4. The von Neumann/Stapp Approach

Von Neumann quantum theory is a formulation in which the entire physical universe, including the bodies and brains of the conscious human participant/observers, is represented in the basic quantum state, which is called the state of the universe. The state of a subsystem, such as a brain, is formed by averaging (tracing) this basic state over all variables *other* than those that describe the state of that subsystem. The dynamics involves *three* processes.

Process **1** is the choice on the part of the experimenter about how he will act. This choice is sometimes called "The Heisenberg Choice," because Heisenberg emphasized strongly its crucial role in quantum dynamics. At the pragmatic level it is a "free choice," because it is controlled, at least in practice, by the conscious intentions of the experimenter/participant, and neither the Copenhagen nor von Neumann formulations provide any description of the *causal origins* of this choice, apart from the mental intentions of the human agent. Each intentional action involves an effort that is intended to result in a conceived experiential feedback, which can be an immediate confirmation of the success of the action, or a delayed monitoring the experiential consequences of the action.

Process **2** is the quantum analog of the equations of motion of classical physics. As in classical physics, these equations of motion are local (i.e., all interactions are between immediate neighbors) and deterministic. They are obtained from the classical equations by a certain *quantization* procedure, and are reduced to the classical equations by taking the *classical approximation* of setting to zero the value of Planck's constant everywhere it appears. Evolution via the quantum Process **2** normally has the effect of expanding the microscopic uncertainties demanded by the Heisenberg uncertainty principle into the macroscopic domain: the *centers* of large objects tend to become diffused over large regions. The disparity between this Process-**2**-generated theoretical indefiniteness and the consciously experienced definiteness of the positions of visible objects is resolved in quantum theory by invoking Processes **1** and **3**.

Process **3** is sometimes call the "Dirac Choice." Dirac called it a "choice on the part of Nature." It can be regarded as Nature's answer

to a question effectively posed by the Process **1** choice made by the experimenter. This posed question might be: Will the Geiger counter be observed to be in the intended position? Or, Will the Geiger counter be observed to "fire" in accordance with the experiential conditions that define a 'Yes' response? The application of quantum theory demands the formulation/posing/choosing of a definite yes-or-no question – or a set of such questions – in connection with each potential experience for which a prediction is to be made.

Although Process **1** brings the conscious choices made by the observer/participant into the dynamics in an essential way, there is a tendency for this dependence upon the agent's choice to be wiped out by the subsequent averaging over the two possible answers, 'Yes' and 'No,' to any question posed by Process **1**. However, Stapp has pointed out that if willful effort can adequately control the *rate* at which a sequence of similar Process 1 events occur then willful effort can become highly causally efficacious: such a sequence of events, if sufficiently rapid, can hold certain properties of the brain in a subspace corresponding to a certain conscious intention. This consciously controllable *arresting of the state of attention* can thus hold in place, in the brain, a "template for intentional action," and the prolongation of the activation of this pattern of brain activity can tend to produce the intended physical action of the body or brain, in accordance with William James's "ideo-motor" theory of action (James, 1890: 522)

This "holding effect" of a rapid sequence of similar Process **1** events is an automatic consequence of the von Neumann equations of motion, and it has been extensively studied, both empirically and theoretically, by quantum physicists under the title "The Quantum Zeno Effect."

This quantum account of the origin of the causal efficacy of conscious will (effort) corresponds closely to the ideas of William James, as is made evident by the following quotations:

``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." (James, 1890:564)

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."

Still later, James says:

``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."

The important conclusion is that the apparent capacity of conscious effort to influence physical actions, which seems so puzzling and illusory within the framework of classical physical theory, flows naturally from the equations of quantum theory.

The question arises: What causes this *causally efficacious* feeling of effort or will?

