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Pragmatic Approach to Consciousness *

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Abstract

Physical scientists were driven during the late twenties to abandon a fundamental idea that had reigned since the time of Issac Newton. To obtain a rationally coherent and practically useful theory of all physical phenomena they turned to a pragmatic approach. The core idea was that the basic physical theory was no longer directly about a physical world that was conceived to exists apart from anyone's knowledge of it. Rather the theory was regarded as being directly about certain of our knowings. This switch appears to be exactly what is needed to establish a rationally coherent theoretical foundation for the science of consciousness. For it converts the immediate objects of psychological and physical theories into things of the same kind, namely human experiencings, rather than things of disparate kinds separated by an unbridgable conceptual gap. Within this pragmatic quantum approach certain particular aspects of human brain structure entail the existence of macroscopic quantum effects that are linked to our conscious experiences. Moreover, our conscious thoughts have causal effects that can both enhance our prospects of survival, and work effectively against thermal noise in the creation of the brain states that guide our behaviour.

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1. Introduction.

In modeling the connection between a person's conscious experiences and the activities of his body and brain it is often assumed that a conception of the human body/brain concordant with the principles of classical physics will be adequate. This assumption would seem injudicious in view of the well known failure of the classical conception of matter at the fundamental level. But it is often argued that quantum effects pertain to atomic-scale processes rather than the large-scale brain activities that govern our conscious experiences, and that this scale difference renders classical description adequate in practice even though it is wrong in principle.

It turns out, however, in the case of human brains, that simple general considerations show that the failure of classical concepts at the atomic scale necessarily has, according to the pragmatic quantum precepts, large macroscopic effects that are linked to conscious experiences. In particular, the irreducible Heisenberg uncertainties in the locations of presynaptic calcium ions entail that the observed macroscopic behaviour of the body/brain will be determined by reductions of quantum wave packets that, according to the pragmatic quantum principles, are representations of conscious knowings. These sudden quantum reductions have no counterpart in classical mechanics. Consequently, within the pragmatic framework, the irreducible Heisenberg uncertainties inject our conscious thoughts into the dynamics of the body/brain in a way that is neither allowable nor imaginable in classical physics.

This result, which will be explained in detail below, resolves a fundamental philosophical problem of long standing: the classical-physics conception of a person's body/brain renders his conscious experiencings causally inert, and hence superfluous with respect to the course of physical events. But many scientists and philosophers find it unnatural that something so different from classically conceived matter as our conscious experiences would become tacked onto the material universe if they play no causal role in the unfolding of physical events.

This problem is nicely laid out by the philosopher Daniel Dennett. Some of Dennett's earlier books were interpreted by critics as evading this difficulty with consciousness by denying, unreasonably, the existence of consciousness. He certainly did deny any sort of ontological mind-matter duality in nature. But in his new book "Kinds of Minds-Toward an Understanding of Consciousness" (Dennett, 1996) he starts right off using the word "mind" to denote, in a perfectly normal way, a personal realm of conscious experience. He quickly distinguishes questions about what exists (ontology) from questions what we know (epistemology), and says that the goal of his book is to show that these two kinds of questions have to be answered together. That thesis, developed in another way, constitutes the essence of what I shall be saying here.

Dennett then continues: "I will argue that we already know enough about minds to know that one of the things about them that makes them different from everything else in the universe is the way we know about them. For instance, you know you have a mind and you know you have a brain, but these are different kinds of knowledge. ....each of us knows exactly one mind from the inside... No other thing is known in that way."

Having thus specified some epistemological aspects of mind Dennett gets, near the end of the book (p. 155), to the ontological side:

"Mental contents become conscious... by winning the competition against other mental contents for domination in the control of behavior, ... A common reaction to this suggestion about human consciousness is frank bewilderment, expressed more or less as follows: 'Suppose all these strange competitive processes are going on in my brain, and suppose, as you say, that the conscious processes are simply those that win the competition. How does that make them conscious?' "

This question appears to reflect the questioner's tacit assumption that the physical brain conforms to the classical-physics conception of it. The classical-physics conception of the physical world is that this world consists of a huge collection of tiny bits of structureless matter. This collection is separated into swarms that constitute stars, planets, apples, tornadoes, locomotives, computers, human bodies, and all of the other objects that we can see, and also the many others that, for one reason or another (e.g., too small, too distant), we cannot see.

