Which Way Does It Cut?

Ockham's Razor in No-Collapse Interpretations

The attempts to clarify Everett's theory of quantum mechanics (Everett 1973) have led to an immense proliferation of substantially different no-collapse interpretations.[1] Many of these, especially the modal interpretations seem closer in spirit to Bohm's "hidden variable" theory of quantum mechanics (Bohm 1952) than to Everett. Important work has been done recently to clarify the relations between all these interpretations (Bub and Clifton 1996, Elby 1998). In the same spirit, this paper tries to elucidate Everett's theory and its relation to other no-collapse interpretations by starting with Bohm's version of quantum mechanics and reducing its "ontological furniture" in three steps. The resulting "bare" theory is in striking agreement with Everett's theory, but has been rejected as not explaining the appearance of definite and stable measurement results (Bell 1987). The argument at each elimination step therefore has to be that the feature under consideration is not necessary to explain the appearance of definite measurement results within a no-collapse interpretation. The actual arguments will not be given in this paper. The sole aim is to make an Everettian position clearer by relating it unambiguously to Bohm's interpretation that is well understood on most accounts. Arguments for each of the three claims can be evaluated separately, making Everett's claim that he can save the phenomena accessible to rational assessment. The choice of Bohm as a starting point is in no way necessary. I hope that it will be plausible from the argument itself that any no-collapse interpretation with some form of a value state would serve the purpose as well.

To explain definite measurement outcomes in a theory without collapse, Bohm postulates an additional theoretical entity, a particle position evolving deterministically in time. The particle moves under the combined influence of mechanical forces and an

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[1] For recent overviews of no-collapse interpretations, see for example (Barrett 1999) or (Healey and Hellman 1998).

effective force caused by the quantum mechanical state itself in analogy to a classical field. Bohm's theory, therefore, can be seen as the deterministic Schrödinger dynamics of a quantum mechanical state plus the specification of a trajectory that determines outcomes for all possible measurements. (Both the quantum mechanical state and the trajectory are defined in configuration space, not in geometrical space.) It is a peculiarity of Bohm's picture that the quantum mechanical state has a double function: it acts both as a force field and as a probability distribution for the particle position. The latter function is necessary to account for the Born rule of standard quantum mechanics. A second peculiarity is the fact that there is no back reaction from the particle position onto the quantum mechanical state. In this regard, the quantum mechanical state is different from a classical field (such as the electromagnetic field). Therefore, every quantum mechanical state defines a family of all possible Bohm trajectories just as a probability distribution in statistical mechanics defines a family of possible trajectories if an equation of motion is given. (This would not be possible if the particle position had a physical effect on the quantum mechanical state.) More specifically, the quantum mechanical state gives a probability distribution and a set of phase-relations over the set of possible trajectories. Therefore, the addition of Bohm's theory to a bare no-collapse model is simply given by the specification of one of the trajectories defined by both the quantum mechanical state and Bohm's equation of motion as the real trajectory.

The first claim in the reductive argument is that this objective selection of one trajectory as real is unnecessary. It can be replaced by a picture in which reality is indexical, very similar to David Lewis's interpretation of modal logic known as modal realism (Lewis 1986). Instead of claiming that one of the many possible worlds given by a modal statement is objectively real, we can assume that reality is an indexical term used in each possible world to refer to this world itself. As already stated in the beginning, I will not argue for the justification (or usefulness) of such a claim, but merely point out that it is a consistent assumption which simply replaces one semantic model for the interpretation of Bohm's theory with another. Of course, if we were to accept such a move, it would be necessary to do a considerable amount of clarification on conceptual issues. Examples are the distinction of a physical system from its many possible states, or, if the system under consideration is a conscious observer, the distinction between a phenomenal reality for the observer (given by a single trajectory) and absolute reality given by the totality of all trajectories. However, the issues are quite analogous to the ones in modal logic, and therefore many of the results can be taken over. Especially, the notion of an indexical is helpful in understanding Everett's concept of a relative state (Saunders 1996).

