them to prejudicially dismiss the possibility that a properly formulated quantum mechanics can provide not only a set of practical rules but also a description of what can rationally be considered to be reality itself. If that possibility can be realized, then the properly formulated theory ought to yield -- as orthodox quantum theory in fact does -- a rationally coherent understanding of the connection between what had seemed, in earlier conceptualizations, to be two aspects of reality that were rationally disconnected, namely our psychologically described minds and our physically described brains.

The prejudices in question, though completely lacking empirical support, are, nevertheless, psychologically potent in the minds of many physicists. They pertain to what Einstein called "spooky action at a distance", and the associated quantum collapses. These "spooky actions" are fundamental features of the quantum mechanical rules. Thus the strong prejudice is that reality simply cannot involve such essentially instantaneous transfers of information over large distances enforces the view that the quantum formalism simply cannot describe reality. Yet these spooky actions are an integral part also of the orthodox *relativistic quantum field theory*, which fulfills all of the *empirical* demands of the theory of relativity. Thus the prejudices in question lack any empirical basis, and ought not, from a scientific point of view, restrict the realm of theoretical possibilities.

This conclusion is strongly supported by the fact that, given the validity of the *predictions* of quantum mechanics, spooky actions at a distance cannot be universally prohibited [6]. In particular, given a certain experimental setup involving two far-apart experimental regions in each of which a free choice is made between two alternative possible experimental settings of an apparatus located in that region, and given the validity of the predictions of quantum mechanics in each of the four alternatives possible cases specified by these choices, it is not possible to require in each of these four alternative possible cases that the outcomes in each region be independent of which free choice is made in the faraway other region: In at least one of the alternative possible cases the outcomes in one region must depend upon which experiment is freely chosen in the faraway region at essentially the same instant of time. This conclusion is based exclusively on empirically verified macroscopic *predictions* of quantum mechanics, and the idea of free choices, which is needed to define the independent variables. There is no reference to, or condition on, anything else.

The predictions of quantum mechanics pertinent to this proof have been validated empirically. Hence we have here an action-at-a-distance property derived from empirical properties of nature herself.

On the other hand, the principles of relativistic classical mechanics ensure that this same action-at-a-distance property cannot hold in classical mechanics. Thus the principles of classical physics forbid an action-at-a-distance property that *empirical properties* of the observed world entail! This undermines the rationality of using the absence of faster-than-light actions in relativistic classical mechanics to impose this condition on nature herself.

2. Orthodox Quantum Mechanics

The rationally coherent orthodox formulation of quantum mechanics was given in 1932 by the eminent mathematician and logician John von Neumann. Von Neumann has been called “the last of the great mathematicians” and “ the most scintillating intellect of the century”. Nobel Laureate Hans Bethe said “I have sometimes wondered whether a brain like von Neumann’s does not indicate a species superior to that of man.” Another expression of the same idea was a joking suggestion that von Neumann was actually an outer space alien who had trained himself to perfectly imitate a human being in every way.

Von Neumann’s orthodox formulation of quantum mechanics is widely used by mathematical physicists and others who need a mathematically precise and rationally coherent formulation of the theory. This orthodox formulation has the additional virtue of bringing back into the physical theory a mathematically precise and logically coherent putative conception of objective physical reality itself, namely the physically described quantum mechanical state of the universe, evolving according to the rules specified by von Neumann. Those rules link the evolution of the physical reality to certain *psychological* realities, namely to human choices that are “free” in the sense that they are neither determined by, nor even statistically biased by, the totality of the present and past physical realities represented in the theory. In spite of the inclusion of these elements of freedom, the orthodox theory is nevertheless concordant with all of the empirically validated predictions of classical and quantum mechanics, and, moreover, with the capacity of a person’s freely chosen mental intentions to influence that person’s upcoming bodily behavior in the way that he or she mentally intends.

The main logical problem with the earlier Copenhagen formulation of quantum mechanics was that that it introduced, in order to account for our descriptions of our experiences, not only our streams of experiences themselves and the quantum mechanical representation of the physically described aspects of reality. It introduced also a *classical physical description* that is logically incompatible with the quantum description. Thus all sorts of inconsistencies arose. Von Neumann eliminated this classical description, and, along with it, the associated inconsistencies.