According to the classical-physics conceptualization, these things that are seen from afar are to be conceptualized as being, in essence, like collections of tiny moving "billiard balls", where each ball is essentially structureless, but is connected by some forces to its nearest neighbors.

The essential idea of the classical-physics conceptualization of the physical world is that this reality can be conceived of by *stripping away from what we might actually see*, which can be colored by all of our personally appended ornamentations and significances and meanings, every property but the spacetime trajectories of the structureless bits: these trajectories alone constitute the basic classical-physical reality. (Even the fields can be conceived of as consisting of such trajectories.) Nothing beyond this stripped-down ontology is needed to make the principles of classical physics work.

The motions of the "billiard balls" that constitute the activities of the classically described physical brain can, in the mind of someone who knows that brain from the outside, be analyzed in many ways. However, no matter how many layers of modules monitoring modules are present, and no matter how many physical memories tracks are being laid down, and no matter how how many feed-back structures are operating, if that brain is built out of nothing but the particles and field of classical physics, and these entities have no properties or qualities not specifically assigned to them by the principles of classical physics, then within that classical conceptual framework, there is no logical necessity for there to exist, by virtue of the existence of that brain and its activities, any conscious knowings beyond the 'knowings from the outside' that the classical framework is built upon. There is, within the conceptual framework of classical physics, no logical requirement for there to be, in association with your brain, any special conscious knowing that can be identified with your conscious knowings. For your brain itself, and all its activities, are, according to the classical-physics conceptualization of it, exactly the set of spacetime trajectories of its component bits: nothing more or less. Within the classical-physics framework all aspects of your brain beyond what is represented by the idea of these trajectories themselves, gathered into various and sundry swarms, are ornamentations attached by knowings from the outside.

This fact that the existence of your brain and its activities does not, within the classical-physics framework, logically require the existence of any 'knowings from the inside' (of your brain by your brain) does not mean that these knowings do not exist. It only means that classical mechanics does not require them to exist. Yet if the existence of these conscious knowings is, within classical-physics framework, not required by the existence of the physical body/brain and its activities, then these knowings could be left out of the classically conceived reality without upsetting the classical-physics causal description of the behaviour of the body/brain. Since that description is causally complete, these knowings must, within that framework, be causally inert. However, a conceptual framework that includes your conscious knowings but makes your behaviour causally nondependent upon your knowings lacks full logical coherence.

This logical deficiency motivates turning to a quantum-mechanical treatment in which mind and body are causally interpenetrating in a way that is both mathematically describable and pragmatically useful. I begin by documenting the subjective/experiential character of the orthodox Copenhagen interpretation of quantum mechanics.

2. The subjective character of the orthodox interpretation of quantum mechanics.

In the introduction to his book "Quantum theory and reality" the philosopher of science Mario Bunge (1967) said: "The physicist of the latest generation is operationalist all right, but usually he does not know, and refuses to believe, that the original Copenhagen interpretation — which he thinks he supports — was squarely subjectivist, i.e., nonphysical."

Let there be no doubt about this.

Heisenberg (1958a): "The conception of objective reality of the elementary particles has thus evaporated not into the cloud of some obscure new reality concept but into the transparent clarity of a mathematics that represents no longer the behavior of particles but rather our knowledge of this behaviour."

Heisenberg (1958b): "...the act of registration of the result in the mind of the observer. The discontinuous change in the probablitity function... takes place with the act of registration, because it is the discontinuous change in our knowledge in the instant of registration that has its image in the discontinuous change of the probability function."

Heisenberg (1958b:) "When old adage 'Natura non facit saltus' is used as a basis of a criticism of quantum theory, we can reply that certainly our knowledge can change suddenly, and that this fact justifies the use of the term 'quantum jump'. "

Wigner (1961): "the laws of quantum mechanics cannot be formulated...without recourse to the concept of consciousness."

Bohr (1934): "In our description of nature the purpose is not to disclose the real essence of phenomena but only to track down as far as possible relations between the multifold aspects of our experience."

