Henry Stapp on Quantum Mechanics, Spirit, Mind, and Morality

QUANTUM INTERACTIVE DUALISM: AN ALTERNATIVE TO MATERIALISM

by Henry P. Stapp

Abstract. René Descartes proposed an interactive dualism that posits an interaction between the mind of a human being and some of the matter in his or her brain. However, the classical physical theories that reigned during the eighteenth and nineteenth centuries are based exclusively on the material/physical part of Descartes' ontology, and they purport to give, in principle, a completely deterministic account of the physically described properties of nature, expressed exclusively in terms of these physically described properties themselves. Orthodox contemporary physical theory violates this condition in two separate ways. First, it injects random elements into the dynamics. Second, it requires psychophysical events, called Process 1 interventions by John von Neumann. Neither the content nor the timing of these events is determined, even statistically, by any known law. Orthodox quantum mechanics considers these events to be instigated by choices made by conscious agents. This quantum conception of the mind-brain connection allows many psychological and neuropsychological findings associated with the apparent physical effectiveness of our conscious volitional efforts to be explained in a causal and practically useful way. According to this quantum approach, conscious human beings are invested with degrees of freedom denied to the mechanistic automatons to which classical physics reduced us.

Keywords: consciousness; dualism; free choice; mind-brain; quantum mechanics.

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The Role of the Observer in Contemporary Physical Theory

The conception of nature initiated in the seventeenth century by Isaac Newton developed by the end of the nineteenth century into what is now called classical physics. According to the precepts of classical physics, the world is made of classically conceived particles and classically conceived fields. Classically conceived particles are like miniature planets, careening through space under the influence of fields of force generated by these particles. The structure of the theory entails that once an initial state of all of the particles and fields in the universe is given, the physical state of the universe at all later times is fixed by laws that act exclusively at the microscopic level; the changes occurring at each location in space are determined wholly in terms of *nearby* properties of these particles and fields. The causal closure of the physical is thereby ensured.

Difficulties with these classical ideas began to appear around 1900. Technology had advanced by then to the stage where it was possible to measure *macroscopic* (visible) properties of large physical systems whose behaviors depended sensitively upon the behaviors of their microscopic atomic constituents. The observed results could not be reconciled with the classical conception of those atomic parts. Late in the year 1900 Max Planck discovered a new constant of nature that did not fit the old picture, and it soon became clear that the mounting perplexities were connected to this constant.

Many of the best mathematical minds of the generation wrestled with this problem, but it was not until 1925 that Werner Heisenberg discovered the amazing and unprecedented solution: the numbers that in classical physics describe the physical properties of a system must be treated as mathematical actions (operators) instead of numbers. An essential difference between numbers and actions is that the order in which two *numbers* are multiplied does not matter—2 times 3 is the same as 3 times 2—but the order in which two *actions* are performed can matter. According to the rules discovered by Heisenberg, the difference generated by changing the order in which these actions are applied involves Planck's constant. In particular, if one takes the equations of quantum mechanics and replaces Planck's constant everywhere by zero, one recovers the corresponding classical theory. Classical physics thereby becomes an "approximation" to quantum physics, namely the approximation obtained by replacing the true value discovered by Planck by zero.

Because Planck's constant is an extremely tiny number on the scale of human activities, the classical approximation is normally a very good approximation in the realm of phenomena that do not depend upon the details of what is happening at the atomic level. However, brains are controlled by ionic processes occurring in nerves, so it is not clear, a priori, that the classical approximation will always suffice. Indeed, a detailed examination based on an analysis of the critical brain process of exocytosis—the dumping of neurotransmitter molecules into the synaptic cleft that separates communicating neurons—shows that, at the level of basic principles, quantum mechanics must be used in the treatment of the dynamical processes occurring in human brains (Schwartz, Stapp, and Beauregard 2005). The classical approximation can, *for special reasons*, be adequate for many purposes, but the applicability of the classical approximation to brain dynamics is neither automatic nor universally guaranteed. According to contemporary basic physics, quantum mechanics must be used as a matter of basic principle, with the classical approximation usable in those special cases where it can be justified.

The most radical departure from classical physics instituted by the founders of quantum mechanics was the introduction of human consciousness into the dynamical and computational machinery. This change constitutes a revolutionary break with the classical approach, because the success of that earlier approach was deemed due in large measure precisely to the fact that it kept consciousness out. However, the need for a rationally coherent and practically useful theory forced the creators of quantum mechanics to bring into the theory not merely a passive observer, superposed ad hoc onto classical mechanics, together with the knowledge that flows passively into his or her consciousness, but, surprisingly, an active consciousness that works in the opposite direction and injects conscious intentions efficaciously into the physically described world.

