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Consciousness in Quantum Physics and The Mind-Body Problem

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Following the lead of von Neumann and Wigner, Goswami (1989) has developed a paradox-free interpretation of quantum mechanics based on the idealistic notion that consciousness collapses the quantum wave function. This solution of quantum measurement theory sheds a considerable amount of light on the nature of consciousness. Quantum theory is applied to the mind-brain problem and a solution (quantum functionalism) is proposed for the paradox of the causal potency of the conscious mind and of self-reference. Cognitive and neurophysiological data in support of the present theory are also reviewed.

Neisser (1976) has said that cognitive psychology is not ready for consciousness. Some functionalists seem to agree with him – consciousness is a difficult concept to incorporate in the philosophy of functionalism (Rey, 1983). On the other hand, there have been many attempts to define consciousness and to explain its role in the mind-body problem in the pages of this journal (for a review, see Natsoulas, 1983; see also Snyder, 1984, for an earlier application of quantum mechanics). Of particular importance is the work of Sperry (1980, 1983, 1987), who regards consciousness as an emergent phenomenon that has causal action on the body (brain).

Consciousness has been invoked in connection with the quantum measurement problem first by von Neumann (1955) and later by London and Bauer (1983) and Wigner (1962). Quantum objects are described in quantum mechanics by a wave function, generally a *coherent superposition* of contradictory facets, or possibilities. However, experiments reveal only one facet in any particular observation. To get around this *measurement problem*, it is

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postulated by the above authors that consciousness collapses, or *reduces*, the multifaceted quantum wave function to one facet. These early works, however, were based on a dualistic view of consciousness and matter as separate realities and they have bogged down with paradoxes (see later).

Recently, Goswami (1989) demonstrated that the paradoxes of quantum measurement can be completely resolved if one adapts a view of consciousness promulgated by idealistic philosophers such as Plato (1980) and Kant (1934) in the West and Shankara (1978) in the East. This view holds consciousness to be primary—and matter an epiphenomenon within consciousness. The fundamental premises of the interpretation are: (1) quantum objects (which include the entire material world) remain as formless ideas mathematically described as wave functions or coherent superpositions, akin to Platonic archetypes, in a transcendent domain until consciousness collapses the wave functions leading to their manifestation in the world of appearance; this is the basic idealistic ontology; (2) consciousness is unitive and transcendent; it collapses the quantum wave function (that is, reduces it from many co-existing possibilities to one manifest actuality) discontinuously from outside space and time; and (3) a quantum measurement can be said to be complete only when mind-brain awareness is present in the event of collapse (further review of these premises is given below).

There is a necessary distinction here between consciousness and awareness. Consciousness is defined both as the ground of being and as the subject/self of consciousness (the latter has the associated problem of self-reference to which we shall return later). Awareness, on the other hand, is defined as the field of mental objects, akin to ordinary space for physical objects.

In view of the last premise above, it is clear that the idealistic resolution of the measurement problem promises an important new application of physics to the mind-brain problem. The primary purpose of this paper is to carry out the essential steps entailed in such an application. In conventional studies of the mind-brain problem, the philosophy of material realism (the idea of one objective world built on matter) is at least implicit, especially the aspect of material epiphenomenalism – that mind and consciousness are epiphenomena of the material brain. But material realism faces seemingly insurmountable difficulties in quantum mechanics (see below); thus it is essential to reexamine the mind-brain problem and find a reformulation of it within the basic idealistic premise.

The Neurophysiological Debate

In the normally reductionistic view of the material epiphenomenalist (functionalism), mind is the higher level of a hierarchy of levels, and the brain, the neuronal substrata, is the lower level. In this view the lower level (brain) is the causal determinant of the higher (mind); it cannot be the other way around (Dennett, 1981). Thus the model precludes free will. Moreover, in the materialistic model, all experiences are either genetically or environmentally programmed; creativity—real creative leaps to new contexts or meaning of experiences – is difficult to explain.

Sperry's (1980) solution to the problem of free will and creativity is holism. According to Sperry, the causally potent reality of the conscious mind is a holistic emergent order that arises from the organizational interaction of the neuronal substrata, but is not reducible to it.

But Ryle (1949) scorns holism, declaring something like this: there is no whole without the reductive parts; the parts are the whole. Any concept of a whole apart from the parts, such as the emergent consciousness in Sperry's thinking, is a ghost in the machine. It smacks of dualism.

Because Sperry's thinking does indeed smack of dualism, Popper and Eccles (1976) have propounded an explicitly dualistic (pluralistic actually) solution of the mind-body problem. According to Eccles-Popper's model, mental properties belong to a separate world, world 2, and meaning comes from a still higher world, world 3. Eccles also proposes a liaison brain to mediate between the brain states of world 1 and the mental states of world 2. Eccles and Popper's basic point is that the mind's capacity for conscious freedom requires it to operate from outside of the physical system. If the physical brain is all the system there is, its behavior is bound to be determined, because any proposal of action-initiating conscious mind is bound to end up in the paradoxical causal loop, brain-mind-brain, that snared Sperry.

Can there be consciousness without freedom, without causal potency, as reductionism demands? Sperry's interactionism – freedom of choice and consciousness viewed as emergent holistic phenomena of the brain – is paradoxical. Can consciousness be an epiphenomenon of matter (albeit emergent) and still have creative freedom causing material actions? The Eccles-Popper theory makes good points but bogs down with all the usual criticisms that can be leveled at dualism: How can the two worlds of the conscious mind and insentient matter interact without exchanging energy? How can they exchange energy without contradicting the evidence for the law of conservation of energy? Is the liaison brain not just another version of Descartes' pineal gland?