In his book "The creation of quantum mechanics and the Bohr-Pauli dialogue" (Hendry, 1984) the historian John Hendry gives a detailed account of the fierce struggles by such eminent thinkers as Hilbert, Jordan, Weyl, von Neumann, Born, Einstein, Sommerfeld, Pauli, Heisenberg, Schroedinger, Dirac, Bohr and others, to come up with a rational way of comprehending the data from atomic experiments. Each man had his own bias and intuitions, but in spite of intense effort no rational comprehension was forthcoming. Finally, at the 1927 Solvay conference a group including Bohr, Heisenberg, Pauli, Dirac, and Born come into concordance on a solution that came to be called "The Copenhagen Interpretation". Hendry says: "Dirac, in discussion, insisted on the restriction of the theory's application to our knowledge of a system, and on its lack of ontological content." Hendry summarized the concordance by saying: "On this interpretation it was agreed that, as Dirac explained, the wave function represented our knowledge of the system, and the reduced wave packets our more precise knowledge after measurement."

Certainly this profound shift in physicists' conception of the basic nature of their endeavour, and the meanings of their formulas, was not a frivolous move: it was a last resort. The very idea that in order to comprehend atomic phenomena one must abandon ontology, and construe the mathematical formulas to be directly about the knowledge of human observers, rather than about the external real events themselves, is so seemingly preposterous that no group of eminent and renowned scientists would ever embrace it except as an extreme last resort. Consequently, it would be frivolous of us simply to ignore a conclusion so hard won and profound, and of such apparent direct bearing on our effort to understand the connection of our knowledge to our bodies.

Einstein never accepted the Copenhagen interpretation. He said: "What does not satisfy me, from the standpoint of principle, is its attitude toward what seems to me to be the programmatic aim of all physics: the complete description of any (individual) real situation (as it supposedly exists irrespective of any act of observation of substantiation)." (Einstein, 1951, p.667) and "What

I dislike in this kind of argumentation is the basic positivistic attitude, which from my view is untenable, and which seems to me to come to the same thing as Berkeley's principle, *esse est percipi.* (Einstein, 1951, p. 669). Einstein struggled until the end of his life to get the observer's knowledge back out of physics. But he did not succeed! Rather he admitted that: "It is my opinion that the contemporary quantum theory...constitutes an optimum formulation of the [statistical] connections." (ibid. p. 87). He referred to: "the most successful physical theory of our period, viz., the statistical quantum theory which, about twenty-five years ago took on a logically consistent form. ... This is the only theory at present which permits a unitary grasp of experiences concerning the quantum character of micro-mechanical events." (ibid p. 81).

One can adopt the cavalier attitude that these profound difficulties with the classical conception of nature are just some temporary retrograde aberration in the forward march of science. Or one can imagine that there is simply some strange confusion that has confounded our best minds for seven decades, and that their absurd findings should be ignored because they do fit our intuitions. Or one can try to say that these problems concern only atoms and molecules, and not things built out of them. In this connection Einstein said: "But the 'macroscopic' and 'microscopic' are so inter-related that it appears impracticable to give up this program [of basing physics on the 'real'] in the 'microscopic' alone." (ibid, p.674).

The present paper is based on my judgement that our probings into nature have revealed a profound failure of the classical-physics conceptualization of nature precisely at the point under discussion here, namely the connection of epistemology to ontology.

3. Epistemology and Ontology.

The Copenhagen interpretation of quantum theory is epistemological: the theory is construed to be about our knowledge, and the quantum jumps—the famous "reductions of the wave packets" — are considered to be the kind of sudden changes that naturally accompany changes in someone's knowledge. Yet nature must surely contain some reality besides our knowledge: for what happens to my knowledge when I am sleeping?

From a mathematical point of view the simplest way to represent a reality compatible with quantum phenomena is to let the quantum state represent both our knowledge of reality, in the way claimed by the Copenhagen interpretation, and also reality itself.

This move is philosophically attractive, because it moves us in the direction of an increased comprehension of the underlying unity of nature, a unity revealed by the amazing way that aspects of nature that appear at first to be completely different eventually turn out to be the same thing in different guises. The course of science has been essentially the process of uncovering this underlying unity: celestial and terrestial dynamics were unified by Newton; electro-magnetism and light were unified by Maxwell; space and time were unified by Einstein, as were spacetime and gravity; heat and molecular motion were unified by Boltzmann and others: these are just a few highlights of the unrelenting scientific process of revealing underlying oneness behind apparent diversity.