The Copenhagen quantum-classical physical description had been introduced in association with a mysterious movable cut, called the Heisenberg cut, which had the incredible property that everything “below” the cut was described in the quantum mechanical language, and every physically described thing “above” the cut was described in the terminology of classical physics. Von Neumann removed the ambiguities and inconsistencies associated with this movable cut by moving it all the way up, so that all physically described elements were placed below the cut, and hence were described quantum mechanically, leaving above the cut only the psychologically described parts of the pragmatic theory. Von Neumann called the psychologically described residue associated with each observer that person’s “abstract ego”. It comes directly from the pragmatic theory.

This shift places the boundary between the mentally described and quantum mechanically described aspects of nature at the separation between the minds and brains of observing agents, where it naturally belongs, not out at some ill-defined “measuring device”, as the Copenhagen interpretation does. It turns quantum theory into a description of the causal connection, via von Neumann’s dynamical rules, between our minds and their associated *quantum-physically described* brains. The classical concepts, which are known to be both fundamentally false, and incompatible with the precepts of quantum mechanics, are eliminated.

An important virtue of the orthodox theory is this: it provides not just a mathematically and logically precise formulation of the pragmatically successful rules. It provides also the principles underlying a rationally coherent and dynamically integrated conception of a psychophysical reality in which we human beings are embedded *as psychophysical agents that can freely instigate probing actions of our own mental choosing. It allows 'what the theory is describing' to be consistently interpreted as a reality that has both physical and mental aspects, with the mental aspects not determined by the physical ones. The observers are equipped with free choices that are included not "ad hoc", simply because we feel that our choices are somehow free. They are included because they are logically required, in order to break a symmetry and allow our perceptions to have the character that they actually possess, rather than being continuous smears of possible experiences of kind that actually populate our streams of consciousness. Thus, for example, the pointer on a measuring device will, by virtue of some probing action, and nature's response to it, be either "swung to the right" or "not swung to the right", rather than the* mixture *of these conflicting possibilities that the purely mechanical part of the law of motion, namely the Schroedinger equation, acting alone would generate.*

Stated differently, the central problem in the construction of an adequate quantum theory is to resolve the wave-particle puzzle. This is the fact that the evolution of the physically described quantum mechanical state in accordance with the purely mechanical law of motion -- the Schroedinger equation -- produces a physically described structure that is a giant smear of systems of the kind that we human observers perceive. If the dynamics were to be governed solely by this purely physical equation of motion, which is the completely natural quantum analog of the classical law of motion, then the dynamics would not be connected to experience in the way that a pragmatic theory should.

Von Neumann solved this core difficulty in essentially the way specified by Copenhagen quantum mechanics, upgraded to achieve mathematical precision and logical coherence. This solution injects free choices made by observing agents into the dynamics. These choices are "free" in the sense that they are not determined by the purely mechanical (Schroedinger) component of the full equation of motion. Each observing ego is empowered to pose probing questions about the facts of the world in which it finds itself. To each posed question Nature either immediately returns a positive answer in the form of a characteristic responding feeling F, or returns no response. If nature responds, then the system being observed will, *after this answer is returned*, possess the property corresponding to the question. If no response is returned, then the system, after the question is posed, will definitely not possess the property in question.

Von Neumann expressed essentially these ideas in the mathematical framework of quantum mechanics. This probing process allows an observing ego to learn, by trial and error probing, the structure of the world in which it finds itself. This structure will be in the form of relations between its feelings. Thus the brain whose properties are being directly probed is described in the mathematical language of quantum mechanics, whereas the ego's representation of its increasing knowledge is described in terms of its feelings. The connection between these two representations is created by a constructive process governed by von Neumann's rules. This process connects psychological features of the probing ego to physical properties of the brain whose properties it is directly probing.

It is essential here that the physical state *after* the probing question be something depending on the combination of the ego's free choice and nature's statistically controlled response. This newly created state generally differs from the prior state, and hence this pair of choices is influencing the flow of physical events. Thus the observer is not a mere passive witness to a flow of physical events that is proceeding independently of his probing actions.

This profound change in the causal structure is the essential difference between classical and quantum physics. Our understanding of it emerged, only after the fact, from the science-based effort to rationally comprehend puzzling empirical findings that violated classical ideas, not from any preconceived intention to rescue free will.

