Can a qubit be your friend? Why experimental metaphysics needs a quantum computer.

Howard M. Wiseman[1], Eric G. Cavalcanti[1], and Eleanor G. Rieffel[2]

[1]*Centre for Quantum Dynamics, Griffith University, Queensland, Australia*
[2]*Quantum Artificial Intelligence Laboratory, NASA Ames Research Center, CA, USA*

A recent paper by two of us and co-workers [1], based on an extended Wigner's friend scenario, demonstrated that certain empirical correlations predicted by quantum theory (QT) violate inequalities derived from a set of metaphysical assumptions we called "Local Friendliness" (LF). These assumptions are strictly weaker than those used for deriving Bell inequalities. Crucial to the theorem was the premise that a quantum system with reversible evolution could be an observer (colloquially, a 'friend'). However, that paper was noncommittal on what would constitute an observer for the purpose of an experiment.

Here, we present a new derivation of the LF inequalities that uses four metaphysical assumptions which, in conjunction, imply LF for a human-level-intelligent friend:

1. Local Agency: In an experiment, an intervention x is uncorrelated with any events which are relevant to the outcome of the experiment and outside x's future light-cone.

2. Physicalism: Any thought supervenes upon a physical process.

3. Ego Absolutism. My communicable thoughts are absolutely real.

4. Friendliness: If a party displays cognitive ability on par with my own, then any thoughts they communicate are *as real as* my own.

In addition to these four metaphysical assumptions, this new no-go theorem requires two assumptions about what is *technologically* feasible: Human-Level Artificial Intelligence, and Universal Quantum Computing. The latter is often motivated by the belief that QT is universal, but this is *not* an assumption of the theorem. Our new theorem is that the six assumptions lead to a contradiction. It is intended to give a clear goal for future experimentalists, and a clear motivation for trying to achieve that goal, by using assumptions that are logically independent, widely held, not reliant on the exact correctness of QT, and relevant to how different approaches to QT respond to the no-go theorem. To establish the final point, we consider a variety of existing interpretations or modifications of QT, showing that for each of our six assumptions there is an approach that violates that, and arguably only that, assumption. The popular stance that "quantum theory needs no interpretation" does not question any of our assumptions and so is ruled out by the theorem.

[1] Kok-Wei Bong et al., "A strong no-go theorem on the Wigner's friend paradox", Nature Physics 16, 1199–1205 (2020).