The *classical-physics-based* response is to affirm the belief – or faith – that the cause is completely describable in *micro-local* terms: in terms of essentially mechanical contact interactions between tiny physical elements. But this faith is not based on science! Science tells us that the old micro-local classical ideas *cannot be correct*. Consequently, there is no *rational* reason to insist, *on the basis of science*, that the cause of the feeling of effort must be describable microlocally. Idea-like qualities are certainly parts of reality, and there is no evidence from science that they cannot be *irreplaceable* components of the causal chains that connect our experiences to each other. Contemporary basic physical theory explicitly introduces into the dynamical equations the physical effects of our conscious choices about how to act, and it is counterproductive, at least at the level of practical science, to eliminate these pertinent, controllable,

and knowable variables in favor of idealized theoretical concepts that are known to be false, and involve parameters that are unknowable not only in practice but also in principle.

This tripartite quantum dynamics involving Choice, Causation, and Chance [Processes **1**, **2**, & **3**, respectively] and the implementation of Will (Volition) via the conscious control of the rapidity of Process **1** events, provides the foundation of a quantum approach to neuro-psychology. But how well does this quantum approach work in actual practice?

The Pashler Data

A great deal of experimental work over the past three decades in the field of The Psychology of Attention is summarized in Harold Pashler's book of that title [Pashler, 1998].

Pashler organizes his discussion by separating perceptual processing from post-perceptual processing. The former covers processing that, first of all, identifies such basic physical properties of stimuli as location, color, loudness, and pitch, and, secondly, identifies stimuli in terms of categories of meaning. The post-perceptual process covers the tasks of producing motor actions and cognitive action beyond mere categorical identification. Pashler emphasizes [p. 33] 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.'' The existence of these two different processes, with different characteristics, is a principal theme of Pashler's book. [pp. 33, 263, 293, 317, 404.] He argues that the former processes are carried out in parallel, but that the latter processes, which seem to require effortful choosing, operate in series, and have a capacity that can be enlarged by willful effort, but is limited.

Pashler's conclusion is based on the analysis of a huge array of recent experiments. But the central finding is succinctly illustrated in a result dating from the nineteenth century: mental exertion reduces the amount of physical force that a person can apply. He notes that: ``This puzzling phenomena remains unexplained.'' [p. 387]. However, if we take the sequence of Process I events associated with an agent

to have a limited “capacity” in terms of events per second, then this effect is an automatic consequence of quantum theory: creating a physical force by muscle contraction requires a *conscious effort* that prolongs the existence of the neural template for action that opposes the Process-**2**-generated tendency of the brain to evolve toward a more relaxed state. This prolongation is produced by the Quantum Zeno Effect, and its effect is roughly proportional to the number of bits per second of central processing capacity that is devoted to the task. So if part of this processing capacity is directed to another task, then the applied force will diminish.

This example is just one simple case. But it illustrates the general principle: identification of Pashler’s limited central serial “capacity” with the rate of occurrence of Process **1** events, assumed to be increasable by willful effort, up to a limit, appears to explain the general features of all of the many diverse empirical results cited by Pashler in support of his thesis. (Stapp, 2001)

This success of von Neumann’s psychophysical theory in accounting for Pashler’s data does not mean that classical physics could not be supplemented in an ad hoc way that would enable it to match that performance. However, the von Neumann theory allows the data to be explained directly in terms of *the already existing explicitly described tripartite process that constitutes the core of contemporary basic physical theory*, whereas an explanation based on classical physics is not only predicated on the untenable idea that microlocal causation can be extended to the realm of the motions of ions within nerve terminals, but also rests on a theory that, although false, is dynamically and logically complete without entailing the existence of consciousness. In contrast, von Neumann’s equations, namely those that specify the effects of Process **1** and **3,** specify definite dynamical connections between consciousness and brain activity, and they do so in a theoretical framework that automatically entails all of the valid predictions of classical physics. So what is the rationale, in neuro-psychology, for rejecting the fundamental equations of contemporary physics, which encompass consciousness, and all of the phenomenally valid classical features, in an empirically satisfactory, logically coherent, and practically useful way, in favor of classical concepts that are known to be fundamentally false and that leave consciousness out?