Although, in von Neumann's formulation, the direct interaction between the probing ego and the physically described aspects of nature is between the ego and its brain, the mathematical structure entails that the entire physically described universe will be instantly reduced to the part of its former self that is compatible with the new state of that brain. These global jumps are the radical new feature of quantum mechanics, and are a cause of consternation in the minds of people who insist on thinking, on the basis of appearances, that nature herself conforms to classical ideas. But these classical appearances are saved in spite of these global jumps, and in fact due to these global jumps, which allow localized free choices to alter global "real essences" without upsetting classical experiences.

I shall later give explanations of these wonderful features. But some physicists, most notably Einstein, hoped to evade this spooky action at a distance. They hoped that because quantum mechanics was a statistical theory about "our knowledge" that is similar in some ways to classical statistical mechanics, that the action-at-a-distance feature that can be evaded at the level real essences by reverting to a quasi-classical theory. That tack has been pursued under the title "hidden variable theories". or, euphemistically, "realistic theories", where "realistic" is short for "quasi-classical". Those attempts to recover locality by combining classical concepts with quantum predictions, fail. The approach [6] deduces a nonlocality property directly from validated empirical findings and a strong conception of free choices.

3. Quantum connection between mind and brain

The orthodox quantum theoretical connection between mind and brain is close to the opposite of the classical theoretical idea of that connection. In the classical physics our minds are conceived to be puppets controlled by our physical brains. In orthodox quantum mechanics a person's brain is, instead, the instrument by means of which that person's mind/ego, embedded in a physically described world, learns about this physical world in which it finds itself; forms valid expectations about its future experiences; and acts to influence what it will find to be the case.

But how, in more detail, does it all work?

The mind, or "abstract ego", has a battery of efforts E each of which corresponds to an act of putting to Nature a particular question about the world inhabited by that ego.

According to the quantum precepts, Nature immediately responds by either returning a feeling F that is tied to the effort, F=F(E), or by failing to return immediately a response. In the first case the *brain being probed* has, immediately after the response is delivered, the physical property that is represented in the mind of the probing agent by the feeling F. In the second case, that brain has the physical property that is the negation of that property. In either case the ego is immediately free to pose another question. If the ego were to "immediately" pose the same question then it invariably would, according to the quantum rules, receive the same answer as before. It this same question were to be posed after a short delay, then, according to the quantum rules, the probability that Nature would deliver the same response is specified by the state of the probed brain, which is evolving in accordance with specified physical laws. This leads, via well defined rules, to predictions about future experiences that turn out to be valid.

The ego of the infant begins in the womb to inquire about the structure of the world in which it finds itself, and, by virtue of its intrinsic conceptual capacities, begins, by trial and error, to acquire a conception of that world. This conception is a construction in terms the validated feelings F that it has experienced as responses to its probing actions.

Now it might seem to a reader honed on the precepts of classical physics that giving these conceptual properties to our minds begs the question. The basic scientific problem, as they might conceive it, is precisely to explain these wonderful powers and properties of our minds exclusively in terms of the physical properties of our brains. But that would mean demanding that a proper science-based understanding of the empirically valid theory conform to the precepts of a different theory that is both inconsistent with it and empirically false.

To achieve both agreement with all empirical data and the rational coherence required of a theory of reality, the orthodox theory backs away from the classical notion that the principles of classical mechanics that work so well in the astronomical and large-scale terrestrial realms, extend in a direct way to biology and atomic physics. It is the rejection of that extrapolation that is the basic move of quantum mechanics. Yet, in spite this well-known failure of the ideas that work so well in astronomy to extend to the atomic and molecular domains, and the well-known dependence of brain behavior on atomic and molecular processes, most scientists who seek a deep understanding of the mind-brain connection persist in clinging to the astronomy-based concepts. In conformity with what Sir Karl Popper called "Promissory Materialism", they expect that an understanding of our minds will emerge from dogged adherence to a theory that is known to be invalid, and which, as a matter of basic principle, leaves out the minds that they are trying to understand. They balk at basing their thinking on its empirically valid successor, which is *fundamentally about* exactly what they are trying to find out about, namely the connection between the mental and physical aspects of reality, and, more directly, the connection between a person's mind and that person's brain.