Is there a resolution to this debate? The resolution I will attempt is to apply the ideas of quantum mechanics and quantum measurement to the mind-brain. I will show that the effective antidote for dualism is idealism. I will also develop a quantum mind-brain model in which a self-reference such as Sperry's does emerge, but the issues of free will and creativity obtain a twist. I will begin with a brief review of the idealistic interpretation of quantum mechanics.

Quantum Mechanics and the Nature of Consciousness

As mentioned before, quantum mechanics is a mathematical theory for predicting wave functions, coherent superpositions of weighted possibility structures. The standard probability interpretation identifies the weights as statistical; thus quantum mechanics predicts the probability of a particular event or outcome, and these predictions have been verified in myriads of experiments. However, the phases of the different components of the coherent superposition are also important, for they give rise to the well-known interference phenomena, likewise experimentally verified (for example, by the classic double slit experiment). Thus the probability interpretation does not solve the ontological problem of the meaning of the coherent superposition.

To probe the meaning, let us discuss the paradox of Schroedinger's cat (Schroedinger, 1948). Suppose we put a cat in a cage with a radioactive atom, a Geiger counter, and a poison bottle; further suppose that the atom in the cage has a half life of one hour, a fifty-fifty chance of decaying within the hour. If the atom decays, the Geiger counter will tick; the triggering of the counter will break the poison bottle, and the cat will die. If the atom does not decay, none of the above things happens, and the cat will live.

How does quantum mechanics describe the state of the cat after the hour? As a coherent superposition, literally, as a half-alive and half-dead cat. This seems absurd, and indeed, if we make an observation, the cat is found either alive or dead. And then the question arises, What is so special about our making an observation that resolves the diabolical dichotomy?

The standard Copenhagen interpretation of quantum mechanics (see Stapp, 1972) tries to mollify the consternation using Bohr's complementarity principle. The coherent superposition is said to be an abstraction; as an abstraction the cat is able to exist as both live and dead. This is a complementary description, complementary to the dead or alive description that we give when we do see the cat. Moreover, posing as logical positivists, Copenhagenists say that we should confine our discussion of reality to what is seen instead of trying to find ontological significance to what we cannot observe.

How do Copenhagenists deal with the second paradox: Who/what determines the outcome when an observation is made, when the cage of the cat is opened? Again Copenhagenists avoid the issue. A macro measuring apparatus is always needed to amplify and record a quantum event. If we treat the measuring apparatus in classical terms, if the state of a measuring apparatus is assumed never to become dichotomic, then the measurement of the decay of the atom above terminates with the Geiger counter, and Schroedinger's paradox is avoided.

But any macrobody (the cat or the Geiger counter or any observing machine) is a quantum object; there is no such thing as a classical body unless we are willing to admit a vicious quantum/classical dichotomy in physics. It is true that a macrobody's behavior can be predicted in most situations from the rules of classical mechanics (this is called the Bohr correspondence principle); this is the reason that we often loosely refer to macrobodies as classical. But the measurement process is not one of these occasions, the correspondence principle does not apply here.

Thus, it is difficult, if not impossible, to deny that all objects obey quantum uncertainty and must pick up quantum dichotomy. If a chain of apparati measures a quantum object in a coherent superposition, they all in turn pick up the dichotomy of the object ad infinitum (von Neumann's [1955] infinite chain). This has been rightly compared with a Goedelian knot (Peres and Zurek, 1982). How do we get out of such a logjam? In a very Goedelian fashion, by jumping out of the system!

Since our conscious observation seems magically to cure the dichotomy of the cat, it must be consciousness that collapses the cat's wave function—this is the von Neumann-Wigner resolution. However, the act of observation must be a jump out of the system, consciousness must work discontinuously from outside of the material world and from outside the jurisdiction of quantum mechanics. An influence outside space-time that propagates without local signals is called nonlocal in physics. Thus, consciousness must be nonlocal, which in idealism is referred to as transcendent. The Aspect experiment (see Aspect, Dalibard, and Roger, 1982), discussed later, supports the idea of nonlocal influence.

I will restate the von Neumann-Wigner resolution in the context of an idealistic ontology: it is our consciousness whose observation of the cat resolves its alive-or-dead dichotomy. Coherent superpositions, the multifaceted quantum waves, exist in the transcendent order until consciousness brings them to the world of appearance with the act of observation. And in the process, consciousness chooses one facet out of two, or many, that are permitted by the mathematics of quantum mechanics, the Schroedinger equation; it is a limited choice, to be sure, subject to the overall probability constraint of quantum mathematics (i.e., consciousness is lawful).

But questions have been raised. There are the issues of causal action of mind over matter and of solipsism. It is these questions that have been resolved in an earlier paper (Goswami, 1989).

