Requirements on Solutions

Given a clear definition of the measurement problem and the significance that a solution could have, one should consider what it would take for a proposed solution to be considered as a correct solution to the Quantum Measurement Problem. The following is an initial step to define the requirements that an acceptable theory should meet. There are two categories of potential solutions. A Category 1 Theory addresses the following requirements:

R1.1: The theory predicts the specific physical conditions under which measurement occurs and the physical conditions under which Schrödinger unitary evolution occurs.

R1.2: R1.1 is validated by experiment.

R1.3: Given a specific set of physical conditions under which a measurement has occurred (R1.1), the theory predicts:

R1.3.1 the potential system outcomes that might occur under the specific physical conditions assumed and their relative frequency of occurrence.

R1.3.2 for each potential system occurrence in R1.3.1, the potential state evolution(s) of the system and accompanying potential state evolution(s) of the measuring device (plus local environment, if needed).

R1.4: R1.3 is validated by experiment.

Requirement R1.1 requires specifying the micro-macro divide that is needed to resolve the measurement problem. Note that both R1.3 and R1.4 might appear to be met by invoking the measurement postulate of von Neumann. However, the prescription must be based on the underlying phenomena. The Hermitian operator that defines the measurement in von Neumann's theory is assumed known. However, R1.3 goes beyond this in the sense that such a Hermitian operator is not assumed known but would be derived from physics of the proposed theory.

A second class of theories, denoted as Category 2, make the claim that one or more of the requirements above are impossible to achieve by virtue that the conditions under which a measurement occurs prohibit one or more of the requirements from being met. This is a rather interesting logical possibility. In such a case, there would need to be an in-principle failure of the ability to experimentally investigate the measurement problem via techniques that, under the current quantum formalism, are in principle capable of discriminating Schrödinger unitary evolution from non-Schrödinger evolution such as the operations developed in Chapter 3. However, a

Category 2 theory still must include non-Schrödinger or non-unitary measurement operations, in order to resolve the measurement problem. That is, a Category 2 theory cannot be entirely a Schrödinger unitary solution.

An assumption was made in Category 2 that the operations proposed to discriminate unitary evolution from measurement are in-principle impossible. On the other hand, if the conditions under which a measurement occurs prohibit these discriminating operations, then it is plausible that some or all of R1.1-R1.4 cannot be fulfilled. Therefore, it is proposed that a Category 2 theory meet the following requirements before being accepted:

R2.1: The theory provides a theoretical rationale that the conditions under which a measurement occurs prohibits the experimental discrimination of Schrödinger unitary evolution from non-Schrödinger evolution via UMDT tests.

R2.2: The theory provides a restricted set of implementable unitary and measurement quantum operations. The conditions are specified for which unitary operations are applicable, and the conditions for which measurement operations are applicable, subject to the limitations of R2.1.

R2.3: Experimental evidence confirms that the operations that are outside the proposed restricted set of quantum operations indeed fail to be implementable and provides compelling evidence for the proposed theory.

As an example of a theory that could fall into this category, consider a theoretical measurement model that shows to actually discriminate unitary evolution from non-unitary evolution, two non-commuting observables of the device would be needed to be known simultaneously, which is impossible. And that the model proposes a non-unitary collapse mechanism that occurs in relation to the conditions for which discrimination between unitary evolution and non-unitary evolution becomes impossible. Moreover, suppose it is found via experiments that indeed such operations fail to be capable of being implemented successfully because there does appear to be such an inherent limitation in the process of measurement. Then such a theoretical model and a negative experimental demonstration might logically be capable of ruling out theories that purport to meet one or more of the R1.1-R1.4. On the other hand, such a demonstration would imply that there exists a restricted set of implementable operations.

If a solution is found for a Category 1 theory that meets R1.1-R1.4, then the current formalism of quantum mechanics would be augmented to explain the conditions under which measurement occurs as well as a prescription for the measurement observable in von Neumann's theory. In such a case Einstein would be correct in his thesis that Quantum Mechanics in its current form is incomplete. If a resolution is found for a Category 2 theory that meet R2.1-R2.3, then it is a logical possibility that the current two postulates of quantum mechanics have predictive power, but with an amended structure. The set of implementable operations would need to be restricted. The amended structure of a Category 2 theory would include the conditions under which the unitary postulate can be applied versus when the measurement postulate would be applied, subject to the limitations of R2.1. In this case, the Category 2 theory and its new restrictions would be critical in order to complete quantum mechanics. In either case, it appears that Einstein is correct in the following: quantum mechanics in its current form cannot at this time be considered to be complete.

What if a given theory has not yet met either R1.1-R1.4 or R2.1-R2.3? Then such a theory in our view should be considered in a deductive investigation as a scientific hypothesis if there is some evidence that supports the theory, or a conjecture or speculation otherwise regarding the resolution of the measurement problem.