Specifically, orthodox quantum mechanics, like Copenhagen quantum mechanics, is a theory of the relations between experiences that belong to various abstract egos (personal minds). It is based on the notion that there exists an evolving physical world that is described in terms of the mathematical principles of quantum mechanics, as described by von Neumann. This notion specifies that the experiences belonging to a person's abstract ego be directly connected to the physical world through that person's physically described brain. The specified connections between a person's mind and brain allows that person, by means of experienced responses to his or her probing actions, to form a conception of the structure of the world in which it is embedded, and, moreover, to influence the future evolution of that world, and thereby its own future experiences.

As regards the powers that the theory ascribes to the minds of the probing agents, let it not be forgotten that the underlying philosophy of quantum mechanics is essentially pragmatic. I have been emphasizing that the intrinsic rational coherence of the mathematical structure described by von Neumann allows that structure to be conceived to be a representation of "reality". But "reality", apart from the thoughts, ideas, and feelings that we directly know, is in the end conjectural. To be useful, the contents and powers that the theory assigns to our minds should match our actual understanding of our minds, in order that we be able to tie the theory to the putative reality. In Bohr's words "The task of science is both to extend the range of our experience and reduce it to order" [7] In this way of looking at the scientific endeavor our minds as we know them are the givens. We want to expand them in useful ways built securely on validated empirical findings. Utility is the bottom line, and our theory of reality must encompass it. But to be useful to us the theory needs to inform us about how one's existing mind can, by virtue of its intrinsic powers, form valid expectations about the contents of future minds, and develop ways to influence those future minds in intended ways. The key to such an understanding is an understanding of the way that a mind is connected to its brain; for that connection is that mind's bridge to the future.

4. Understanding instantaneous action at a distance

But how are the needed instantaneous actions at a distance rationally understood in a world conforming to all of the empirical demands of the special theory of relativity?

When I, by virtue of my understanding of the meaning of my experiences, can conclude that I have seen the pointer swing to the right, I normally find that an immediate re-examination will confirm that prior finding, but that after a while things may change. And if I enquire, I will find that others in the room will have similar experiences.

Inquiring minds, confronted by such findings, have developed a conception of a communal world in which our individual minds are embedded. Efforts by many thinkers, working over many centuries, led to von Neumann's 1932 proposal about the nature of a psychophysical world, and the way in which our minds are embedded in it.

A basic need of the theory is to explain *intersubjective agreement* in a rationally evolving world that accommodates our independent, and sometimes seemingly capricious, causal inputs. This problem was solved in von Neumann's theory (following the Copenhagen lead) by collapses of quantum states at certain "instants". These "instants" extend over the entire universe, and the collapses at these instants constitute "instantaneous actions-at-a-distance".

These "instants" were originally considered to be *flat* 3-dimensional surfaces that separated the past from the future. By moving forward in time these instants "now" separated the "open" future of potentialities and possibilities from the "closed" fixed and settled past.

But the notion that these surfaces are "flat" is at odds with the theory of special relativity. In the relativistic quantum field theory proposed independently by Tomonaga[8] and Schwinger[9] these instants "now" are taken to be non-flat 3-dimensional continuous surfaces in the 4-dimensional space-time having the property that every point on such a surface lies outside the (closed) forward light cone of every other point on that surface. This allows one to think that the needed advances into the future are achieved by an ordered sequence of tiny steps in each of which a current "instant" is changed to the next "instant" by a small advance confined to small (say brain-sized) region. The mind-brain connection pertains to what is happening to the mind and the brain in such a localized event. The postulated instantaneous "collapse of the quantum state of the universe" occurs along the new instant "now". That gives a dynamically defined meaning to a point that is both faraway and "now". Although that idea of a physically well-defined faraway "now" is completely contrary to the *ideas* of relativity theory, all of the quantum theoretical predictions about actual observations are absolutely in line with the principles of relativity theory. That is why Einstein was unable to give a convincing argument that faster-than-light actions cannot be real: relativistic quantum field theory has such instantaneous actions at a distance without violating any empirical requirements of special relativity.

