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Whiteheadian Process and Quantum Theory of Mind *

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Abstract

There are some deep similarities between quantum theory and Whitehead's idea of the process by which nature unfolds. Heisenberg asserts that what is really happening in a quantum process is the emergence of an 'actual' from potentialities created by prior actualities. Whitehead says that the world is made of 'actual occasions' each of which arises from potentialities created by prior actual occasions. The orthodox Copenhagen interpretation of quantum theory maintains that the formulas of quantum theory are about 'our knowledge', whereas Whitehead claims that the formation of an actual occasion involves psychological aspects such as appetite and satisfaction.

On the basis of these similarities an attempt is made here to use Whitehead's conception of process to supply the two elements that are missing from contemporary quantum theory, viewed as a description of nature. Present-day quantum theory specifies, by means of the Schroedinger equation, the growth and development of the potentialities for the next actual event, but it does not provide the analogous

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rules for the formation and selection of this next actuality. The fact that the actuality in the orthodox approach to quantum theory is 'our knowledge' suggests that psychological elements may be entering into to this latter process. On the other hand, scientific practice calls for a tight-knit mathematical description of nature. This poses the problem of how to integrate the experiential and physical aspects of reality into a unified quantum mechanical description that rationally encompasses the disparate characteristics of these two aspects of nature.

The Schroedinger equation in relativistic quantum field theory—or more precisely the Heisenberg equations of motion—is constructed so as to favor spacetime points over extended structures characterized by frequency. Reasons are advanced here for believing that whereas the expansion phase of the quantum process, which the phase in which the burgeoning of potentialities occurs, is governed by the spacetime-dominated Schroedinger equation, the subsequent contraction phase, which constructs and selects the new actuality, is govern by extended structures having repetitive forms in spacetime; and that, moreover, it is these extended structures that are associated, in the special context of brain-like physical structures, to the experiential aspects of nature.

It is suggested that a key role in the contraction phase is played by light. The quantum mechanical representation of electromagnetic radiation by coherent states transforms the basic description into the frequency domain: the representation is in terms of modes, each of which has a frequency, an amplitude, a phase, and an extended structucture in space. Natural selection, at a pre-biological level, should lead to the emergence of habits (perceived as physical laws) that favor the formation of self-replicating patterns. They would provide the stability needed for the maintenance of complex extended structures and the expression of novelty. This general thesis is developed here within the context of an effort to describe the missing half of the dynamical equations of motion, namely the half governing the contraction phase of quantum process.

Disclaimer

1. Introduction.

Quantum mechanics, regarded as a tool for making certain kinds of practical predictions, appears to be complete. But as a description of nature it is not. Attempts by scientists form a picture of an enveloping structure that imbeds quantum mechanics have tended to assume that the imbedding reality must be similar to the world that is postulated to exist within the framework of classical mechanics. That latter world is like the world that we see around us, extrapolated to a very fine scale. It consists of tiny entities (particles) and local fields. Each *particle* has, at each instant of time, an exact position in space; each *field* has, at each instant of time and each position in space, a well defined amplitude. However, a principal tenet of the orthodox Copenhagen interpretation of quantum theory is that although we must *in practice* use the classical concepts to describe, to each other, the experiments that we perform, and the outcomes that appear to us, we need not, and ought not, suppose that there really exists a world of this simple classical type. On the contrary, the realities upon which science in general, and quantum theory in particular, is based is "our knowledge", and orthodox quantum theory scrupulously avoids all commitment about what any other aspects of nature are really like.

In the seventy years since the creation of quantum theory physicists have tried, in many ways, to construct a theory of the imbedding reality that removes from basic theory the contamination by human observers. Most scientists believe that the world existed, and obeyed laws, long before human beings—or even primitive life—came into being. This belief motivates the search for a conception of nature that does not make human knowledge a central feature of the theory. It has, in the past, seemed to most scientists this means some sort of resurrection of a classical-type reality, with consciousness merely an aspect of a more basic physical description that resembles the reality imagined to exist in classical physical theory.

It is indeed, of course, highly implausible that human experience should play a central role in the evolution of the universe. On the other hand, human experience does exist, and a complete theory of nature must explain how these experiences are related to the rest of nature. The full reality ought to have some natural place for experiential-type things.