It is, of course, obvious that we human beings do *in practice* inject our conscious intentions into nature whenever we act in an intentional way. But in classical physics it was assumed that any such human action was merely a complex consequence of the purely physical machinery. However, the quantum generalization of the classical mechanical laws proposed by Heisenberg and his colleagues do not generate by themselves a dynamically complete deterministic physical theory. They have a causal gap. Something else is needed to complete the dynamics.

The added element introduced by the founders of quantum mechanics was called Process 1 by John von Neumann [1932] 1955. This process brings consciousness intentions actively into the dynamics. Such an intention, once actively chosen, has physical effects that are fixed by the known quantum laws. But which one of the set of physically possible intentions will be chosen, and when that intention will be implemented, are not determined by the known laws of quantum mechanics. These are free choices in the specific sense that they are not determined by any currently known laws and in practical applications are treated as free input variables of the theory.

This intrusion of observers into quantum dynamics is not an ad hoc emendation. It is logically tied to the essential core of quantum mechanics, namely Heisenberg's replacement of numbers by actions.

A physical theory must correlate certain mathematical aspects of the theory to empirical data. It must connect certain mathematical features of the theory to corresponding perceptual realities in the streams of consciousness of human beings. It is perhaps not unexpected that a theory whose basic elements are mathematical actions should relate certain mathematical actions to experiences associated with physical actions. In quantum theory—in its original and still-used-for-all-practical-applications form—this is just what happens. The pertinent physical actions are physical probing actions, where a *physical probing action* is an action that yields *one* experienced outcome or feedback from a set of prespecified (by Process 1) experientially distinct possible outcomes.

The paradigmatic example of Heisenberg's replacement of numbers by actions is this: The number x that represents how far a classically conceived object has moved along a straight line from some base point $x=0$ is replaced by a corresponding mathematical action (or operator) x. This *mathematical action* x is the mathematics counterpart of the physical probing action whose outcome would be the number x that represents the location of the object, insofar as that location is well defined. Similarly, the *mathematical action* p is the mathematics analog of the physical probing action that would yield as outcome the number p that specifies the momentum of the object, insofar as this momentum is well defined. [The momentum is $p= mv$, where m is the mass of the object, and v is its velocity.]

Not every mathematical action has a physical analog, but every possible physical probing action is supposed to have a mathematical analog.

Heisenberg's rule asserts that the mathematical actions x and p satisfy $xp–px=i\hbar$, where $\hbar$ is Planck's constant divided by 2 pi, and i is a number that when multiplied by itself gives –1.

Now, it might seem that the fact that xp differs from px by some tiny number should have no great effect on the basic conceptual structure of the theory. But that is not the case; this small change upsets the whole apple cart. The reason is this: The numbers that occur in classical physics represent the internal properties of some physical system—eventually the entire physical universe—whereas the action that replaces such a number represents a probing action performed upon that physical system by an observing system external to it. That is, a number that in classical physics represents an internal property of a physical system, with no implicit or explicit reference to anything external to that physical system, is replaced in quantum mechanics by an element that represents an action performed upon that system by a system that is observing or probing it.

This means that the seemingly minor or merely mathematical change of replacing numbers by actions induces an enormous conceptual change. It shifts the subject matter of the theory from self-contained physical systems to the interplay between physical systems and observing systems that actively probe them. A monistic materialist ontology is shifted to a dualistic one involving observing and observed systems, and these systems are now causally connected by the mathematically specified Process 1, which injects the effects of a conscious intent into the quantum mechanically described properties of the observed system. This conceptual change is profound.

Psychophysical Action in Copenhagen Quantum Theory

The formulation of quantum theory proposed by its founders is called the Copenhagen interpretation. It is epistemological and pragmatic. It is designed to allow physicists to apply the mathematical rules of quantum theory to the practical problem of making predictions about observable outcomes of experiments that they can in principle perform. The theory is built around the idea that conscious agents design and perform experiments of their own choosing, observe outcomes, and communicate to colleagues what they have done and what they have learned. The language to be used in these communications is described by Niels Bohr:

> . . . it is imperative to realize 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. (Bohr 1958, 88)

> The decisive point is to recognize that the description of the experimental arrangement and the recording of observations must be given in plain language suitably refined by the usual physical terminology. This is a simple logical demand since by the word "experiment" we can only mean a procedure regarding which we are able to communicate to others what we have done and what we have learnt. (Bohr 1963, 3)

This description is *psychological*, in the sense that it is a description of the intentions and perceptions appearing in someone's stream of consciousness.