In view of these precedents it is reasonable examine the consolidation of mind and matter brought about by positing that the quantum state represents not only our knowledge, in the way specified by orthodox quantum theory, but also aspects of the reality that surrounds it.

This apparently obvious move seemed untenable to the founders of quantum mechanics because of the notorious 'quantum jumps'. These jumps seemed natural for a representation of 'knowledge of reality', but unacceptable as a behavior of reality itself.

Physicists were reluctant to accept the physical realness of these jumps because behaviour of this kind contradicted a strongly held prejudice stemming from the theory of relativity. But overcoming irrational prejudice is a virtue, particularly if it allows science to describe reality.

The irrational prejudice was the conviction that a free choice made by someone in one region could not affect a faraway real physical situation at a speed faster than light. This idea, that no effect of a free choice can travel faster than light, originated in the context of a strictly deterministic classical theory. But it is an open the question whether it must continue to hold in a context where determinism itself is question.

It turns out, in fact, that this no-faster-than-light demand is logically incompatible with the *predictions* of quantum theory themselves, quite apart from all matters of ontological interpretation (Stapp, 1997). So abandoning this prejudice not only removes a logical contradiction: it also makes possible the simplest mathematical representation of physical reality consistent with quantum phenomena.

The theory to be described here is based on this identification of the quantum state with both reality itself and also our knowledge of reality in the way specified by the Copenhagen interpretation. This move does indeed carry the overtones of Berkeley's *esse est percipi* that Einstein objected to, but was unable to circumvent in three decades of trying. In the present context our core problem is, as emphasized by Dennett, precisely the breakdown of the normal idea of the separation between epistemology and ontology. Hence it makes sense to examine the alternative conception of this relationship that physics is pressing so hard upon us.

4. Quantum Effect of Presynaptic Calcium Ion Diffusion.

Let me assume here, in order to focus attention on a particular easily analyzable source of an important quantum effect, that the propagation of the action potential along nerve fibers is well represented by the classical Hodgson-Huxley equation, and that indeed all of brain dynamics is well represented by the classical approximation apart from one aspect, namely the motions of the pre-synaptic calcium ions from the exit of the micro-channels (through which they have entered the nerve terminal) to their target sites. The capture of the ion at the target site releases a vesicle of neurotransmitter into the synaptic cleft.

The purpose of the brain activity is to process clues about the outside world coming from the sensors, within the context of a current internal state representing the individual's state of readiness, in order to produce an appropriate "template for action", which can then direct the ensuing action (Stapp, 1993). Let it be supposed that the classically described evolution of the brain, governed by the complex nonlinear equations of neurodynamics, will cause the brain state move into the vicinity of one member of a set of attractors. The various attractors represent the various possible templates for action: starting from this vicinity, the state of the classically described body/brain will evolve through a sequence of states that represent the macroscopic course of action specified by that template for action.

Within this classically described setting there are nerve terminals containing the presynaptic calcium ions. The centers of mass of these ions must be treated as quantum mechanical variables. To first approximation this means that each of these individual calcium ions is represented as if it were a statistical ensemble of classically conceived calcium ions: each individual (quantum) calcium ion is represented as a cloud or swarm of virtual classical calcium ions all existing together, superposed. This cloud of superposed virtual copies is called the wave packet. Our immediate interest is in the motion of this wave packet as it moves from the exit of a microchannel of diameter 1 nanometer to a target trigger site for the release of a vesicle of neurotransmitter into the synaptic cleft.

The irreducible Heisenberg uncertainty in the velocity of the ion as it exits the microchannel is about 1.5 m/sec, which is smaller than its thermal velocity by a factor of about 4×10^{-3}. The distance to the target trigger site is about 50 nanometers. Hence the spreading of the wave packet is of the order of 0.2 nanometers, which is of the order of the size of the ion itself, and of the target trigger site. Thus the decision as to whether the vesicle is released or not, in an individual instance, will have a large uncertainty due to the large Heisenberg quantum uncertainty in the position of the calcium ion relative to the trigger site: the ion may hit the trigger site and release the vesicle, or it may miss it the trigger site and fail to release the vesicle. These two possibilities, yes or no, for the release of this vesicle by this ion continue to exist, in a superposed state, until a "reduction of the wave packet" occurs.