Explicitly, the concern of mind over matter in the paradox of Schroedinger's cat is this. If the cat is a coherent superposition (both alive and dead) before we look, but has a unique state, dead or alive, after we look, then we must be *doing* something by just looking. Thus Phillip Pearle (1984, p. 458) wonders, "It is hard to believe that a tiny peek at a cat would have a big effect on the physical state of the cat." This is a problem that dualists like Wigner seek to solve by vainly trying to find evidence of psychokinesis, moving matter within the mind (Mattuck and Walker, 1979). But in idealism, objects are already in consciousness as primordial, transcendent, archetypal possibility forms. *The collapse is not about doing something to objects via observing, but consists of choosing among the alternative possibilities that the wave function presents and recognizing the result of choice.*

Next let us examine the question of solipsism summarized beautifully in the paradox of Wigner's friend (Wigner, 1967). Suppose that instead of making the observation of the cat himself, Wigner asks a friend to do so. His friend opens the cage, finds the answer, and then reports it to Wigner. At this point, we can say, Wigner has just actualized the reality that includes his friend and the cat. But there is a paradox here. Was the cat alive or dead when Wigner's friend observed it, but before he reported the observation? To say that the state of the cat did not collapse when his friend observed the cat is to maintain that his friend remained in a state of suspended animation until Wigner asked him, that his friend's consciousness could not decide whether the cat was alive or dead without Wigner's prodding. This amounts to solipsism – only Wigner's consciousness is real, all other consciousness, including his friend's is Wigner's imagination. But the world would be a pandemonium if individual people were to decide the behavior of the objective world, because we know subjective impressions are often contradictory. Hence the argument of solipsism is regarded as a fatal blow against Wigner's resolution of Schroedinger's cat.

However, there is an antidote to solipsism. Wigner's problem arises from his dualistic thinking, his consciousness separate from his friend's. The paradox disappears if there is only one subject – not separate subjects as we are used to thinking. The antidote to solipsism is a unitive subject-consciousness, a basic premise of idealistic philosophy. If Wigner's friend's consciousness is in essence no different than Wigner's, if it is always one consciousness collapsing the wave function, there is no paradox.

There is, however, a subtle criticism that can be applied to unitive, nonlocal consciousness collapsing the wave function of quantum objects – such a consciousness is omnipresent. An omnipresent consciousness collapsing the wave function does not resolve the measurement paradox because we can ask, at what point is the measurement complete if consciousness is always looking? The answer is crucial. *The measurement is not complete without the inclusion of the immanent mind-brain-awareness!* Indeed, this agrees with our empirical observation that there is no experience of a material object without the presence of a concomitant mental object such as the thought, "I see this object," or at least, awareness. The answer that it is always the manifest participation of a brain-mind-awareness that is instrumental in collapsing the wave function is also completely in line with the spirit of idealistic philosophy (especially in the writings of Eastern philosophers). A cognitive experiment described later also supports the idea.

The Meaning of the Aspect Experiment

Einstein, Podolsky, and Rosen (1935) and later Bohn (1951) pointed out that two electrons (or other quantum objects) can be so correlated that if we observe one, thus collapsing its wave function, the correlated partner's wave function must also collapse instantly. Since this violates the locality principle, it was called the EPR paradox (it is a paradox for material realism where locality is a basic tenet), but now it is generally recognized that quantum collapse *is* nonlocal in this case. The Aspect (1982) experiment with atoms emitting "polarization-correlated" photons, demonstrated that the mutual "influence" is indeed nonlocal, that is, instantaneous, occurring without the intermediary of a local signal.

According to the idealistic interpretation, it is the conscious observation that collapses the wave function of one of the two correlated photons in the Aspect experiment. And as said above, the wave function of the correlated partner also collapses immediately. But a consciousness that can collapse the wave function of a photon at a distance instantly must itself be nonlocal, transcendent.

Summary of Idealistic Interpretation of Quantum Measurement

To summarize:

1. What is being measured? A quantum object which exists as a coherent superposition in a transcendent domain of reality.

2. What is the role of the measurement apparatus? The macro measuring apparatus is needed to amplify and record a quantum event. The point is this. A measuring apparatus is classical only in the sense of the correspondence principle; although ultimately quantum in nature, through its complexity it loses the practically instant regenerativity that a simple quantum object has. Because of this long regeneration time, a measuring apparatus can make a record (although ultimately only temporary) after its wave function is collapsed and the measurement is completed.

3. What collapses the quantum wave function? A transcendent, unitive consciousness.

4. When is a measurement completed? The measurement is completed only when a conscious being (presumably a mind-brain) looks with awareness at the macro apparatus involved with the event of measurement.

There is a causal circularity in the last proposition and it is this: awareness is needed to complete the measurement, but without the completion of measurement, there is no awareness. This causal circularity is connected with the problem of self-reference. Thus, a central problem for the idealistic quantum solution of the mind-brain problem being proposed here is to resolve the causal circularity above and to understand how self-reference in the form of an immanent, personal I emerges as an epiphenomenon of experience.

Idealistic Hypothesis Toward a Solution of The Mind-Brain Problem, Quantum Functionalism, and a Theory of Self-Reference

What must the structure of the brain be that it can be the vehicle via which consciousness experiences the world? What in the structure of the brain-mind allows both conditioned and creative experiences? The answer proposed here is that the brain-mind must have a quantum in addition to its classical (in the sense of the correspondence principle) machinery. The quantum mind-brain is regenerative and its states are multifaceted; it is the vehicle for conscious choice (via collapse of the "chosen" facet) and for creativity. On the other hand, the classical component of the mind-brain can form memory (because the classical has a long regeneration time), and thus can act as a reference point for experience. Is there any evidence for a quantum component in the mind-brain?