The experimenters are, within the framework provided by quantum theory, free to choose which experiments they will perform. Bohr writes:

> The freedom of experimentation, presupposed in classical physics, is of course retained and corresponds to the free choice of experimental arrangement for which the mathematical structure of the quantum mechanical formalism offers the appropriate latitude. (1958, 73)

> To my mind there is no other alternative than to admit in this field of experience, we are dealing with individual phenomena and that our possibilities of handling the measuring instruments allow us only to make a choice between the different complementary types of phenomena that we want to study. (1958, 51)

This free choice made by experimenters, and its representation in the mathematics, is called Process 1 by von Neumann. It is "free" in the sense that these choices are not determined by anything in contemporary physical theory; they are fixed neither by any law nor by any of the random variables that enter into the theory. In actual practice these choices are made by a human agent on the basis of his predilections or his felt or imagined needs.

Process 1 is represented in the mathematical structure as a division of the mathematically described quantum state of the system being probed into a countable set of components, each of which is assigned a probability in such a way that these probabilities add up to one (unity). Each of these components is supposed to correspond to a definite experienced outcome of a probing action, distinguishable from all the other possible outcomes. After the intervention of this Process 1 decomposition of the state of the probed system into a set of discrete components, nature chooses one of the possible outcomes of this probing action. This "choice on the part of nature" is asserted to conform to a statistical rule. This choice of outcome obliterates from the prior collection of possibilities all components but the chosen one, which is itself a new smeared-out cloud of possibilities, or potentialities.

This "reduction of the wave packet" or "collapse of the wave function" is asserted to be accompanied by the occurrence in the agent's stream of consciousness of the experience associated with the chosen component. The agent thereby acquires *knowledge*: the agent learns something about the observed system from the experienced feedback from his or her probing action.

The Process 1 choice of which probing action to take can be represented in the stream of consciousness of the agent as an intentional choice to act in such a way as to either receive or not receive a specified feedback "Yes." Multiple-choice questions can be reduced to a sequence of such "Yes or No" questions.

The Mind-Brain Connection in von Neumann's Orthodox Formulation

The Copenhagen formulation of quantum theory separates the psychophysical world into two parts. One is described in terms of the quantum mathematics, the other in terms of our everyday experiences refined by the concepts of classical physics.

The founders elected to include in the second part not only the minds and bodies of the probing agents but also their physical measuring devices. That proposal has two awkward features. The first is that the unified physical world is artificially broken into two parts that are described differently. The second is that if one has a set of measuring devices, each one measuring the output of its predecessor, it becomes ambiguous just where to draw the line that divides the two differently described parts of nature.

Von Neumann showed that one can place the entire physical world, including the bodies and brains of the agents, in the physically described world. Then the entire physical world is described in the mathematical language of quantum mechanics. In this von Neumann formulation the physically described action associated with the consciously intended probing action by the agent is a mathematically described action on the brain of that agent. The psychophysical causal connections thereby become *mind-brain* causal connections. This makes the theory similar to a Cartesian Interactive dualism—with, however, causal connections between the two realms now specified, in part, by the basic laws of physics.

This feature overcomes the main objection to Cartesian dualism, which was the lack of any understanding of how a person's mind could have any effect upon that person's brain.

This von Neumann form of quantum mechanics, in which the entire physical world is described quantum mechanically, was dubbed the "orthodox interpretation" by von Neumann's colleague Eugene Wigner. Quantum theory is built in practice around the Process 1 effect of a person's psychologically described intentional actions upon physically described properties, and in the von Neumann formulation these physically described properties are properties of that person's brain.

The Process 1 actions can be likened to the posing of the "Yes or No" questions in the game of twenty questions: The agent freely chooses the questions in accordance with his or her own reasons or feelings, subject to no known laws, and nature returns answers, subject to specified statistical requirements.

The Copenhagen interpretation of quantum theory, created by the founders, was designed to be practical—designed to allow physicists to use the theory to make predictions about their future experiences on the basis of what they have learned from their prior probings. Thus human beings played a special role; pigs don't do physics.