If there is a situation in which a certain particular *set of vesicles* is released, due to the relevant calcium ions having been captured at the appropriate sites, then there will be other nearby parts of the (multi-particle) wave function of the brain in which some or all of the relevant captures do not take place—simply because, for those nearby parts of the wave function, the pertinent calcium ions miss their targets—and hence the corresponding vesicles are not released.

More generally, this means, in a situation that corresponds to a very large number N of synaptic firings, that, until a reduction occurs, all of the 2^N possible combinations of firings and no firings will be represented with comparable statistical weight in the wave function of the brain/body and its environment. Different combinations of these firings and no firings can lead to different attractors, and thence to very different macroscopic behaviours of the body that is being controlled by this brain.

The important thing, here, is that there is, *on top of the nonlinear classically described neurodynamics*, a quantum mechanical *statistical effect* arising from the spreading out of the wave functions of the centers of mass of the various presynaptic calcium ions relative to their target trigger sites.The spreading out of the wave packet is unavoidable, because it is a consequence of the Heisenberg uncertainty principle. This spreading is extremely important, because it entails that every vesicle release will be accompanied by a superposed alternative situation of comparable statistical weight in which that vesicle is not released. This means that wave function of the entire brain must, as a direct consequence of the Heisenberg uncertainty principle, disperse into a shower of superposed possibilities arising from all the different possible combinations of vesicle releases or non-releases. Each possibility can be expected to evolve into the neighborhood of some one of the many different attractors. These different attactors will be brain states that will evolve, in turn, if no reduction occurs, into different possible macroscopic behaviors of the brain and body.

Thus the effect of the spreadings of the wave functions of the centers of the presynaptic calcium ions is enormous: it will cause the wave function of the person's body in its environment to disperse, if no reduction occurs, into a profusion of branches that represent all of the possible actions that the person is at all likely to take in the circumstance at hand. The eventual reduction of the wave packet becomes, then, the decisive controlling factor: in any given individual situation the reduction selects—from among all of the possible macroscopically different large-scale bodily actions generated by the nonlinear (and, we have supposed, classically describable) neurodynamics—the single action that actually occurs.

In this discussion I have generated the superposed macroscopically different possibilities by considering only the spreading out of the wave packets of the centers-of-mass of the pertinent presynaptic calcium ions relative to the target trigger sites, imagining the rest of the brain neurodynamics to be adequately approximated by the nonlinear classically describable neurodynamics of the brain. Improving upon this approximation would tend only to increase the quantum effect I have described.

It should be emphasized that this effect is generated simply by the Heisenberg uncertainty principle, and hence cannot be simply dismissed or ignored within a rational scientific approach. The effect is in no way dependent upon macroscopic quantum coherence, and is neither wiped out nor diminished by thermal noise. The shower of different macroscopic possibilities created by this effect can be reduced to the single actual macroscopic reality that we observe only by a reduction of the wave packet.

5. Brain and Consciousness.

The classical-physics conception of the physical world was described above: the basic point was that the physical world is conceived to consist of "knowables". But in the pragmatic/quantum approach we take "knowings" to be the basic reality, and think of the objective reality as, basically, a representation of a set of possible knowings. Then when we learn something we project our new knowing onto the pragmatic/quantum objective reality by restricting the prior set of possible knowings to a new more restricted set. Specifically, the quantum reality is conceptualized as a set of knowings compatible with a wave packet that is represented by a statistical ensemble of visualizable classical worlds. When a new knowing occurs, this event is represented by reducing the prior wave packet to the part of it that is compatible with the new knowing. Thus ontology and epistemology become reconcilable because the ontology is built basically out of idealized epistemological stuff.

By adopting a quantum-theoretical approach we open the way, of course, to a quantum treatment of various chemical processes that are important to the functioning of the brain. But that is NOT the point here. Those atomic processes can surely be treated to sufficient accuracy by a quasi-classical model that merely adjusts atomic-scale properties that have little to do directly with our consciousness. The point of going to the pragmatic/quantum framework is to accommodate the huge macroscopic quantum effects that are directly forced upon us by the Heisenberg uncertainty principle, and that make the reduction of the wave packet of decisive importance in the determination the large-scale behaviour of the body/brain. These reductions of the wave packet are, within the pragmatic/quantum framework, projections of our knowings onto our mathematical representation of physical reality .