Bohm (1951) noted that there seems to be an uncertainty principle operating for thoughts. For example, if we concentrate on the content of thought, we lose the line or direction the thought is following. On the other hand, concentrating on the direction of thought leads to the loss of sharpness of content.

We can generalize Bohm's observation and posit that thought has an archetypal component. Its appearance in the field of awareness is associated with two conjugate variables, *feature* (instantaneous content akin to the position variable of physical objects) and *association* (the movement of thought in awareness akin to the momentum variable of physical objects).

Thus, mental phenomena such as thought seem to exhibit complementarity. Although always manifested in form (described by attributes such as feature and association), we can posit that between manifestations, thought exists as transcendent archetypes, quite similar to the quantum object with its transcendent coherent superposition (wave) and manifest one-faceted (particle) aspects.

Harman and Rheingold (1984) have shown that there is plenty of evidence of discontinuity and acausality in the mental phenomenon of creativity (see also Boles, in press). As discontinuity and acausality are characteristic features of a quantum jump, Goswami (1988) has suggested that a creative experience consists of a quantum jump. There is also evidence of nonlocality in the mind's action as well – in recent brain-wave coherence experiments (see later).

These parallels between the mind and the quantum – uncertainty, complementarity, quantum jumps, and nonlocality – are not conclusive, but they do suggest something radical – that what we call mental experiences consist of modes that are akin to the objects of submicroscopic matter, modes that obey a mechanics that is similar in structure to quantum mechanics. We have argued above that ordinary matter at the base level consists of submicroscopic quantum objects that can be called the archetypes of matter. Similarly, we will assume that mentation at the base level consists of the archetypes of mental objects; however, these archetypes are made of the same basic stuff that material archetypes are made of, and they also obey quantum mechanics, and thus quantum measurement considerations apply to them as well.

In recent years several authors have seriously attempted to invoke a quantum mechanism in the macroscopic working of the mind-brain to resolve the mind-brain problem (Bass, 1975; Eccles, 1986; Goswami, Keutzer, and Clark, 1981; Stapp, 1982; Stuart, Takahashy, and Umezwa, 1979; Walker, 1970; Wolf, 1984). Of these, the work of Stapp is especially relevant to the present work.

In Stapp's model, the mind-brain is looked upon as two interacting computers that feed programs to each other; one is a classical computer (in the sense of the correspondence principle), but the other is a quantum computer. In what follows, I adapt Stapp's model and extend it further.

We will look at the mind-brain's quantum computer as a many-body macroquantum system whose states can be represented as products of its normal modes. (Although macrosystems are usually classical in the sense of the correspondence principle, there are other examples of a macro-quantum system, e.g., a superconductor, a superfluid, or a laser.) These normal modes constitute the mental archetypes introduced earlier. And the states of the brain's quantum system are what I will call pure mental states. Let us also assume that the bulk of the brain is classical, and that it plays the analog of the measurement apparatus that we use to amplify and record submicroscopic material objects in order to "see" them. Suppose that the classical apparatus (the classical computer) of the brain amplifies and records the quantum mind objects. This last assumption incorporates one of the most persistent riddles of the mind-brain problem – the mind-brain identity. Currently, philosophers either postulate the mind-brain identity without clarifying what is being identical with what, or try to define some kind of psychophysical parallelism. But with the present hypothesis, in every quantum event, the mind-brain identity expresses the simple statement that there is a one-to-one correspondence between the state of the quantum computer and the state of the classical computer that measures it (see Figure 1).

Classical Versus Quantum Functionalism

Let us return to the picture of the mind-brain as a computer. A computer has a base level of structure, its hardware, and a higher functional level, the programs or software. It is in this division of structure and function that the mind-brain is similar to the computer; one thinks of the brain as the structure, or low or micro level, and the mind as the function, the high or macro level. This picture of the brain and mind as the hardware and software of a (classical) computer is the basis of the currently popular philosophy of functionalism (Fodor, 1981; Van Gulik, 1988).

In the functionalist philosophy, it is completely equivalent to talk about the mind-brain from the point of view of either level, structure or function (but one must not mix levels); and one often speaks of one mental program causally affecting another as a matter of convenience. It is the hardware level, however, that is recognized as the ultimate causal level in classical functionalism. And this conflicts with the action-initiating mind of Sperry's theory, because Sperry implies the existence of a high-level program that causally initiates action at the hardware level. This is not permitted in "classical" functionalism. Here Sperry's perplexing brain-mind-brain causal circle translates into a hardware-software-hardware circle; and again, if mind's software is only a conglomerate of brain hardware, then the circle implies hardware acting on hardware without a cause, something that classical systems refuse to do. This is why (classical) functionalists must avoid causal initiation at the software mind level.

Classical functionalism also is plagued with the problem of self-reference. It cannot answer questions such as who reads meaning into the programs? The postulate of a central processor program (which is much like a homunculus) does not solve this problem (Van Gulik, 1988). Additionally, in spite of all the talk of high level mental programs, classical functionalism is incapable of explaining the qualia of conscious experience (Nagel, 1974). Some philosophers regard these failures of functionalism as reasons for doubting the existence of a conscious self altogether (Rey, 1983). But a more succinct explanation of this failure is that we cannot generate consciousness as an epiphenomenon of matter.

There is an unfounded assumption in classical functionalism that the brain stuff is classical hardware. But suppose the brain-mind consists of hardware that is both classical and quantum. In the idealistic model proposed here, the experienced mental states are the products of the interaction of both classical and quantum software (see Figure 1).