The resulting picture we are left with is that the quantum mechanical state is associated with a family of equivalent trajectories. This, of course, is still much more than a bare quantum mechanical state: just like the time evolution of a probability distribution does not define a unique set of individual trajectories, so does the quantum mechanical state not imply any specific transtemporal identifications of space-time points as given by a trajectory. The second claim of our reductive program is that there is no need for the specification of trajectories above the quantum mechanical state. Again, it will have to be argued that abandoning the existence of objective trajectories does not conflict with the appearances, in this case, with our very fundamental beliefs that physical systems, including ourselves, have well-defined histories over time. The need for such an argument was long ignored because Everett's model was identified with a many-worlds interpretation in which trajectories for "worlds" are again interpreted as more or less objective. It seems that Bell was the first to recognize the need for such an argument within Everett's theory (Bell 1987). I have proposed an answer along the lines of Everett's picture in a recent paper (Lehner 1997a). It is one of the most important features of Everett's model that observers are endowed with memory: their present state encodes information about past states. How can it be said that these memories are valid if there is no objective matter of fact about the past? Since the validity of our beliefs about the future and the past cannot be judged by comparison to an objective history, another criterion of consistency with objective facts is necessary. The proposed criterion is simply whether the probabilities attributed by the phenomenal state correctly conditionalize the probabilities given by the objective state. (The quantum mechanical state is now understood as giving probabilities not over trajectories, but over instantaneous states.)

After the second step, what is left of Bohm's picture is barely more that the quantum mechanical state. However, it is important to realize that we still have an extraneous element left, namely a specific basis in which the quantum mechanical state is interpreted as a probability distribution. In Bohm's case, this is of course the position basis. If we had started with a different interpretation, such as the modal interpretation, the basis would be different, but whatever value state we had chosen would now leave us with some preferred basis. The third claim in the elimination process is that the selection of such a preferred basis is unnecessary as well. The need for a justification of this claim is known as the basis problem of Everett's theory. I have proposed an answer to this question based on the phenomenon of decoherence (Lehner 1997b). The fundamental claim is that decoherence provides a sufficiently stable and well-defined basis for all every-day macroscopic processes, including sensory perception and neural processing, to explain functionally the existence of a preferred basis in our phenomenal reality. It needs to be argued furthermore that the probability attributions based on such an approximative functional basis still give an approximately correct conditionalization according to the consistency criterion introduced in the second step.

It is obvious that all three claims need strong arguments, since they all are in blatant conflict with fundamental beliefs grounded in our self-consciousness. At this point however, the relevant thesis is not that satisfactory arguments for these claims can be given, but merely that if they could be given any trace of Bohm's position state would have been eliminated from the picture and we would be left with a "bare" quantum mechanics in the sense that no theoretical entity has been added to the linear dynamics of quantum mechanics. It seems very plausible that this was the kind of theory Everett wanted to propose even though he did not give the arguments outlined here. Regardless of whether such a theory is plausible (much less correct) I hope that the eliminative procedure has shown that it is consistent and amenable to rational evaluation: each of the three claims are quite specific and arguments for or against them can be assessed independent of a prior ontological commitment (such as to many worlds, histories, or minds). It also should be plausible that an analogous eliminative procedure can be used on any other no-collapse interpretation that uses value states to explain measurement outcomes, as for example on modal interpretations.

Of course, behind this presentation stands the belief that if the three claims are correct Everett's theory is preferable to Bohmian quantum mechanics. As is well known, the additional elements of Bohm's model create conflicts with special relativity and the physically plausible assumption of locality of physical interactions (see for example Barrett 1997). But there are also more fundamental (albeit more subtle) problems about the use of value states in Bohm's and modal interpretations (see Barrett 1997 in the case of Bohm, Healey 1998 for modal interpretations). It is mostly for reasons of historical irony that I have invoked Ockham's razor: it has frequently been cited as an argument against the "ontological extravagance" of Everett's theory. It should be clear from the argument given here that Ockham's razor cuts both ways: in return for accepting the numerical exuberance of an infinitude of coexisting possibilities we get a smaller number of ontological categories in Everett's model. After all, the original use of Ockham's razor was exactly to weed out the abundance of categories of scholastic metaphysics.

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