The Libet Data

Probably the best way to understand the essence of the quantum approach to consciousness is to see, in detail, how it applies to the famous Libet experiments about willful action. (Libet, 2003)

The "problem" with the Libet data is that when an action is 'willed'– such as 'willing' a finger to rise– a readiness potential (RP) appears *before* the experience of 'willing' appears. Libet explains this by saying that the conscious choice to perform this action does not occur until the state of readiness is in place: the conscious choice is simply a choice either to "Veto" or "Consent To" a specified action, whose physical 'template for action' is already in place, imbedded in the structure of a particular pattern of neural activity. [This is slight elaboration upon Libet's explanation.]

In the exposition that follows I shall introduce some symbols and equations. Non-physicists should regard each of these as just a pictorial or symbolic representation of the corresponding idea that I describe in words, together with the promise that this picture, in the minds of physicists, encodes a definite mathematical procedure.

Quantum theory is based on Heisenberg's discovery that the empirical facts of physics (many of which are logically incompatible with the basic precepts of classical physics) can be described by a new theory, quantum theory, which can be constructed by replacing the "numbers" in classical physics by "actions" (operators). [The ordering of the *numbers* in a product does not matter, but the order in which *actions/operations* are performed does matter.]

In vN/S theory the dynamics of a conscious brain depends critically upon an essential correspondence between certain actions/operators in the mathematical structure and associated human experiences. Each such action is represented by a "projection operator" P, which

satisfies PP=P. [The double action PP of a projection operator P has the same effect as a single action P.] If the experience is labeled by ‘e’ then the associated projection operator is represented by P(e). In von Neumann’s formulation of quantum theory this operator P(e) acts upon the state of the brain of the observer/participant/agent and specifies the neural correlate of the experience ‘e.’ The mappings P(e) specify a mind-to-matter correspondence that plays a key role in the dynamics of the brain of a conscious agent.

Any adequate theory of the connection between the stream of consciousness and the brain processes of the conscious agent must involve connections between conscious events and associated patterns of brain/neural activity. These are the so-called “neural correlates of consciousness,” the NCC’s. But technical differences between classical theory and quantum theory render the dynamical roles of the NCC’s very different in these two theories. In classical theory the conscious events are either (perhaps “emergent”) causally inert by-products of brain activity that have no influence on physical processes. or they are certain properties of a person’s brain activity that can be described in terms of the concepts of classical physics, and that also appear in streams of consciousness as psychologically describable experiences. In both cases, the person’s conscious experiences play no essential causal role in the determination of his actions, in the sense that the causal chain can be described in purely physical terms. On the other hand, a person’s conscious choices enter *irreplaceably* into the quantum dynamics as free input variables, replacing the in-principle-unknowable classically conceived parameters.

Here, in more detail, is how the theory works!

The (quantum) state S of a system is an action/operator, called “the statistical operator” [or “the density matrix.”] It specifies the statistical weight [probability] of every projection operator P associated with that system. The formula for the statistical weight of P – the probability of getting the answer ‘Yes’ to the question associated with P – in the state S is:

<P> = Trace PSP/Trace S.

[If A is an action/operator then Trace A is a *number* that is generated by performing a certain kind of quantum averaging process on A. Normally an operator "acts on" the operator that stands to its right. But the rightmost operator in a chain can also act back around on the left-most operator of that chain, like a snake biting its own tail. This produces the "Trace" of that chain of operators, which might be a single operator. The connection of the mathematical formulas to measurable numbers is always given by this Trace operation.]

Quantum dynamics is built upon these operators P(e) and S, and on *two kinds of choices*. The first kind of choice is made by the experimenter/observer/participant. It is called "Process **1**" by von Neumann.

The other kind of choice was called by Dirac "a choice on the part of nature." I have called it "The Dirac Choice." I also call it "Process **3**" to distinguish it from von Neumann's Process **1** and Process **2**. [Process **2** is the quantum analog of Newton's classical equation's of motion, and is obtained by replacing classical numbers by corresponding quantum operators.]