Most importantly, the causal potency of the quantum computer of the mind arises from the nonlocal consciousness that collapses the mind's wave function. And it is this nonlocal consciousness that experiences the outcome of this collapse. Thus, in the idealistic model, some of the predicaments of classical functionalism are immediately avoided. A crucial question now arises: In such a system can we explain self-reference of the kind that we experience, our individual I-ness? The answer is yes, and this explanation also eliminates the causal circularity of the idealistic theory of quantum measurement.

	QUANTUM	CLASSICAL
MIND	QUANTUM SOFTWARE Normal modes=Pure mind states Creativity Mental archetypes Quantum Modality - "I am"	CLASSICAL SOFTWARE AI domain Learned programs, Conditioned behavior Classical Modality - "I am this"
BRAIN	QUANTUM HARDWARE Macro-quantum system Physical archetypes	CLASSICAL HARDWARE Classical measurement apparatus, Memory storage, etc.

Figure 1. Quantum Functionalism.

Quantum Measurement Theory

According to von Neumann (1955), the state of a quantum system undergoes change in two separate ways. The first is a continuous change completely predictable from the mathematics of quantum mechanics, the Schroedinger equation. The state spreads as a wave, becoming a coherent superposition of a number of potential states allowed by the situation; each potential state has a certain statistical weight given by its probability amplitude. The result of a measurement introduces a discontinuous change in the state; all of a sudden the superposition – the multifaceted state that exists in potentia – is reduced to just one actualized facet. We can think of the spreading out of the state of superposition as the development of a pool of possibilities, and think of the measurement process that realizes only one of the states of the pool (within the overall constraint of the probability rules) as a process of selection.

The mind-brain's quantum system must also develop in time following the above rules of measurement theory and become a coherent superposition. And the classical brain's functional machinery plays the role of the measuring apparatus (i.e., amplifying and recording the result of the collapse of the pure mental state), but it becomes a coherent superposition also. Before the collapse, the state of the mind-brain thus exists as potentialities of myriad possible patterns that Heisenberg called "tendencies." The collapse actualizes one of these tendencies, which leads to a conscious experience upon completion of the measurement. And importantly, the measurement is a discontinuous event in space-time.

According to the idealistic interpretation, consciousness chooses and recognizes what becomes the outcome of the collapse upon observation of any and all quantum systems. This must include the quantum system that we postulate in the brain-mind. Thus, we reach the consequence of talking about the dual-systems computer of the mind-brain in the language of measurement theory as interpreted by idealism: our consciousness —that is, we — choose the outcome of the collapse of the quantum state of our mind-brain. Since this outcome is a conscious experience, this means that we choose our conscious experiences! And yet, we remain unconscious of the underlying process. It is this *un*consciousness that leads to the illusion of a separate I that arises from self-reference. The illusion takes place in two states, and the basic mechanism involved is tangled hierarchies.

Tangled Hierarchies

In a simple hierarchy the lower level feeds the upper level, and the upper level does not react back. In a simple feedback the upper level reacts back, but we still can tell what is what. With tangled hierarchies, the two levels are so mixed up (by a discontinuity in the causal chain, e.g., a limit circle, Prigogine, 1980) that we can no longer identify the different hierarchical levels.

Tangled hierarchical systems are autonomous. The famous liar's paradox is a prime example. "Epimenides was a Cretan who said, 'All Cretans are liars.' " This is an example of a tangled hierarchy, because the secondary clause reacts back on the primary, and soon we lose track of which is primary (i.e., giving truth value), and which is secondary. Is Epimenides telling the truth? If he is, he must be telling a lie. The answer every time reverberates; if true, then lie, then true, ad infinitum.

Compare the liar's paradox with an ordinary sentence, *your face is red*; an ordinary sentence refers to something outside itself, or at least an objective statement can be made of its content. But the complex sentence of the liar's paradox refers back to itself, it is autopoietic. That is how we get caught in its infinite delusion — the closure of the system within itself and separate from all else. In other words, we are dealing with self-referential systems. The tangled hierarchy is a way of achieving self-reference (Hofstadter, 1980). The self-reference arises because of a veil, a clear stonewalling against our attempt to see through the system causally and logically. It is the discontinuity — in the case of the liar's paradox — the infinite oscillation (infinity is a discontinuity) — that prevents us from seeing through the veil.[1]

[1]In an Escher drawing, *Print Gallery*, a young man inside a gallery is looking at a picture of a ship that is anchored in the harbor of a town. But the town has a print gallery in which there is a young man who is looking at a ship that is anchored in the harbor of a town . . . . This is a good example of a tangled hierarchy.

But there is one more aspect of a tangled hierarchy which we see best by considering the self-referential sentence: *I am a liar.* In this compressed form of the liar's paradox, the self-reference of the sentence, the fact that the sentence is talking about itself, is not necessarily self-evident. For example, if we show the sentence to a child or a foreigner who is not very conversant with the English language, the response might be, "Why are you a liar?" They may not see at first that the sentence is referring to itself. Thus the self-reference of the sentence arises from *our* implicit, if not explicit, knowledge of the language. It is as if the sentence is the tip of an iceberg; there is a vast structure underneath which is invisible. This invisible structure can be called the inviolate level. It is a level that is transcendent from a point of view restricted to the system. Yet it is the inviolate level (in the case of the self-referential sentence, our implicit conventions of the language, and in the case of the Escher drawing, Escher himself) that is the "cause" of the self-reference of the system.

