3. The Bohm Approach.

The Copenhagen and von Neumann formulations of quantum theory are non-deterministic. Both specify that human choices enter into the dynamics, but neither specifies the causal origins of these choices. The question thus arises: what determines these choices?

One possibility is that these choices arise in some yet-to-be-specified way from what we conceive to be the *idealike aspect of reality*. That option was pursued by Penrose, with his suggestion that our thoughts are linked to Plato's world of ideal forms. Another – seemingly different – possibility is that there is a *more complete physical description* that involves physically described entities that are different from the smeared out structures of the orthodox formulations, and that these *other physical elements* determine the features left undetermined by the orthodox formulations.

This second approach was developed by David Bohm (1952, 1993). His formulation of quantum theory postulates, in effect, the existence of the old-fashioned world of classical physical theory. This classical-type world is supposed to exist in *addition to the wave function of quantum theory* and, like that wave function, it evolves in a way completely determined by what precedes it in time. This theory reinstates determinism in a way compatible with the predictions of quantum theory, but at the expense of abandoning locality: Bohm's theory entails strong, long-range, instantaneous action-at-a-distance.

One serious failing of Bohm's approach is that it was originally formulated in a non-relativistic context, and it has – after half a century and great effort – not been extended to cover the most important domain in physics, namely the realm of quantum electrodynamics, which is the theory that covers the atoms that make up our bodies and brains, along with the tables, chairs, automobiles, and computers that populate our daily lives. This deficiency means that Bohm's theory is, at present, primarily a philosophically interesting curiosity, not a practically useful physical theory.

Also, Bohm's theory, at least in its original form, is not really germane to the issue of consciousness. For Bohm's theory *successfully achieved its aim,* which was precisely to get rid of consciousness: i.e., to eliminate consciousness from the basic dynamical equations, just as classical physics had done.

Bohm recognized, later on, that some understanding of consciousness was needed, but he was led instead, to the notion of an infinite tower of mechanical levels, each controlling the one below, with consciousness somehow tied to the mystery of the infinite limit. (Bohm, 1986, 1990) This infinite-tower idea tends to negate the great achievement of the original theory, which was to reinstate physical determinism in a simple way. To examine this conceivable option of a *complete physical determinism compatible with the empirical predictions of quantum theory* it is instructive to examine Bohm's original deterministic model in order to see how, within that deterministic consciousness-free framework, consciousness nevertheless enters effectively, at the level of scientific practice.

As explained in the introductory section, scientific practice involves setting up experimental conditions that fill consciously experienced objectives. In von Neumann's theory these consciously chosen actions influence the subsequent course of events in The Observed System, which, according to von Neumann's re-construction of quantum theory, is primarily the brain of the human participant. A key point is that these choices, made by the experimenter about how he or she will act, are treated in von Neumann's theory, and also by Copenhagen quantum theory, as *input data*, to be fixed by the experimenter. These choices are *treated* as free, controllable, input boundary conditions.

In Bohm's theory these choices are not actually free: freedom is an illusion. The apparently free choice is, at a deeper dynamical level, completely determined by *physical* conditions, just as it was in classical physics. However, the putative existence of this deeper dynamical underpinning does not subvert or displace the quantum dynamics. The analysis of Heisenberg shows that, even within the context of Bohmian mechanics, the human observers can never determine, or *know*, which of the conceivable logically possible classical Bohmiam worlds their experiences belong to. The Heisenberg Uncertainty Principle cannot be evaded: the most that experiencers can ever actually ***know*** about the Bohmian classical world of which they are a putative part is represented by a quantum wave function.

This limitation *in human knowledge* is acknowledged by Bohm. Indeed, Bohm's theory leaves scientific practice the same as it is in the Copenhagen approach. This *equivalence at the practical level* of Bohm's model to the Copenhagen formulation means that in actual practice the unfillable gap in human knowledge mandated by the uncertainty principle is bridged by using quantum dynamics to replace the *in-principle-unknowable information about the microscopic physical conditions* by *in-practice-controllable and knowable realities*, our conscious choices about how to act. That is, although the details of the Bohmian microstructure can, as a matter of principle, never be known to us, and hence cannot be directly used to make predictions, we can and do experience the immediate consequences of our conscious choices about how to act, *and these experiences place conditions on the putative Bohmian microstructure*. These knowable input conditions entail *statistical* consequences in the realm of subsequent human experiences, which can be computed on the basis of the quantum mechanical equations. Thus these equations allow us to evade the need to know anything about the unknowable Bohmian micro-substructure beyond what is specified by quantum mechanical states.

The bottom line is that, *even within the context of the deterministic Bohmian theory, it is the quantum rules that constitute the useful scientific tools,* because they allow us, without needing to know anything about the in-principle-unknowable classical idealizations, to make predictions pertaining to what we can know. This conclusion will continue to be true in the context of *any* deterministic theory that is *compatible with* the statistical rules of quantum theory.

When solving a problem in physics there is always a question about which variables to use. At the level of practical science it is advantageous to use variables that are controllable and knowable in actual practice rather than unknowable in principle. Why bring unknowable parameters into science, instead of knowable ones that we can *in practice* control, when we have equations that bring these controllable parameters directly into the description of dynamical process, leaving out the unknowable ones, and that, according to the unchallenged arguments of Heisenberg and Bohr, tell us all that we can ever learn (within the framework of the principles of physics) about the effects of our conscious choices upon our future conscious experiences?

The advantages of using equations involving controllable and knowable parameters rather than unknowable ones are just as real in neuroscience as they are in atomic physics. Of what use are (highly nonlocal) deterministic equations that depend on the in-principle-unknowable motions of classically conceived calcium ions inside nerve terminals, in place of our knowledge about our controllable actions and their experienced feedbacks?

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