In classical physics there is just one dynamical process, namely the classical approximation to the quantum Process **2**. But orthodox quantum theory has two additional processes, one involving a choice made by a conscious participant/agent/observer about how he will act, and one made by Nature about how she will respond to the agent's choice.

Contemporary orthodox quantum theory does not specify what the agents's choice will be. In atomic physics the agent's choice is treated as a free variable that is fixed by the aims of the experimenter/participant. These aims are considered to lie outside the realm of atomic physics. They are to be covered by neuro-psychology, and are presumably determined by some combination of the neurological-physical and psychological-experiential processes that enter into quantum neurodynamics.

Figuring out exactly what this combination is, from a detailed analysis of the psycho-neurological data, is the task of neuroscience,

psychology, and physics, working together. Only the general overall quantum dynamical framework was provided by von Neumann.

To get a preliminary general orientation, I have proposed a simple model for the agent's choice.

The state S(t) of the participant's body-brain is defined by taking the "partial trace (over all ***other*** degrees of freedom in the universe)" of the state of the universe at time t (say, in the rest frame of the cosmic background radiation, just to be specific.)

Then the projection operator P(t) is defined to be that operator in the set {P(e)} that maximizes

Trace P(e)S(t)P(e)/Trace S(t).

This special P(t) is the P(e) that has at time t the greatest statistical weight.

As a first guess, I propose that a Process **1** event associated with P(T) occurs automatically at any time T=t such that <P(t)> = Trace P(t)S(t)P(t)/Trace S(t) reaches a local (in time) maximum. This Process **1** puts to Nature the question: Does the quantum jump of S(T) to the state P(T)S(T)P(T) occur?

Notice that the timing and form of this event is determined jointly by the physical side, from S(T), and by the psychological side from P(T). But it is determined, nevertheless, by a mathematical law: it is not coming from "out of the blue." The Process **1** event changes S(T) to S'(T) = P(T)S(T)P(T) + P'(T)S(T)P'(T), where P' = (1-P).

Then Nature's choice, Process **3**, occurs. It is a "quantum jump." The State S'(T) is reduced to P(T)S(T)P(T) with probability Trace P(T)S(T)P(t)/Trace S(T) or to P'(T)S(T)P'(T) with probability Trace P'(T)S(T)P'(T)/Trace S(T). If the chosen state is P(T)S(T)P(T), then the associated experience 'e' occurs: otherwise no experience occurs in conjunction with this Process **3** event.

This "experience" occurs essentially automatically, if Nature's Process **3** answer is 'Yes'. The occurrence of the experience is a

consequence of these partly deterministic and partly statistically deterministic equations. Consciousness enters only indirectly, by virtue of the limitation on the set {P(e)} of all P(e)'s, which enters into the definition of P(t).

Conscious Will comes in if the state actualized by the 'Yes' choice on the part of Nature not only eliminates all components of the brain state that fail to have the template for an action specified by P(T), but also puts to the agent the question "shall I exert the effort needed to ask again of nature, almost immediately, the question specified by P(T)". If the rapidity of these Process **1** events is sufficiently great then this sequence of Process **1** events will activate the Quantum Zeno Effect, which will tend to hold the state S(t) in the subspace defined by this P(e), and this can, according to James's ideo-motor theory, produce the physical raising of the finger, which should lead to the feedback experience 'e' of raising the finger.

This completes the more detailed description of the basic elements of vN/S theory, which will now be applied to the Libet experiment.