It is sufficient to consider a model of the brain that is mainly classical. To a good first approximation the introduction of quantum theory merely involves introducing on top of the normal classical statistical ensemble arising from our incomplete knowledge a further statistical ensembles of classical motions arising from the irreducible quantum uncertainties.

At first sight this just seems to overlay the classical statistical ensemble of brain states by another layer of statistical uncertainty that adds nothing perceptible to the uncertainties already present.

But there is a basic difference. In any single empirical instance only one member of the classical component of the statistical ensemble is actually present, but all of the members of the quantum superposition that are forced to be present by the uncertainty principle are necessarily all present simultaneously, until a reduction occurs. This presence in principle of the various superposed possibilities is the essence of quantum theory: it is entailed by the fact that the different superposed members of the quantum ensemble can interact with each other.

The presence of these superposed possibilities means that in any given empirical instance, no matter which classical element of the ensemble is actually present, the quantum ensemble spreads over all of the various possible attractors. Consequently, this quantum reduction exercises an overriding control over the choice of attractor: this choice *could* be the same for each of the alternative possible members of the classical ensembles, and hence independent of which of the alternative classical states (generated, for example, by the thermodynamical mixture of possibilities) is present. For the quantum principles are absolutely mute on this sort of unphysical question: *What would the choice have been if the occurring situation had been other than what it actually is?*

Thus the quantum choice could in principle be independent of which member of the classical statistical ensemble is present. But in that case the quantum choice would wipe out the classical uncertainties introduced by the thermal noise.

This point is raised merely to emphasize that the quantum choice is the decisive control element in cases—such as the human brain—where the irreducible quantum uncertainties are so great that essentially all of the alternative macroscopic possibilities are included within the range spanned by the quantum uncertainties.

The quantum choices, in this pragmatic/quantum framework, are projections of our knowings onto our representation of physical reality. If the knowing is the 'knowing of my decision to raise my arm' then the projection of that knowing reduces the wave packet of my brain to one in which a certain attractor is actualized, namely an attractor that embodies the template for action that initiates and directs the raising of my arm. The reduction restricts the wave packet to one that is compatible with the new knowing, in complete parallel to the way that a 'knowing of the location of a pointer on some measuring device' reduces the wave packet of the pointer, and hence also the wave packet of the entire world, to a form that is compatible with that knowing.

There is no problem here with the fact that a mere "knowing" can do something. For 'knowings' are recognized to be real elements of the ontological structure, supplementing the 'material' things that, although formerly thought to be independent basic realities, appear now as dynamically entwined parts of a greater whole that includes our minds.

This way of constructing the theory of consciousness and its connection to experiment is practical, and coherent, and it meshes nicely with our basic physical theory, quantum theory, without adding any significant mathematical burden to the theory of consciouness beyond what is needed in classical mechanics: for most purposes it will be adequate to regard the brain as merely a statistical ensemble of classical brains. But the theory nevertheless puts our knowings, which are certainly real parts of nature, into the ontology in a natural way, and allows them to play a key dynamical role, freed from the rigid control of local purely mechanical laws.

Bringing consciousness in the physical theory in this natural and efficacious manner points the way to natural resolutions of the basic philosophical problems that have beset the philosophy of mind and psychology for most of this century. It resolves the puzzlement about how something like a "feeling" can arise out of the motions of a set of "billiard balls" by simply asserting what quantum theory has already shown, namely that the world cannot be understood as being built out of such classically conceived matter: it is better understood as being built out of an entwined complex consisting of two kinds of stuff: potentialities that obey laws analogous to those that govern classical matter, and the experiential actualities that those potentialities are potentialities for. Adopting to this quantum mechanical conception of nature does not lead to any loss of the practical computational power provided by classical physics. Quite the opposite: this more modern conception of nature was essentially forced on physical scientists by the demand for a logical framework that provides an accurate, comprehesive, rational, and practically useful account of our experiences in what had formerly been thought to be the domain of the purely physical sciences. And in the study of mind/brain phenomena it will *usually* be adequate to regard the brain as simply a statistical ensemble of classically described brains, with this ensemble being always compatible with everything we know. So we get the philosophical advantages essentially for free in cases where the classical and quantum predictions agree.