Hofstadter (1980), whom I have largely followed in the above explication of tangled hierarchies, thinks that there are tangled hierarchies in our brain's programs resembling a classical computer as in classical functionalism. Hofstadter believes that one can build a silicon computer with tangled hierarchical programs, but then that computer would be self-referent.

But there is a category mistake in this kind of thinking, because a tangled hierarchy requires a transcendent level as well as an infinite regression. Hofstadter cannot generate a transcendent, inviolate level from a material level any more than Escher's drawing can generate Escher or material apparatus can collapse a quantum wave function. There has to be a *real* jump out of the system from the system's point of view. To see how tangled hierarchy and self-reference arise in the mind-brain, let us turn to Schroedinger's cat once more.

Schroedinger's Cat Revisited

Quantum mechanics says that Schroedinger's cat is half dead and half alive after the hour. According to von Neumann's argument, discussed previously, if we send a whole hierarchy of insentient machines successively to observe the reading of each previous machine, starting with the one that observes the cat, it is logical (since all the machines obey quantum mechanics) that all of them will acquire the quantum dichotomy of the cat's state, ad infinitum.

By having the cat's wave function in its quantum superposition, we have in effect opened up the possibility that all material objects in the universe are susceptible to contracting the contagious quantum superposition. The quantum superposition has taken on a universality, a glaring infinity. But the system does not collapse. This incompleteness is a logical necessity if we play von Neumann's game.

To resolve the infinity we have to jump out of the system and recognize the inviolate level. According to the idealistic interpretation of quantum mechanics, the nonlocal consciousness collapses the mind-brain from outside space-time, thus terminating the von Neumann chain. There is no paradox from this perspective.

It is different, however, from the perspective of the mind-brain. The following is a crude model of the brain-mind's response to an ambiguous stimulus. The stimulus is processed by the sensory apparatus and presented to the dual computer. The state of the quantum computer expands as a coherent superposition, and all the classical measuring apparati that couple with it also become coherent superpositions. But there is no program that chooses among the different facets of the coherent superposition; there is no program in the mind-brain that we can identify as a central processing unit – the subject is not a homunculus acting at the same level as the mind-brain's programs. Instead, what we have is a tangled hierarchy of classical and quantum programs where there is a discontinuity, a breakdown of causal connection within space-time in the process of selection from the possible choices in the probability pool that the quantum program gives. The choice is a discontinuous act of the transcendent domain, an act of our nonlocal consciousness; no linear cause-effect description of it in space-time is possible. Consciousness collapses the total quantum state of the dual computer of the mind-brain, resulting in the separation of subject and object, but, because of the veil of the tangled hierarchy, it identifies itself with the I of the primary awareness which is actually an object in consciousness. This primary self experience will be referred to as the quantum modality of the self.

Thus our "I" and the objects we experience arise codependently, but neither has any inherent self-nature. This is a major tenet of Buddhist idealism (the doctrine of *paticca samuppada* – dependent co-arising; Rahula, 1974).

Learning: Emergence of the Ego

Experiences lead to learning, one aspect of which is developmental changes in the brain's substructure (memory). There is a well-known characteristic of learning – learning a performance reinforces the probability of the same subsequent performance. Thus it is reasonable to assume that learning increases the likelihood that the quantum-mechanical states of the dual computer after the completion of measurement will correspond to a prior learned state; in other words, learning biases the mind-brain. Before experience, before learning, the probability pool from which consciousness chooses spans the mental states common to all people at all places at all times. With learning, certain responses gradually gain greater weight over others. This is the developmental process of the mind's classical, learned programs.

It should be noted that once a task has been learned, then for any situation involving it, the likelihood for the corresponding memory to trigger a learned response approaches one hundred percent. In this limit, the behavior of the dual computer becomes classical. Here we can see the mind-brain analog of Bohr's correspondence principle.

Fairly early in our physical development, the learned programs accumulate and dominate the mind-brain's behavior, despite the fact that the quantum program is available for new creative experiences. But when the creative potency of the quantum program is not engaged, the tangled hierarchy of the programs of the mind-brain, in effect, becomes a simple hierarchy of the learned classical programs. At this stage, the creative uncertainty as to "who is the chooser" of a conscious experience is removed, and we begin to experience a separate individual self, ego, that chooses, that has "free will."

To further elucidate the situation, suppose a learned signal arrives at the mind-brain. In response, the quantum computer and its classical measuring apparati expand as coherent superpositions, but the memories of the classical computer respond also with the learned programs associated with the given stimulus. After the event of collapse associated with the primary experience, a series of secondary-collapse processes takes place; the quantum computer develops in unambiguous states in response to the classical learned programs, and each is amplified and collapsed. This series results in secondary experiences that have a distinctive quality, such as habitual motor activity, thoughts (e.g., I did this), etc. The learned programs that contribute to the secondary events are still part of a tangled hierarchy, for if we follow them, there is a break in their causal chain corresponding to the role of the quantum program and its collapse by nonlocal consciousness. But this discontinuity is obscured and interpreted as an act of free will of a (pseudo-) self and is followed by the (false) identification of the nonlocal subject with a limited individual self associated with the learned programs – this is ego.