The original commitment by the subject to, say, "raise my finger within the next minute" will condition his brain to bring forth a succession of potential RP's, distributed over the next minute. When the probability for any one of the potential RP's in this sequence peaks (reaches a local maximum) the associated Process **1** question "shall I initiate the raising of my finger" is asked. Because the commitment is spread over a minute the probability that Nature's answer will be 'Yes' will be very small for each individual RP in the sequence. Hence most of the possible RP's in the sequence will not be actualized: they will be tossed out by the "No" answer on the part of Nature. But for some one of these Process **1** events Nature will say "Yes," and the associated initiating experience 'e' will occur. If, in the light of the feelings thus actualized, the agent "chooses to exert the effort needed to raise the finger", then a sufficiently rapid sequence of Process **1** events will be actualized, and this will cause the finger to rise.

The conscious choice to exert the needed effort that causes the finger to rise occurs, therefore, *after* the beginning of the build-up of the associated readiness potential, just as Libet says. This readiness

potential is actualized by Nature's first 'Yes' answer. None of the "potential readiness potentials" associated with the 'No' answers to the earlier Process **1** events will have been actualized. So the physical situation actualized by the 'Yes' answer at some time T will actualize a physical situation that includes a readiness potential that has already begun its build up before time T, and peaked at time T. But the mental decision to consent, not veto, comes after T, and only if this consent is given will the Quantum Zeno Effect kick in and hold persistently in place the "template of action" needed to consciously raise the finger.

It might seem that this occurrence of the build up of the readiness potential *before the conscious choice that triggers the raising of the finger* might violate causality requirements. But the computations of orthodox quantum theory show that this kind of precursor activity *cannot be controlled* in such a way as to, say, send a specified message backward in time. It is controlled in this case by **Nature's choice** to say 'Yes' at time T, not before. *Given* this 'Yes" choice *on the part of Nature* the (human) agent is given the choice to consent or veto the rapid sequence that will cause the finger actually rise. This human choice to consent or veto, on the basis of his feelings, is treated in quantum theory as a free variable. But one must take into account the fact that if the consent is given then Nature must choose, *with specified statistical weights*, between the 'Yes' and 'No' answers to each of the Process **1** questions in the ensuing rapid sequence. The result is that the granting of the consent can directly and strongly influence whether or not the finger will rise, but will have no effect, on the average, on whether or not the precursor readiness potential appears: the fact that that this RP appears was fixed already by the 'Yes' answer given at time T. Consequently, the occurrence of the RP is not controlled by the subsequent "free choice of whether or not to exert the needed effort, and there is no conflict with the stringent causal requirements of the theory of relativity, which forbids sending controlled messages except via physical transfers of momentum energy. There can be no such transfer backward in time (or outside the forward light cone) and hence no violation of the requirements of the theory of relativity, even though the readiness potential appears before the conscious choice that actually *causes* the finger to rise.

The projection operators P(e) are necessarily nonlocal operators: they grasp in a unified way an informational structure that can extend over a large part of the body-brain of the participant. This brings into the dynamics holistic features that are in principle beyond the reach of systems that operate according to the local principles of classical physics. These holistic features are in line with our perception and conception of ourselves as creatures that can consciously grasp complex informational structures as wholes, and can choose to act efficaciously on the basis of those graspings.

Applications in Neuropsychology and Neuropsychiatry

This theory has been applied in both Neuropsychology and Neuropsychiatry. In the former case (Oschner, 2002; Schwartz, 2003) human subjects are first instructed how to alter their mental reactions to emotionally-charged visual stimuli by adopting certain mental strategies. Then their reactions to such stimuli are studied using fMRI under differing choices of mental set. The brain scans reveal profoundly different patterns of response to the stimuli according to the strategy chosen by the subject. The key *empirical* input variables here are the willful choices by the human subject about how he or she will (mentally) act, and vN/S theory provides a physics-based framework for analyzing the data in terms of these input parameters, without being limited by the idea that basic science requires all psychogenic causes to be explained purely by classically conceived physiological causes. Indeed, quantum theory says that micro-local explanations of brain dynamics in terms of the concepts of classical physics are impossible in principle, and suggests that willful choices about how to act be treated as the pertinent causally efficacious psychogenic input parameters, in line with the treatments of the Libet and Pashler data.