Classical mechanics was designed to be ontologically and dynamically complete without any explicit reference to conscious experience. So insofar as the conceptual basis for the imbedding reality conforms to the ideas of classical mechanics there will be no reason for consciousness to be present: if a completely physical description in terms of things like positions of particles and the values of local fields is possible, then the existence of experiential qualities will not be logically entailed. They will not be logically entailed because the classical description is in terms of objective behaviour, and there is no way to deduce, logically, the existence of subjectively felt experiences purely on the basis of classical-type concepts that deal exclusively with objectively described behaviour.

It is of course possible that the inner aspect is purely gratuitous: that it is just simply there, with no reason to be there, and no dynamical role to play.

An alternative possibility is that the underlying reality contains primitive seeds that can flower into human conscious experiences within the special environment of human brains. According to quantum theory, these brains can have the capacity to hold potentialities created by earlier actual events, and to feed these potetialities into the creation of complex new actualities that are interpretable as new pieces of empirical knowledge.

Whiteheadian Process contains primitive seeds that can flower, within such an environment, into human conscious experiences.

It must be recognized that the 'physical reality' of the quantum mechanical description of nature is more idea-like than the physical reality of classical mechanics. The closest quantum analog to physical reality is the evolving state of the universe. But this state represents only probabilities, which are normally regarded as idea-like things. Or perhaps the quantum state represents 'potentialities'. But these also are more idea-like than classically conceived reality. Moreover, even the condition that the experiential aspects of nature be completely determined by (supervene on) the evolving physical state does not carry the implication that it does in classical mechanics, namely that the experiential aspects are either dynamically superfluous, or are mere reformations or re-statements of the consequences of an underlying local dynamical process. In quantum dynamics the *expansion phase* is governed by the Schroedinger equation, which is the analog of the equation of motion in classical mechanics, and, like it, is local (i.e., based on interactions localized at space-time points). But the dynamics of the *contraction phase* is not governed by the analog of the classical dynamical equations. So there is an essential aspect of the quantum dynamics which, if viewed from a narrow classical point of view, would seem to be nonphysical, but which, when viewed from a quantum point of view is seen as the necessary second part of the dynamical behaviour of the quantum state. The experiential aspects of nature might therefore be completely specifiable given the description of the evolving quantum state of the universe, but that representation could be more like a reconstruction of a cause from its effects than the construction of an effect from its independently acting local causes.

I shall describe here an adaptation of Whitehead's ideas designed to provide an ontological framework for contemporary physical theory. Thus the narrower problem of the origin and development of human conscious experience is posed here within the context of the larger problem of constructing an adequate ontological framework for quantum theory.

Quantum theory was framed by its creators as a pragmatic theory, rather than an ontological one: it provides methods for calculating predictions about what our experiences will be under certain kinds of empirically specified conditions, rather than a picture of what is actually going on. One reason for this cautious reticence is that the answers that quantum theory provides, for the special sorts of questions that it is designed to deal with, do not allow one to draw any compelling or natural ontological conclusions, except for the negative ones that classical mechanics, though extremely useful in many contexts, is profoundly wrong, and that classical ideas about causality are profoundly wrong. In this circumstance the scientifically prudent course is to claim no more than what the evidence justifies, and this means refraining from drawing any detailed ontological conclusions.

However, other kinds of empirical evidence are available. For example, cosmological and astrophysical data do not fit the quantum format of an experimenter preparing a small system, and studying its evolutions between its preparations and its subsequent observation, under conditions in which the small system may assumed to be free of any interaction with its environment. However, the focus in this paper will be on a different sort of evidence that also is not dealt with by orthodox quantum theory.

In orthodox quantum theory we human observers stand outside the quantum system that we are studying. Information comes to us through our senses, and is filtered and processed in complex ways before appearing to us as knowledge about feature of the world outside our bodies. The theory is based on a correspondence between (the contents of) our experiences about the world around us and aspects of the quantum theoretical model of that outside world.