Von Neumann's theory is a development of the pragmatic Copenhagen form. But if one considers the von Neumann theory to be an ontological description of what is really going on, one must of course relax the anthropocentric bias and allow agents of many ilks. Yet the theory entails that it would be virtually impossible to determine, empirically, whether a large system that is strongly interacting with its environment is acting as an agent or not. This means that the theory, regarded as an ontological theory, has huge uncertainties.

However, our interest here is the nature of human agents. Hence, the near impossibility of determining the possible existence of other kinds of agents will mean that our lack of information about the existence of such agents will have little or no impact on our understanding of ourselves.

The Physical Effectiveness of Conscious Will

An important question now arises: How does the psychoneurological connection via Process 1—which can merely pose questions, not answer them—allow a person's conscious choices to exercise effective control over his or her physical actions?

A Process 1 action appears in the mathematics as a posing of a question. But it can appear in the consciousness of the agent also as an intention to achieve some intended feedback. The relevant question is one with just two possible answers, Yes and No, where Yes is the desired feedback and No is the failure of the Yes feedback to occur. But whether Yes or No appears is not determined by the agent, who chooses only the question. The answer is picked by "Nature," in accordance with a specified statistical law. So the effectiveness of conscious intent would appear to be diluted by the entry of quantum randomness in the choice (on the part of nature) of the outcome of the posed question. Indeed, the quantum laws generate, in general, a strong tendency for the statistical fluctuations in the feedbacks to wipe out, after appropriate averaging, any net effect of the choice of questions upon physical properties; the quantum effect of the intent tends to be washed out by the quantum elements of randomness.

However, a well-known and much-studied feature of quantum theory provides a natural way out.

The Quantum Zeno Effect. An important feature of the dynamical rules of quantum theory is as follows. Suppose a Process 1 action that leads to a Yes outcome is followed by a rapid sequence of very similar Process 1 actions. That is, suppose a sequence of very similar intentional acts is performed, and the actions in this sequence occur in very rapid succession on the time scale of the evolution of the original Yes state. The dynamical rules of quantum theory entail that the sequence of outcomes will, with high probability, all be Yes: The original Yes state will, with high probability, be held approximately in place by the rapid succession of intentional acts, even in the face of very strong physical forces that would, in the absence of this rapid sequence of intentional acts, quickly cause the state to evolve into a very different state.

The timings of the Process 1 actions are, within the orthodox formulations, controlled by "free choices" on the part of the agent. So it is consistent and plausible to add to the von Neumann rules the provision that the rapidity of the succession of essentially identical Process 1 actions can be increased by mental effort. Then we obtain, as a strict mathematical consequence of the basic dynamical laws of quantum mechanics described by von Neumann, a potentially powerful effect of mental effort on the physical world!

This holding-in-place effect is called the quantum Zeno effect. That appellation was picked by physicists R. Misra and E. C. G. Sudarshan (1977) to emphasize a similarity of this effect to a paradox discussed by the fifth-century B.C. Greek philosopher Zeno the Eleatic.

The *quantum* "holding" effect is a rigorous consequence of the basic orthodox laws of quantum mechanics supplemented by the assumption that mental effort can instigate a rapid repetition of a Process 1 action. In the present context the intentional act is associated with a macroscopic pattern of brain/body activity identified as a "template for action." This particular pattern of neural/brain activity is actualized by the Yes response to the Process 1 intentional probing action. The succession of similar probing actions must occur rapidly on the scale of the natural time scale of the template for action in order for the quantum Zeno effect to come into play and hold this template of action in place.

The quantum Zeno effect can, in principle, hold an intention and the associated template for action in place in the face of strong mechanical forces that would tend to change the latter. This means that agents whose mental efforts can increase the rapidity of Process 1 actions would enjoy a survival advantage over competitors who lack this feature. Agents who possess this capacity could sustain beneficial templates for action in place longer than competitors who lack it could. Thus the dynamical rules of quantum mechanics can endow conscious effort with the causal efficacy needed to permit its evolution and deployment via natural selection. Given this potentially strong causal effect of mental effort on brain activity, both the survival dynamics in the evolution of species and the trial-and-error learning in the life of the individual would tend to establish a positive correlation between the conscious intention associated with a Process 1 action and the functional effect of this action on the brains of the agents.