I have focused here on human science, and hence on human body/minds. But reductions of the wave packet associated with other kinds of systems should also occur, and be connected to other kinds of"knowings". However, the effort to extend the theory to nonhuman"knowers" should, I believe, be built upon the development and testing of the theory in the human case, where the empirical evidence is more direct.

6. Quantum Enhancement of Psycho-states.

An important question for science is this: Does the quantum dynamical involvement of our knowings, and the reductions that represent them, alter the predictions of this theory relative to those of the parallel classical statistical account. The answer is a qualified "yes". One possible cause of difference is now described.

Let a "psycho-state" be a brain state, or patterns of brain/body activity, that corresponds to a conscious experience: according to the pragmatic theory, a psycho-state is a (functional) representation of an actual knowing.

For reasons to be described now, the quantum dynamics should increase, relative to classical mechanics, the statistical likelihood of the occurrence of psycho-states relative to states having no phenomenal/epistemological content.

Within the classical approximation to quantum mechanics the predictions of the classical and quantum theories are the same. This approximation is obtained, in our simplified example where the quantum effects were confined to the motions of presynaptic calcium, by allowing the wave packets of the presynaptic calcium ions to be just statistical ensembles of classical trajectories. Then the whole model becomes classical. There can still be reductions of wave packets, but these are classical reductions that can be understood in the normal classical way as just picking out from a ensemble of imagined copies of the system those members that are compatible with a new knowing. That reduction is mathematically essentially the same in the classical and quantum theories. It is rather the dynamical evolution that is different. The quantum wave packet evolves (when no reduction is occurring) according to the Schroedinger equation, and this evolution is not identical to the evolution of a statistical ensemble of classical copies.

The difference can be dramatic. In the evolution of a classical statistical ensemble the individual trajectories evolve independently: they are together only in our imagination. But in the quantum case neighbors act on each other. Indeed, the Schroedinger equation is essentially an equation for hydrodynamical flow (Feynman, 1965).

Imagine scooping water out of a bucket with a repeated motion that takes the water always from the same place: one can nearly empty the bucket, even though the water is always taken from one place. For water rushes in to fill a void, due to the action of the different molecules upon their neighbors.

Similarly, a repeated taking away of the same substate out of the state of the brain can be expected to take away more when the dynamics is controlled by quantum theory, in contrast to classical statistical mechanics, because in the quantum case the 'diffraction effect' works to fill up a void created by removing superposed neighbors, but there is no analogous effect in the corresponding classical statistical theory.

We do not yet know what physical criteria distinguishes psycho-states from the others, apart from the capacity of these states to represent "knowings": that, indeed, may be all that is needed. But the hydrodynamical effect described above entails that it would be advantageous for an organism to be organized so that templates for actions that increase its chances of survival are psycho-states: the hydrodynamical effect will cause such states to acquire more statistical weight in a quantum system than in the corrsesponding classical system because a repeated taking away of the state corresponding to a certain knowing will cause probability to flow into that state to fill the void, and thus contribute more to a repeated action. Thus organisms that are conscious of the actions that enhance their chances of survival could become more likely to survive. This effect could follow just from the pragmatic quantum statistical rules themselves, without any assumption that mind acts to bais the probabilities specified by the basic principles of quantum theory.

Another possibly important effect of the collapses could arise if the workable templates for action are so finely honed that the thermal noise makes it difficult for them to be formed: it might be like trying to get a key into a lock with a palsied hand. In such a situation the quantum hydrodynamic effect described above would automatically act to 'suck' the key into the lock, and thus to counteract the uncontrollable thermal agitation.

The most important thing, however, is that although these quantum enhancement effects might be difficult to observe directly with the technologies available today, their possible existence in principle shows that the pragmatic account is not, in principle, empirically identical to its classical approximation. Hence it is reasonable to hope that the philosophical coherence of the pragmatic quantum approach reflects a movement toward a truer picture of nature that eventually will be supported by empirical ramifications.

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