5. Conscious control of physical behavior

"It is to to my mind utterly inconceivable that consciousness has nothing to do with a business which it so faithfully attends" [10] {Wm. James, Principles, vol 1, p. 136}

James's feeling may, in the opinion of materialists, be sheer prejudice, unsupported by any solid empirical evidence. But their own contrary opinions might warrant greater credence if they were based on valid physical laws that reduce our conscious experiences to causally inert witnesses. However, the physical theory that had once supported that notion is now known to be fundamentally false. It has been replaced by a theory in which inputs considered to originate, at least partially, in our psychologically described egos, have profound effects on the evolution of the physical.

Yet in this new theory the role of the ego in the unfolding of physical events is restricted to the mere posing of questions. So a critical question is how this capacity of an ego merely to pose questions allows its intentions to influence, in the way that it mentally intends, the physical behavior of its brain and body.

The answer rests on a very basic feature of quantum mechanics described by Misra and Sudarshan [11], and associated by them to one of Zeno's Paradoxes. I call this effect "The Quantum Zeno effect". It must be emphasized, straight-away, that this effect is very different from an effect studied empirically by Wineland's group [12], and given by them this same name. I use the term to describe the "Zeno" property of quantum mechanics described by Sudarshan and Misra.

This "Zeno" effect is easily understood. The quantum state of a system is often called the state "vector". A vector is a directed line segment in a space: it begins at one point in that space, called the origin of that vector, and ends at another point, that can be called the tip or end-point of the vector. The mechanical evolution of the quantum state *under the process controlled by the Schroedinger equation* consists of a motion of the tip of a vector that moves around with both its origin and length fixed. The length is the distance between the origin and the tip.

In the visually accessible case of a three-dimensional space, one can think of a spherical globe, with the origin of the vector fixed at the center of the globe, and the tip moving around on the surface. The basic idea of quantum mechanics is that the motion is not always that simple Schroedinger-equation-directed motion. At some instant when the state vector is, say, Vbefore, an observing agent can ask: Will I find the vector that describes my experience to be Vafter. The statistical character of quantum mechanics stems from a single simple rule: the probability that the answer will be "Yes" is the square of the cosine of the angle between Vbefore and Vafter.

The quantum Zeno effect follows directly from a very simple application of this basic rule. Suppose the agent's probing action corresponds to the question "Will my probing effort yield the response corresponding to my finding the physical state vector to be VO?

Of course, only someone who understands quantum mechanics will be able to understand the agent's action in this technical way. But it does not matter whether the human agent understands his effort in this way. Realistically interpreted orthodox quantum mechanics assumes that this it what is really going on, and is what the agent has learned to feel and understand in his or her own way. The quantum effect in question is of such great generality that the details of the mapping between the human idiosyncratic experience and the putative underlying reality are not relevant.

Suppose that an agent's felt probing action corresponds to the question: "Will a 'Yes' response to this probing action that I am now initiating signify that the state vector of the system I am probing will, after my probing, be the vector V0?" Suppose that the answer is 'Yes'. And suppose the Schroedinger equation, acting alone, would cause V0 to evolve during one second into some different vector V1, having the same origin and length The quantum Zeno effect is the fact that, independently of the further details of the physical situation, if the agent were repeatedly to pose the same question at a very rapid rate, during that one second interval, then the answers received will continue, during that interval, to be "Yes" with probability approaching unity as the rapidity of the probing action tends to infinity: In the large N limit the state vector will be frozen at V0.

This result is easy to understand. A little reflection shows that if N is the number of probing actions made during the one second interval, and v is the normal velocity on the constant radius (say r=1) sphere, then the probability that the vector will still be V0 after one second is the cosine of v/N raised to the power 2N. That number approaches unity (i.e., one) as N tends to infinity: the rapid posing of the same question tends to freeze the state at the value associated with the positive answer to that "freely chosen" probing action.

A simple extension of this result is that if the rapid sequence of probing actions corresponds not to one single vector, V0, but to a sequence of vectors, Vn, that lie along some chosen path on the unit sphere, then the state of the system being probed will tend to be dragged along that path defined by the chosen sequence of probing actions. Thus this quantum process -- built directly, and trivially, upon the most elemental quantum rule, the cosine-squared rule -- elevates the ego's capacity merely to choose its probing actions to a capacity to cause its brain to behave in a way that will cause its body to behave in the way that the ego mentally intends.

