Comment on "Tests of Signal Locality and Einstein-Bell Locality for Multiparticle Systems"

In Ref. [1], Roy and Singh take the novel step of expressing the postulate of signal locality (i.e., no faster-than-light signaling) as a set of inequalities, and they make the important observation that these inequalities are open to experimental test. As Roy and Singh point out, numerous authors (including themselves [2]) have demonstrated that nonrelativistic quantum mechanics (NRQM) and local quantum field theory (LQFT) do not allow superluminal signaling. (For review, see Refs. [3,4].) Roy and Singh further say that "A violation of the [Roy-Singh inequalities] ... would also imply a violation of quantum theory which respects signal locality" [1, p. 2762]. However, all of the various no-signaling proofs can be seen to depend upon locality assumptions which could be construed as extraneous to the formalism of quantum mechanics proper.

Proofs within the context of LQFT depend either upon assumptions about the localizability of the interaction Hamiltonian between measuring apparatus and system [3], or upon the postulate of microcausality [2,3,5,6], which states that observables at a spacelike separation always commute. Neither of these approaches really addresses the question of signal locality; the locality of the system-apparatus interaction is exactly what one has to establish in the general case, while microcausality was introduced to the general formalism of QM as an additional restrictive postulate specifically in order to ensure conformity of LQFT with relativity [7,8]. No-signaling proofs within the framework of NRQM also depend upon the assumption that the effects of measurement are fully localizable. This assumption can be expressed in various ways: for instance, by using the reduced density matrix to compute probabilities and expectation values in spacelike separate subsystems [9]; by allowing observables acting on spacelike separate subsystems to commute [10]; by allowing joint probabilities to be defined for spacelike separate observables [11]; or by directly working out the consequences of a local system-apparatus interaction Hamiltonian [12].

These arguments make it clear that one cannot exploit nonlocal correlations by means of purely dynamically localizable measurements in order to violate signal locality, in spite of some early suggestions that this might be possible [13]. (That, in effect, would amount to a violation of the second law of thermodynamics.) However, they leave entirely open the possibility that some hypothetical apparatus might have nonlocal effects upon the multiparticle system; as far as we know, this is not generally prohibited within QM. It is true that any procedure carried out by humans must involve steps (such as flicking a switch) that are manifestly local; however, it does not follow that these purely local operations cannot be coupled to nonlocal processes in such a way as to produce a violation of relativity.

Should such hypothetical nonlocal observables happen to commute in their action on the global system, then the proofs cited above that rely upon commutativity (such as [4]) show that there would be no signaling. However, we do not know what would happen in the case of noncommuting nonlocal operators. Whether there are such remains to be determined by further experimental and theoretical analysis. In this context, it obviously would be question begging to rule them out simply because they might violate relativity. Indeed, with the clarification afforded by the above-mentioned proofs we can now say that the problem is just to examine this possibility.

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