In the psychiatric cases (Schwartz, 2002) the crucial communication between therapist and patients was enhanced by instructing the patients that quantum theory allows bona fide psychogenic influences of freely chosen actions, and interpreting differences in brain scans of patients as evidence of the therapeutic value of properly directed willful conscious control of attention. Psychogenically based therapy is given a foundation in basic physics. (Stapp, 1999)

The key elements of the theory are the NCC's, which are specified by the projection operators P(e). But how is this mapping between the two conceptually disparate regimes established. The answer is by trial and error empirical testing of the correspondence between quality of conscious effort and quality of experiential feedback. Every healthy alert infant is incessantly engaged in mapping out the correspondences between efforts and feedbacks, and he/she builds up over the course of time a repertoire of correspondences between the feel of the effort and the feel of the feedback. This is possible because different effortful choices have, according to the quantum equations, different physical consequences, which produce different experiential consequences. This whole process of learning would appear to depend crucially upon the actual causal efficacy of chosen willful efforts.

The focus here has been on the theoretical foundations of pragmatic scientific practice. However, vN/S theory lends itself to ontological interpretation. The essential change from classical theory is that the classical state of the universe represents a purported *material* realty, whereas the von Neumann quantum state of the universe represents a purported *informational* reality. This latter reality has certain matter-like features: it can be represented in terms of micro-local entities (local quantum fields) that *usually* evolve by direct interactions with their neighbors. But the von Neumann quantum state represents the collective knowledge of all agents, and it changes whenever the knowledge of any agent changes. The state changes in three ways: by the mechanical Process **2**; by the injection via Process **1** choices made by agents; and by the injection via Process **3** of choices made by Nature. Taken at face value the quantum state of the von Neumann universe acts like the giant playing board upon which a game of "choices" is being played between agents and Nature. Quite apart from the question of "truth," this "game" conception of quantum theory provides a good understanding of the practical workings of the theory.

It should be mentioned that everything said in this section on the vNS theory is completely compatible with there being very strong interactions between the brain and its environment: the state S(t) of the brain is what is know as the statistical operator (reduced density

matrix) corresponding to the brain. It is formed by averaging (tracing) over all non-brain degrees of freedom, and incorporates all of the decoherence effects arising from interactions with the environment.

Von Neumann's theory provides a general physics-based psycho-physical framework. We now turn to efforts to tie it to the detailed structure of the brain.

Libet, B (1985). Unconscious cerebral initiative and the role of conscious will in voluntary action. *Behavioural & Brain Sciences*, 8, 529-566.

Libet, B. (2003). Cerebral physiology of conscious experience: Experimental Studies. In N. Osaka (Ed.), *Neural Basis of Consciousness*. [Advances in consciousness research series, 49] Amsterdam & New York: John Benjamins.

Ochsner, K.N. & Silvia A. Bunge, James J. Gross, and John D.Gabrieli (2002). Rethinking feelings: An fMRI study of the cognitive regulation of emotion. *J. Of Cognitive Neuroscience,* 14:8, 1215-1229.

Pashler, H. (1998). *The psychology of attention*. Cambridge, MA: MIT Press.

Schwartz, J. & Begley, S. (2002). *The mind and the brain: neuroplasticity and the power of mental force*. New York: Harper-Collins.

Schwartz, J., Stapp, H. & Beauregard, M (2003). The volitional influence of the mind on the brain, with special reference to emotional self regulation. In M. Beauregard (Ed.), *Consciousness, Emotional Self-Regulation and the Brain*. [Advances in Consciousness Research Series]. Amsterdam & New York: John Benjamins.

Stapp, H. (1999). Attention, intention, and will in quantum physics. J. Consciousness Studies, 6, 143-164.

Stapp, H. (2001). Quiantum theory and he role of mind in nature. *Found. Phys*. 31, 1465-1499.

James, W. (1890) *The principles of psychology Vol. II*. New York: Dover.