Process 1 actions operate within a domain of "Heisenberg uncertainties" generated by Heisenberg's replacement of numbers by actions. This domain shrinks to zero in the classical approximation, nullifying all causal effects of consciousness. Thus, from the perspective of orthodox contemporary physical theory, any attempt to understand within a classical idealization of nature the apparent causal effects of our intentional volitional actions upon the physically described world would be an irrational endeavor, because it would be based, essentially, on an approximation that eliminates the effect that one is trying to explain.

Mind and Brain. A person's experiential life is a stream of conscious experiences. The person's experienced "self" is part of this stream of consciousness, not an extra thing that stands outside or apart from the stream. In William James's words, "the thoughts themselves are the thinkers" ([1892] 1992, 209). The "experienced self" is a slowly changing "fringe" part of the stream of consciousness. It provides a background for the central focus of attention.

Von Neumann distinguishes the Process 1 interventions from the "mechanical" Process 2 that governs the evolution of physical systems in the absence of Process 1 interventions. Process 2 is what arises directly out of the procedure of "quantizing" the classical theory. It specifies the evolution of physical systems in the absence of any interventions by observing systems.

The physical brain, evolving mechanically in accordance with the local deterministic Process 2, necessarily generates, in a continuously evolving way, not a single well-defined template for action but rather an amorphous mass of overlapping and conflicting templates for action. A Process 1 action extracts from this jumbled mass of possibilities a particular pair of alternative possibilities, one labeled Yes, the other labeled No. If a Yes response occurs and includes a positive evaluative element that instigates a quick reposing of the query, the quantum Zeno effect can convert this positive evaluation into positive action. Such a use by nature of the quantum Zeno effect would promote the survival of any species that can exploit it. Thus the physical efficacy of conscious effort entailed by this quantum model would provide a naturalistic explanation of how and why our brains developed in a way that can exploit the quantum Zeno effect.

William James's Theory of Volition. Does this quantum conception of the dynamical connection between mind and brain explain anything?

This theory was already in place when my colleague Jeffrey Schwartz brought to my attention some passages from James's "Psychology: The Briefer Course." In the final section of the chapter on Attention James writes:

> I have spoken as if our attention were wholly determined by neural conditions. I believe that the array of things we can attend to is so determined. No object can catch our attention except by the neural machinery. But the amount of the attention which an object receives after it has caught our attention is another question. It often takes effort to keep mind upon it. We feel that we can make more or less of the effort as we choose. If this feeling be not deceptive, if our effort be a spiritual force, and an indeterminate one, then of course it contributes coequally with the cerebral conditions to the result. Though it introduce no new idea, it will deepen and prolong the stay in consciousness of innumerable ideas which else would fade more quickly away. The delay thus gained might not be more than a second in duration—but that second may be critical; for in the rising and falling considerations in the mind, where two associated systems of them are nearly in equilibrium it is often a matter of but a second more or less of attention at the outset, whether one system shall gain force to occupy the field and develop itself and exclude the other, or be excluded itself by the other. When developed it may make us act, and that act may seal our doom. When we come to the chapter on the Will we shall see that the whole drama of the voluntary life hinges on the attention, slightly more or slightly less, which rival motor ideas may receive. (James [1892] 1992, 227)

In the chapter on Will, in the section titled "Volitional effort is effort of attention," James writes:

> Thus we find that we reach the heart of our inquiry into volition when we ask by what process is it that the thought of any given action comes to prevail stably in the mind. ([1892] 1992, 417)

and later

> The essential achievement of the will, in short, when it is most "voluntary," is to attend to a difficult object and hold it fast before the mind. . . . Effort of attention is thus the essential phenomenon of will. ([1892] 1992, 417)

Still later, he writes:

> Consent to the idea's undivided presence, this is effort's sole achievement. . . . Everywhere, then, the function of effort is the same: to keep affirming and adopting the thought which, if left to itself, would slip away. ([1892] 1992, 417)

James apparently recognized the incompatibility of these pronouncements with the physics of his day. At the end of "Psychology: The Briefer Course," he said, presciently, of the scientists who would one day illuminate the mind-body problem:

> . . . the best way in which we can facilitate their advent is to understand how great is the darkness in which we grope, and never forget that the natural-science assumptions with which we started are provisional and revisable things. ([1892] 1992, 433)

It is a testimony to the power of the grip of old ideas on the minds of scientists and philosophers alike that what was apparently evident to James already in 1892—that a revision of the precepts of nineteenth-century physics would be needed to accommodate the structural features of consciousness—still fails to be recognized by many of the affected professionals even today, more than three-quarters of a century after the downfall of classical physics, foreseen by James, has come, much-heralded, to pass.