Contemporary research on the mind-brain connection supplies information about a fundamentally different kind of connection. These connections are not connections of our experiences to aspects of a theoretical model of what these experiences appear to us to be about. They are connections of our experiences to what, according to this model, are the direct physical correlates of these experiences, not the remote cause that has been filtered through the complex interpretive brain processes. An analysis given below shows that the usual arguments for the effective impossibility of acquiring empirical knowledge about the nature of the underlying reality break down when data of this new kind are considered.

Whitehead knew about Bohr's atom, with its discrete jumps, when he created his process philosophy, with its discrete actual occasions. In the atomic case the discrete acts are localized in small atomic-sized regions, and

Whitehead was evidently thinking in terms of such small entities when he said that "a molecule is a historic route of actual occasions."[PR p.98]. However, the Bohr atom was eventually superceded: quantum theory developed in a different way. According to contemporary orthodox quantum theory, the evolution at the atomic level is governed by the Schroedinger equation, which makes the evolution at the atomic level continuous rather than discrete.

On the other hand, there is another part of the overall quantum process that does proceeds by discrete steps. This is the act of observation. This part of the full quantum process involves our conscious experiences, and hence links into a second feature of Whitehead's actual occasions, namely the description of the internal process of the *becoming* of an actual occasion. This process is described in essentially psychological terms, such as "appetite" and "satisfaction". At the most primitive level of actual occasion Whitehead distinguishs these psychological qualities from consciousness. That separation is completely in line with the position, adopted here, that the most primitive actual occasions should carry merely the primitive seeds of consciousness, not the rich flowering of those seeds that constitutes human consciouness. The latter, according to the present approach, is dependent upon the complex functional structure of the human brains that supports it.

The mathematical rules of quantum theory give no preference to the observations of tiny things. For example, the observation of a state of fixed momentum is on a par with an observation of a fixed position, but the former would mean observing a state that extends over the entire universe. Such an observation is no more feasible than an observation of an exact position. The feasible observations upon which quantum theory is based, in practice, are states of human size. Sometimes these are represented as the states of the visible aspects of some measuring devise. But von Neumann showed that all the phenomena covered by orthodox quantum theory could be explained if, instead of introducing three levels of reality—atomic, macroscopic, and experiential— and associating the contractions with the macroscopic level, the only allowed contractions were to be to the patterns of brain activity that correspond to the experiences of observers. This corresponds to the fact that the orthodox interpretation is constructed to be about 'our knowledge'. The present position is an intermediate one in which every human experience is associated with a contraction of the quantum state of the universe to one compatible with a brain state that contains the information represented in that experience, but in which contractions are not limited to these very special cases, but are recognized to be natural general phases of the dynamical evolution of the quantum universe.

As regards metaphysics, let me only add that I take seriously the fact that reality is essentially idealike: the quantum theoretical reality *is* the quantum state of the universe, which evolves an accordance with certain mathematical/logical rules, but is nevertheless, by virtue of the nature of this evolution, ontologically dissimilar to the matter of classical mechanics. It therefore becomes reasonable to assert that a thought that *is* an aspect of a certain actualized state of a brain *is* the actualized intentionality that is created by the contraction of the universe to a state that evolves into potentialities that heavily weight the intended consequences of that thought. For this to happen an image of the intended consequence must be present in that thought, which demands a certain kind of repetitiousness in which the thought blooms within a supporting environment from a seed within itself into a successor that is similar to itself.

2. Von Neumann Process and Heisenberg Process

The starting point of this study is the fact that contemporary quantum theory is ontologically incomplete. Two fundamental questions remain unanswered. The theory requires that questions with yes or no answers occasionally be put to nature, whereupon nature delivers an answer, The relative statistical weights of the two possible answers, yes or no, is then specified by quantum theory. What is not specified by the contemporary form of quantum theory is: (1), what determines which questions are put to nature, and (2) what determines whether the individual answer to a posed question is yes or no?

The objective here is to begin to answer these questions, adhering to the principle that the ontology must bring in no aspects of nature that are not dynamically controlled by the—assuredly nonlocal—dynamical rules that govern the evolution of the quantum state of the universe.

To make the paper reasonably concise I shall assume that the reader is familiar with the rudiments of quantum theory: I very brief description of these rudiments is given in appendix A.