To be sure, our consciousness is ultimately unitive and is at the transcendent level, which we now recognize as the inviolate level. But from inside physical space-time, from the point of view of the classical programs of our mind-brain, we become possessed by individual identity, ego. From inside, limited as we usually are in our ability to discover our system's tangled hierarchical nature, we invoke free will to cover up our assumed limitedness. The limitedness arises from the ignorant acceptance of the point of view of the learned programs causally acting on one another; due to ignorance we identify with a limited version of the cosmic subject – I am this body-mind.

As the real experiencer, the nonlocal consciousness, I operate from outside the system – from outside my brain-mind that is localized in space-time, from behind the veil of the tangled hierarchy of my mind-brain's programs. My separateness – ego – emerges only as the apparent agency for the free will of this cosmic I, obscuring the discontinuity in space-time that the collapse of the quantum mind-brain-state represents. Such a separate self has aspects of an emergent phenomenon, as Sperry suspected. It is manifested out of the interaction of programs of the brain-mind; and matter (classical brain) here plays the important role as the recorder of the learned programs. But the separate self is a false, secondary identity for consciousness because the nonlocal creative potency of consciousness and the versatility of the quantum mind never disappear; they remain present in the primary quantum modality of the self.

Suggestive Evidence

There are some neurophysiological and cognitive data that support certain important aspects of the theory presented above: that there are quantum correlations in the brain; that awareness must be present along with consciousness in order for quantum collapse to occur; and that there are primary and secondary modalities of the self. Let me present the data.

Coherence in the Brain

Is there evidence that the brain has the cooperative action that may reflect the quantum nature of the mental state that it measures? Major evidence for this hypothesis stems from EEG brain-wave studies.

The aspect of a laser beam that enables it to travel to the moon and back while maintaining its form as a narrow pencil comes from the fact that the photons of the beam exist in a state of spatial coherence (an analogy is people dancing in step). The most telling evidence of the quantum nature of a mental state comes from the EEG measurement at the scalp of the spatial coherence of the brain waves (Orme-Johnson and Haynes, 1981). The researchers study brain waves from different parts of the brain, front and back or left and right, to see if these brain waves exhibit any similarity in their phase. Transcendental Meditation researchers, using sophisticated computer techniques, have demonstrated coherence between brain waves from different parts of their subjects' scalps. Furthermore, the degree of coherence is found to be directly proportional to the degree of pure awareness of the meditator, as indicated by subjective reports.

Spatial coherence, as exemplified by the laser beam, is one of the startling properties of quantum systems; classical systems acquire spatial coherence when they act as measurement apparati for quantum systems (induced coherence). Thus these coherence experiments may be giving us direct evidence that the brain acts as a measuring apparatus for a quantum system, the mind.

I should mention also that more recently, the EEG coherence experiment with meditating subjects has been extended to more than one subject with positive results (Grinberg-Zylberbaum and Ramos, 1988). This may be a case of quantum nonlocality of the mind-brain, thus confirming further the quantum nature of the coherence exhibited in these experiments. As Feynman (1982) has pointed out, a classical computer can never simulate nonlocality.

Unconscious Perception Experiments and Coherent Superpositions in the Brain-Mind

There is a cognitive experiment by Marcel (1980) which makes a prima facie case for one of our major tenets of quantum measurement, namely that awareness must be present for a quantum collapse to occur. The experiment uses the phenomenon of unconscious perception (perception without awareness; see Shevrin, 1980) and also suggests that states of the brain-mind may indeed be coherent superpositions.

In the experiment, Marcel (1980) used polysemous words to create ambiguity. Marcel's subjects fixated visually on a screen as a series of three words (the middle word being polysemous) were flashed one at a time at intervals of either 600 milliseconds of 1.5 seconds between flashings. The subjects were asked to push a button when they consciously recognized the last word of the series. The orginal purpose of the experiment was to use the subject's reaction time as a measure of the relationship between congruence (or lack of it) among the words and the meanings assigned to the words in such series as hand-palm-wrist (congruent), clock-palm-wrist (unbiased), tree-palm-wrist (incongruent), and clock-ball-wrist (unassociated). For example, the bias of the word *hand* followed by the flashing of *palm* might be expected to produce the hand-related meaning of *palm*, which then should improve the reaction time of the subject for recognizing the third word *wrist* (congruence). But if the biasing word was *tree*, then the lexical meaning of *palm* as a tree would be assigned and the meaning-recognition of the third word *wrist* should take a longer reaction time (incongruous). And indeed, this was the result.

However, when the middle word was masked by a pattern that made it impossible to see with awareness, but that did not inhibit unconscious perception, there was no longer any appreciable difference in reaction time between the congruent and incongruent cases. This should be surprising, because presumably both meanings of the ambiguous word were available, regardless of the biasing context, yet neither meaning was chosen over the other. Thus, in unconscious perception, there is neither collapse nor choice of a particular meaning. Apparently, choice, and therefore quantum collapse, is a concomitant of conscious experience, but not of unconscious perception. Collapse is due to choice, and it needs conscious awareness.

If the quantum explanation of the Marcel experiment given here is correct, then the experiment also demonstrates the existence of coherent superpositions in the mind-brain. Before choice (collapse), the quantum description of the ambiguous state of the brain-mind exposed to a pattern-masked polysemous word-stimulus must be a coherent superposition of both meanings.