James's description of the effect of volition on the course of mind-brain process is remarkably in line with what had been proposed, independently, from purely theoretical considerations of the quantum physics of this process (Stapp 1999). The connections described by James are explained on the basis of the same dynamical principles that had been introduced by physicists to explain atomic phenomena. Thus the whole range of science, from atomic physics to mind-brain dynamics, is brought together in a single rationally coherent theory of a world that is constituted not of classically conceived matter, bound by the principle of the causal closure of the physical, but rather of mind and matter connected in the way specified by orthodox contemporary physical theory.

No comparable success has been achieved within the framework of classical physics, in spite of intense efforts spanning more than three centuries. The reasons for this failure are easy to see: Classical physics systematically exorcizes all traces of mind from its precepts and thereby banishes any logical foothold for recovering causally effective mind. Moreover, according to quantum physics all causal effects of consciousness act within the latitude provided by the uncertainty principle, and this latitude shrinks to zero in the classical approximation, thereby eradicating the causal effects of conscious intent.

SUPPORT FROM PSYCHOLOGY DATA

Much experimental work on attention and effort has occurred since James's time. That work has been hampered by the apparent nonexistence of any physical theory that rationally explains how our conscious experiences could actually influence activities in our brains. The apparent absence of any viable theory of how mind could influence brain undoubtedly lent support to the behaviorist approach, which dominated psychology during the first half of the twentieth century and which essentially abolished in this field the use not only of introspective data but also of the very concept of consciousness.

The admitted failure of the behaviorist program led to the rehabilitation of "attention" during the early 1950s, and many hundreds of experiments have been performed during the past fifty years for the purpose of investigating empirically those aspects of human behavior that we ordinarily link to our consciousness.

Harold Pashler's 1998 book *The Psychology of Attention* describes a great deal of this empirical work and also the intertwined theoretical efforts to understand the nature of an information-processing system that could account for the intricate details of the empirical data. Two key concepts are the notions of "attention" and of a processing "capacity." The former is associated with an internally directed selection between different possible allocations of the available processing capacity. A third concept is "effort," which is empirically linked to incentives and to reports by subjects of "trying harder."

Pashler organizes his discussion by separating perceptual processing from postperceptual processing. The former covers processing that, first of all, identifies such basic physical properties of stimuli as location, color, loudness, and pitch, and, second, identifies stimuli in terms of categories of meaning. The postperceptual process covers the tasks of producing motor actions and cognitive action beyond mere categorical identification. Pashler emphasizes that "the empirical findings of attention studies specifically argue for a distinction between perceptual limitations and more central limitations involved in thought and the planning of action" (1998, 33). The existence of these two different processes, with different characteristics, is a principal theme of Pashler's book (pp. 33, 263, 293, 317, 404).

In the quantum theory of the mind-brain there are two separate processes. First, there is the unconscious mechanical brain process called Process 2. A huge industry has developed that tries to map out these essentially classically describable processes. But, according to orthodox contemporary physics, another process, von Neumann's Process 1, is also entering into the causal story. Its effects become most manifest in connection with an impulsive feeling described as "effort." The effect of this "effort of attention" is to inject into brain activity, and thence into overt behavior, some effects of intentional input and control that, according to orthodox quantum precepts, cannot be explained in terms of physical causation alone, because the process acts to bring definiteness out of a realm of physical unknowability and indefiniteness created by the uncertainty principle.

Two kinds of Process 1 actions are possible. One kind is determined by brain activity alone. This would be the kind of the action associated with James's assertion that "No object can catch our attention except by the neural machinery" (p. 227). A second possible kind of Process 1 action would presumably involve an evaluation—based on the felt or experiential quality of an event—that would tend to make the Process 1 event immediately repeat itself, or quickly come into being again, with a rapidity that is increasable, up to a certain limit, by a quality of the event called "effort." Such a Process 1 action could, within the quantum framework, induce a rapid sequence of similar actions that would activate a quantum Zeno effect, which would tend to produce the intended action.

The "perceptual" aspect of brain process discussed by Pashler can be associated with Process 2 and with the essentially passive Process 1, whereas the higher-level processing that Pashler identifies can be associated with the active mode of Process 1.

