# Review of: "On Probabilities in Quantum Mechanics"

Omar Khan[1]

1 FAST - National University of Computer and Emerging Sciences (NUCES)

Potential competing interests: No potential competing interests to declare.

The manuscript aims to clarify some concepts about a debate between A. Khrennikov and B. Stacey & R. Schack on the probability interpretation of quantum mechanics. In a larger context, these and other interpretations are a subject of considerable debate. Although the manuscript assumes that the reader will be aware of this debate, it will still be worthwhile to leave at least a few references to studies/surveys beyond the current commentary for those who are not well versed in the area. The manuscript is at best a commentary or opinion such as one would normally find on personal websites/blogs, so in a scientific article context, it does seem out of place. Other than this, the following are summaries of my observations:

1. In Section 2 of the article, the QBIST interpretation is given, describing quantum observations as subjective probabilities linked to an outcome observation (by an agent). The observation is described to be akin to a gambling commitment, and for this, a critique is presented for it being not natural to describe outcomes as bets. While a critique of QBIST is understandable, the critique through this premise alone is problematic. Gambling, or the measure of uncertainty as relative chance, is an important use-case, but not the only one. Other use-cases also exist which provide alternate interpretations of a likelihood measure of an outcome, which is perfectly natural.
2. In Section 3, the postulate of an agent with ideals modeled along the lines of a higher being is presented. My opinion is that metaphysical notions can be removed here, and a mere discussion of an agent whose behavior is governed by a set of rationales formulated through Dutch Book is sufficient to present the postulates. The higher being discussion will be incomplete without addressing other aspects such as consciousness, omnipresence, forms (singular/plural), etc., which are discussed in addition to rationale.
3. In Section 4, authors propose “my terminology,” which is not immediately obvious. The operators reflect commutability, which makes the measurement order independent and points to the possibility of simultaneous measurement without any mutual interference. If it is to the contrary, then the commutability will be non-zero. This appears to be a common interpretation associated with commutability, so the reference to ‘my terminology’ adds some confusion. If it points to some other property in a quantum mechanical context, it should be mentioned instead. As an example, I am thinking that two measurements by Alice and Bob may not be possible in certain contexts if they do not have the same basis (as in interaction on a quantum system through BB84 protocols).
4. In Section 4, last paragraph, I will highly encourage referring to the third observer as Eve instead of Alice. Also, an interpretation of "agent" would be helpful here. Some studies link it to the number of observers, and some link it to the number of worlds.
5. In Section 4, the single agent theory is deduced from the discussion surrounding property $[M1(t), M2(t)]=0$. If this is non-

zero (e.g., due to entangled states, time-varying states, or any other condition applied due to maybe incompatible observers), then wouldn't the interpretation point towards a multiple agents theory? The single agent theory from Ozawa's theorem is then given. Also, the inconsistency in QBISM due to joint probability ≠ 1 is also interesting.

6. In Section 4, one confusion is the last paragraph on disagreement with QBISM. The main basis of QBISM is the perceived belief of an outcome by an observer, which can be updated based on the availability of new evidence acquired through interactions with the system (e.g., measurements). If there are multiple agents, then they will have their own perceived beliefs. They will be updated from the system itself, but not from communication with the other agents. (In practical contexts, communication between agents is described through the BB84 protocol for key distribution, but that is outside the quantum mechanical system). As such, QBISM, in my opinion, does not have any commentary on the quantity of observers, but on the perceived observation of one agent only.
7. A limitation due to superposition is described when defining state vectors as eigenvectors obtained from some operator. A quantum system can exist in a superposition of its eigenstates which will collapse upon measurement. The collapse will be irreversible, and the state having a larger likelihood is more likely to be chosen. So it is not clear why it is a limitation?

I do understand that some answers may be given in authors' previously cited works; as such, the review may be incomplete without a full comprehensive reading. But the feedback is on the basis of the current content of the manuscript, which is incomplete and compels the reader to go through the other extensive previous articles on the matter.