Can an explanation of the Marcel experiment be given using more conventional cognitive models? It seems that classical functionalism, and even the more recent parallel distributed processing network model (for a reivew see Cottrell, 1983), is unable to explain the difference between all the data for conscious and unconscious perception. Moreover, the quantum model predicts interference phenomena which are beyond the classical models; all this will be discussed in a forthcoming publication (Goswami and McCarthy, 1989; see also, Woo, 1981).

Primary Self and Secondary Ego as the Quantum and Classical Modalities of the Subject/Consciousness: Reaction Time and the Experiments of Libet

There is a curious time-lag between a conscious motor response to a stimulus and its verbal report; this can be interpreted as the reaction time between the collapse of a space-time event in the mind-brain in the primary consciousness mode and the verbally reported secondary awareness, or introspection-based expereience, of the ego mode. Thus, introspection, which functionalists have been hard put to incorporate, does play an important role in quantum functionalism.

There is impressive evidence for this introspection time – in our model, the time for the processes of secondary awareness to take place. Libet, Wright, Feinstein, and Pearl (1979) have discovered this intriguing phenomenon in patients undergoing brain surgery at Mount Zion Hospital in San Francisco. Libet et al. measured the time it takes for a touch stimulus on a patient's skin, traveling as the action potential along the neuronal pathway, to reach the patient's brain. The patient was instructed to indicate the arrival of the signal by pushing a button. The authors found that while the patient pushed the button about 0.1 second after the touch was applied, the patient did not report being consciously aware of either the stimulus or his/her response to it until 0.5 second. (The action potential, by the way, takes only about 10 milliseconds to reach the brain. Pushing the button takes another 90 milliseconds, but why does the verbal report of it take another 400 milleseconds?)

As a result of this kind of experiment, it is becoming clear that our verbal reports of when a conscious experience occurs are rather inaccurate. The implication is that the normal ego of our self that arises around thought arises from the processing of secondary awareness of conscious experience. The 400 milliseconds between the conscious response and the verbal report is the time of processing secondary awareness; it is the time taken for introspection. Our preoccupation with the secondary processes (indicated by the time lag) makes it difficult to be aware of our quantum primary modality.

The time-lag of secondary introspection contributes an aura of continuity to our ego-experience of consciousness, a continuity that is not present in the primary quantum process associated with the discontinuous collapse of the mind-brain's wave function. Consciousness divides itself into primary subject-object awareness via a collapse of the quantum wave function that appears as a discontinuity in space and time, but we usually experience the subject-object division in the continuous, classical ego modality of secondary awareness.

It is important, however, to recognize that past experiences, present perceptions, and genetics are not the only contributors to the pool of possibilities involved in the time development of the quantum states of our mind. We are capable of responding with true novelty, as expressed in creative experiences – creativity comes from the availablity of the vast archetypal content of the quantum machinery of the mind. Our creativity is the gift of the nonlocal archetypal contribution to the mental possibility pool (see Goswami, 1988).

An adult person is capable of operating in two modes. The quantum primary mode – where probability, uncertainty, and acausality reign supreme and where creative responses, not just the learned ones, remain available through the entirety of the archetypal banks of the mind-brain's quantum computer – is the fountain of our intuitive insights, the flashes of imagination that cannot be abstracted from prior learning. This is the transpersonal component of the self, an idea propounded by both Assagioli (1976) and Maslow (1968). And the classical ego mode is our continuous, conditioned, and predictable behavior that augments our creative ideas with reason, that enables us to develop and manipulate these ideas into full-blown actualities, and to enjoy the fruits of our accomplishments.

There is circumstantial evidence of exalted experience when the reaction time of secondary introspection of the ego mode is reduced. Maslow's (1968) data on peak experiences find a natural explanation in terms of reduced reaction time and the quantum modality of the experiencing self.

The phenomenon of creativity involving more than one individual (Lamb and Easton, 1984) also gives evidence for nonlocal correlation of mental objects. The many documented cases of simultaneous scientific discoveries of the same basic idea supports this notion.

Summary

Let me summarize the starting hypothesis and results obtained:

1. Quantum objects exist as archetypes in the mathematical form of a wave

function or coherent superposition in a transcendent domain of Platonic idealistic vintage. The wave functions represent a pool of possibilities whose time development is continuous and completely determined by the mathematics of quantum mechanics.

2. In an act of observation the wave function collapses, the multifaceted coherent superposition becomes one-faceted. The collapse is discontinuous and is not described by quantum mathematics.

3. Consciousness, in a measurement by a conscious observer as an act of choice and recognition in the presence of awareness, collapses the wave function. A tangled hierarchy (the von Neumann chain) leads to the self-referent I-am awareness.

4. Consciousness is unitive and nonlocal. The quantum nonlocality of correlated objects is manifest as nonlocal simultaneous events of collapse whenever we observe them.

5. The mind-brain is to be looked upon as a dual system consisting of a quantum system/measurement apparatus. The normal modes of the mind-brain's quantum system are the mental archetypes, the building blocks of pure mental states.

6. Experience leads to learned programs (in the classical brain) which constitute a biasing of the response of the mind-brain (classical correspondence). These classical programs of the mind-brain give rise to processes of secondary experience that obscure the tangled hierarchy and replace it with a false sense of free will. Our personal self-reference arises from the ignorant identification with the point of view of our learned programs.

7. We can categorize the acts of the mind-brain-consciousness as pertaining to two modes. First, the classical behavioral secondary mode, and second, the quantum creative primary mode.

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