Examination of Pashler's book shows that this quantum physics–based theory accommodates naturally all of the complex structural features of the empirical data that he describes. He emphasizes a specific finding: strong empirical evidence for what he calls a central processing bottleneck associated with the attentive selection of a motor action (1998, 33). This kind of bottleneck is what the quantum physics–based theory predicts: that the bottleneck is precisely the single linear sequence of Process 1 actions that the quantum theory of the mind-brain connection is built upon.

The sort of effect that Pashler finds is illustrated by a result he describes that dates from the nineteenth century: Mental exertion reduces the amount of physical force that a person can apply. "This puzzling phenomenon remains unexplained," he notes (p. 387). However, it is an automatic consequence of the physics-based theory described here: Creating physical force by muscle contraction requires an effort that opposes the physical tendencies generated by Process 2. This opposing tendency is produced by the quantum Zeno effect and is roughly proportional to the number of bits per second of central processing capacity that is devoted to the task. If part of this processing capacity is directed to another task, the applied force will diminish.

An interesting experiment mentioned by Pashler involves the simultaneous tasks of doing an IQ test and giving a foot response to rapidly presented sequences of tones of either 2000 or 250 Hz. The subject's mental age, as measured by the IQ test, was reduced from adult to eight years. Effort can be divided, but the aggregate total level of effortful Process 1 actions reaches a definite limit at maximal level of effort.

Another interesting experiment showed that, when performing at maximum speed with fixed accuracy, subjects produced responses at the same rate whether performing one task or two simultaneously; the limited capacity to produce responses can be divided between two simultaneously performed tasks (p. 301).

Pashler also notes that "Recent results strengthen the case for central interference even further, concluding that memory retrieval is subject to the same discrete processing bottleneck that prevents simultaneous response selection in two speeded choice tasks" (p. 348).

In the section on "Mental Effort" Pashler reports that "incentives to perform especially well lead subjects to improve both speed and accuracy" and that the motivation had "greater effects on the more cognitively complex activity" (p. 383). This is what would be expected if incentives lead to effort that produces increased rapidity of the events, each of which injects mental intention into the physical process.

Studies of sleep-deprived subjects suggest that in these cases "effort works to counteract low arousal" (p. 384). If arousal is essentially the rate of occurrence of conscious events, this result is what the quantum model would predict.

"Performing two tasks at the same time, for example, almost invariably . . . produces poorer performance in a task and increases ratings in effortfulness," notes Pashler (p. 385). And "Increasing the rate at which events occur in experimenter-paced tasks often increases effort ratings without affecting performance" (p. 385). "Increasing incentives often raises workload ratings and performance at the same time" (p. 385). All of these empirical connections are in line with the general principle that effort increases the rate of conscious events, each of which inputs a mental intention, and that this resource can be divided between tasks.

A more extended discussion of the Pashler data from the quantum point of view can be found in Stapp 2001 and in Schwartz, Stapp, and Beauregard 2005.

After analyzing various possible mechanisms that could cause the central bottleneck, Pashler notes that "the question of why this should be the case is quite puzzling" (pp. 307–8).

Materialist accounts of these data may be achievable. But the quantum account conforms to specific laws of physics that tie mental events to their causal consequences in the brain in a way that appears to conform to relevant empirical data. A classical account has no such basic theoretical connections upon which to build a theory. Hence, the mind parts are introduced on the basis of empirical findings alone. This makes the classical approach logically flabby compared to its quantum counterpart.

APPLICATION TO NEUROPSYCHOLOGY

The quantum mechanical theory works better in neuropsychology than classical approaches that enforce the causal closure of the physical. To illustrate this point, let us apply the quantum approach to an experiment of Kevin Ochsner and colleagues (2002).

Reduced to its essence, this experiment consists first of a training phase in which the subject is taught how to distinguish, and respond differently to, two alternative possible instructions given while viewing emotionally disturbing visual images. One instruction, "Attend," means "Passively be aware of, but not try to alter, any feelings elicited by the stimulus," whereas "Reappraise" means "Actively reinterpret the content so that it no longer elicits a negative response." The subjects then perform these mental actions during brain imaging. The visual stimuli when passively attended to activate limbic (emotional) brain areas and when actively reappraised activate prefrontal cerebral regions.