6. Libet, volition, and the ordering of cause and effect.

In von Neumann's orthodox theory causes logically precede their effects. Our mental volitions are causes and they logically precede their psychological and physical effects. Some seminal experiments by Benjamin Libet and his colleagues [9] have been interpreted as empirical evidence that nature does not conform to those ideas. But those conclusions stem, according to the orthodox point of view, from a failure to understand what is really happening.

In these experiments the human subject of the experiment performs a physical action that is designed to be a freely chosen action, and that feels to the subject to be a freely chosen action. The plain empirical facts are, first, that this "free choice" appears to precede the physical action, as expected. But several tenths of second before the free choice to perform the action occurs a characteristic electric disturbance called the action potential arises in the brain. The empirical fact that this brain activity precedes the "free choice" to act has been widely interpreted as evidence that the physical brain is in actual control, just as classical mechanics says, and that the mental side effect is merely an after-the-fact mental rationalization that gives credit to the mind for what the physical brain has already done.

In the Libet protocol the subject is instructed to raise a finger sometime in the future, tacitly understood to be within the next 20 or 30 seconds. The subject accepts the instruction, and, according to my understanding of the orthodox theory, his quantum mechanical brain begins to create *potential templates for actions* that conform to the specified instruction. A template for action is a pattern of neurological activity that if actualized, and held stably in place for a sufficient interval, will send out an ordered sequence of physically described signals that will cause the body to behave in a coordinated way.

However, the exact time of the action was not specified by the instruction. Hence the quantum mechanically described brain will create a quantum mechanical *mixture* of various possible templates corresponding to various possible times for the finger-raising action to occur.

But which of the physically equivalent, possibilities will be actualized? This is where the radical key idea of the creators of quantum mechanics enters: the *experimenter (here the subject) decides, via a choice that is not determined by the Schroedinger equation,* whether to perform a physical action that is connected in his mind to an expected mental feedback.

But before the chooser can exercise a freedom to meaningfully choose, he must have a conception of the expected, or hoped for, consequences of the choice. The chooser does not choose in a conceptual vacuum. The chooser – in this case the subject that must choose to perform some particular finger-raising action – must have an image of the consequences of that possible action. The action potential measured by Libet et.al. functions *first* to provide the ego with an image of what he can expect to experience if that template is actualized. This preview must precede the ego's informed choice to act, which must precede the actual physical action.

Many potential templates for action can be considered and rejected by the ego before one is accepted. The rejections leave no direct trace in the mind of the subject, even though each such rejection eliminates from the quantum mechanical brain the strand of potentialities that was rejected.

Von Neumann spends a great deal of effort creating and describing the detailed mathematical machinery that lies behind the surface-level description that I have just given. He pays a great deal of attention to the fact that the different quantum brain states that exist in parallel generally exist not in the form of a *superposition* of possible states, but rather in the form of *mixtures*. This change arises from the fact that the states of the brain of central interest are generally believed to be strongly interacting with their environment in such a way that certain "phase" information becomes irretrievably lost. But that loss of effective information does not alter the fact that the alternative mutually incompatible possibilities continue, according to the orthodox rules, to exist, in the mathematically well-developed form of mixtures.

The upshot is that the observed rise of the action potential prior to the actual choice to act is a reflection of the fact that our choices although "free" are not "blind": prior to the choice to act there must be a representation in the brain of the projected consequences of choosing to act, in order for the ego to bring its values to bear on the choice that it makes. Only then can we be rationally responsible for our actions.

The rational basis of this entire way of conceptualizing things rests on a pragmatic view of science. In order to be useful to us the theory must allow us to identify our mental selves as parts of the theoretical construct that have the power to act in ways that tend to produce experiences concordant with our values.

The orthodox interpretation designed by von Neumann meets this requirement, and agrees with all reproducible empirical data, but at the expense of demanding that the physically described world be profoundly different from what it appears to be.

This disparity at the macroscopic level between the putative description of physical reality offered by orthodox theory and our classically describable experiences stems from the rational need to reconcile the effects of the observer's free choices that the theory allows, and indeed requires, with the demand that all future observations of all observers be concordant with the freedom of each of the individual observers to choose his or her own probing actions, and to witness and remember Nature's responses to them. A huge chasm separates this rationally coherent orthodox conception of physical reality from our naïve idea of it based on everyday experience.

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