The state vector Z is represented by a sequence of complex numbers, $\{z_1, z_2, z_3, ...\}$. The state (of the universe) S is the quadratic form with $S_{ij} = z_i^* z_j$. Von Neumann considered an idealized measurement situation in which a sequence of perfect measurement devices are set in place. Each device measures the outcome displayed by the preceding one, and displays the outcome of its own measurement of that displayed outcome by fixing, say, the position of a pointer whose well separated alternative possible positions indicate the alterative possible outcomes. This sequence of "measuring devices" is assumed to extend right into the brain of the observer, so that the *final* "pointer positions" would be the distinct patterns of brain activity corresponding to an observer's seeing, or otherwise sensing, the outcome displayed by the device that he believes he is observing. Because of the perfect correlations between the outcomes displayed by the various devices in the sequence an action of the projection operator that acts on the position of the pointer of any one of these devices, and resticts that position to be in precisely one or another of one of its possible positions, as opposed to being in a quantum superposition of several of these alternative possible positions, has exactly the same effect as the action of a projection operator acting on the position of any other pointer in the sequence. Thus if the contraction phase is represented by the action of one of these projection operators, then it makes no difference which of these projection operators is doing the job: all have exaclty the same effect, due to the correlations that exist in the quantum state. Thus there is, in the analysis of these experiments, no need to have any projections other than those that act on the brains of the observers. Such a projection onto this state of the brain of the observer contracts the state of the entire universe to one compatible with the knowledge of this outcome: all future experiences of all observers will, according to the fixed rules of quantum theory, be compatible with the knowledge gained by any one of them.

Quantum theory is a statistical theory that does not predict which specific outcome will appear to the observers: it gives only the statistical weighting of each of the alternative possibilities. Von Neumann recognizes this fact, in builds it into the formulation by introducing his process I:

VN Process I:

$S \equiv PSP + (1-P)SP + PS(1-P) + (1-P)S(1-P)$
$\longrightarrow PSP + (1-P)S(1-P)$.

The first term (after the arrow) is the part of the state S that corresponds to the definite outcome 'Yes'; the second term corresponds to the definite outcome 'No'. The two interference terms, which are automatically generated by the action of the Schroedinger equation, are stripped away by the VN Process I. The effect of this action is to define the question that is put to nature. Nature then gives the answer 'Yes' with probability Trace PSP/Trace S, and gives the answer 'No' with probability Trace (1-P)S(1-P)/Trace S.

The definition of the operator P is fixed, fundamentally, by the demand that it correspond to a well defined increase in 'our knowledge': i.e., in the knowledge of one observer, and hence observers.

Certain efforts to remove the human observer from the theory have been based on bringing in 'the environment' instead of the human observer. The point here is that there are subtle features of the environment that are, for all practical purposes, impossible ever to measure. But in the case of an unobservable feature of nature the quantum rules allow one to take a partial trace over the 'unobservable' degrees of freedom. Taking this trace gives the reduced state (density matrix) S'. This reduced density matrix usually has essentially the same form as what is genereted by the VN Process I. So one can get rid of the need for the human observers, at the expense of introducing the notion that some things are, for all practical purposes, not measurable.

Of course, if one is interested only in practical rules, then it is probably better to define the possible observable outcomes by considering what the real observers can observe, than by bringing in presumed unobservable aspects of the environment. If one is interested, rather, in understanding the ontological situation then it is not clear that one should rely on the notion of 'for all practical purposes'. If, contrary to expectations, one did set up an appropriate way of monitor certain aspects of the environment one could, according to theory, detect the supposedly banished interference effects.

The present approach is to take seriously what quantum theory proclaims: nature is idealike.

The VN process defines the question. But the full contraction determines also the answer, 'Yes' or 'No': the new S is either PSP or (1-P)S(1-P). I call this full contraction to the single new state the *Heisenberg reduction.*

It is perhaps important that if the degrees of freedom of the universe are divided into those associated with a certain system and those that are not, and if P acts only on the system (i.e., acts like the identity operator on the other degrees of freedom) then the VN process has no effect on the expectation value of any operator that acts like unity on the system. So the *defining* of a question pertaining to a system is a local process, in the sense that it involves only the system itself. But the corresponding Heisenberg process generally affects large parts of the universe: it generates the fundamentally nonlocal character of quantum theory.

3. Coherent states of the electromagnetic field as basis for contraction.