From the classical materialist point of view this experiment is essentially a conditioning protocol, where, however, the "conditioning" is achieved via linguistic communications pertaining to cognitive concepts. But how do the *cognitive realities* of "knowing," "understanding," and "feeling" arise out of motions of the miniature planetlike objects of classical physics, which have no trace of any experiential quality? How do the vibrations that carry the instructions get converted into feelings of understanding? And how do these feelings of understanding get converted to conscious effort, the presence or absence of which determines whether the limbic or frontal regions of the brain will be activated?

The materialist claim is that *someday* these connections will be understood. Karl Popper called this prophecy "promissory materialism." But can these connections reasonably be expected to be understood in terms of a physical theory that is known to be false, and, moreover, to be false because of an approximation that eliminates the object of study, namely, the efficacious causal connection between psychologically and physically described aspects of the mind-brain system?

There are important similarities and also important differences between the classical and quantum explanations of the Ochsner experiments. In both approaches the atomic constituents of the brain can be conceived to be collected into nerves and other biological structures, and into fluxes of ions and electrons, which can all be described reasonably well in essentially classical terms. In the classical approach, however, the physical changes must in principle be deterministically described in terms of physical variables alone, with no acknowledgment of the existence of the conscious efforts upon which they seem to depend, whereas in the quantum approach the psychologically and physically described aspects are already dynamically connected by the basic laws of orthodox contemporary physics in a way that seems to account nicely for the empirical facts.

The quantum laws are organized around psychophysical events that monitor and guide the physical process in the brain. When no mental effort is applied, the temporal development of the body/brain will be roughly in accord with the principles of classical statistical mechanics. But, according to the quantum laws, important departures from the classical statistical predictions can be produced by a conscious effort that increases the rapidity of the monitoring events. Such an increase can cause to be held in place for an extended period a pattern of neural activity that constitutes a template for action. The holding-in-place of this template will tend to cause the action specified by that template to occur.

In the quantum treatment of the Ochsner experiments the effort of the subject to reappraise *causes* the "reappraise" template to be held in place, and the holding in place of this template *causes* the suppression of the limbic response. These causal effects are, via the quantum Zeno effect, direct mathematical consequences of the quantum rules. Thus the "subjective" and "objective" aspects of the data are rationally tied together by quantum rules that directly specify the causal effects of the subject's choices upon the subject's brain, without any need to specify the physical antecedents of these choices.

The form of the quantum laws naturally accommodates a dynamical breakpoint between the *cause* of a willful action, which is not specified by the theory in its present form, and the *effects* of such an action, which *are* specified by the theory. Consequently, our conscious choices can consistently be treated as *empirically specified consciously controlled input variables*, in accordance with the experimental protocols, just as they are in the realm of atomic physics, with the effects of these free choices specified by the laws of physics. That is, the physical effects of our consciously chosen inputs can be described in terms of physics-based rules for these effects themselves, without needing to say what caused these choices to be what they are; in the quantum treatment the causal connection via the laws of physics is *not from the cause of the conscious choice to the effects of that choice* but rather directly from the conscious choice itself to its physical effects.

This quantum causal explanation falls apart if one descends to the classical approximation, which entirely eliminates the direct effects of our conscious choices upon the physically described properties of nature. But what is the rational motivation for insisting on the use of this approximation?

The applicability of the classical approximation to mind-brain phenomenon certainly does not follow from physics considerations. Calculations based on the known properties of nerve terminals indicate that quantum theory must in principle be used. Nor does it follow from the fact that classical physics works reasonably well in neuroanatomy or neurophysiology: Quantum theory explains why the classical approximation works well in those domains. Nor does it follow rationally from the massive analyses and conflicting arguments put forth by philosophers of mind. In view of the turmoil that has engulfed philosophy during the three centuries since Newton cut the bond between mind and matter, the rebonding achieved by physicists during the first half of the twentieth century must be seen as a momentous development: a lifting of the veil. Ignoring this huge and enormously pertinent development in basic science and proclaiming the validity of materialism on the basis of inapplicable-in-this-context nineteenth-century science is an irrational act.

The only objections I know to applying the basic orthodox principles of physics to brain dynamics are, first, the forcefully expressed opinions of some nonphysicists that the classical approximation provides an entirely adequate foundation for understanding brain dynamics, in spite of the physics calculations that indicate the opposite, and, second, the opinions of some physicists that the hugely successful orthodox quantum theory, which is intrinsically dualistic, should, for philosophical reasons, be replaced by some theory that reconverts human consciousness into a causally inert witness to the mindless dance of atoms. Neither of these opinions has any rational scientific basis.

NOTE

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