Spatial Locality is the hidden variable in entanglement experiments

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Abstract

In a recent *Nature* article, Hensen *et al*. reported that they have accomplished a "loophole-free" test of Bell's theorem. The authors speculated that further improvements in their experimental design could settle an 80 years debate in favor of quantum theory's stance that entanglement is "action at a distance". We direct attention to a *spatial* aspect of locality, not considered by Bell's Theorem nor by any of its experimental tests. We refer to the possibility that two particles distancing from each other could remain spatially disconnected, even when they have distanced enough to ensure that information between them was transmitted faster than the velocity of light. We show that any local-deterministic relativity theory which violates Lorentz's contraction for distancing bodies can maintain spatial locality. We briefly note that the recently proposed Information Relativity Theory satisfies the aforementioned condition, and that it predicts and explains several quantum phenomena, despite being local and deterministic. We conclude by arguing that quantum entanglement is not nonlocal and that the unnoticed spatial dimension of locality is in fact the hidden variable conjectured in the seminal EPR paper.

Keywords: Entanglement; Nonlocality; Bell's Theorem; Quantum Theory; EPR; Lorentz contraction, Information Relativity.

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I. Introduction

Recently, Hensen *et al.*[1] reported a test of Bell's Theorem[2,3] in which two electrons' spins were entangled while at distance which ensured that the interaction between the electrons was faster than light. Hensen *et al*. speculated that further improvements in the implemented event-ready scheme[4], with higher entangling rates, could settle the 80 years debate between the stance of quantum theory, positing that quantum entanglement is nonlocal, and the stance of Albert Einstein, who strongly objected the possibility of action at a distance[5], calling it "spooky"[6]. In this short article we shall demonstrate that the stance of quantum theory regarding the impossibility of a local realistic account for entanglement is incorrect, and that the conjecture made by Einstein, Podolsky and Rosen[5] that entanglement could be the result of some hidden local variables is correct.

II. Spatial Locality

We direct attention to a *spatial* aspect of locality, not considered by Bell's Theorem or by any of its experimental tests, including the recent test by Hensen *et al*[1, 7-10]. We refer to the possibility that two distancing particles could remain spatially disconnected, even when distanced enough to ensure that information between them was transmitted faster than the velocity of light. We ascribe the neglect of a probable spatial locality between distanced particles to its counter-intuitive nature and to the fact that it contradicts the Lorentz contraction predicted by Special Relativity. However, our intuitions are largely gained by observations of large and slow objects, and thus cannot be extrapolated automatically to the behavior of small particles moving and spinning with high velocities. Moreover, the contradiction between the possibility of particles maintaining spatial locality and the Lorentz contraction should not be a source of worry, especially since the Lorentz contraction is in contradiction with Quantum Theory itself[11,12].

We interpret Hensen *et al*.'s findings as strong evidence against the *temporal* aspect of locality, but not against its *spatial* aspect. We argue that any realistic relativity theory which predicts *length extension* between distancing particles cannot be dismissed by Bell's theorem as candidate for explaining entanglement.

III. The Possibility of Local Realistic Entanglement

To substantiate the aforementioned argument, consider a system in which two particles A and B distance from each other along the x axis with constant velocity $\beta\ (= \frac{v}{c})$. Denote the radius of particle B in its rest-frame by Δx_0.

For an inertial system, as the one described above, the relativistic length transformation could be given by a relationship of the form:

$$\Delta x = \Lambda_x(\beta)\, \Delta x_0 \qquad \ldots (1)$$

Where Δx is the length of particle B along the *x*-axis in the reference-frame of particle A, and $\Lambda_x(\beta)$ is a length-transformation factor.

Now consider the set of all continuous and well-behaved local and deterministic relativity theories, in which $\Lambda_x(\beta)$ satisfies the following conditions:

$$\Lambda_x(0) = 1 \qquad \ldots. (2)$$

$$\text{For } \beta \geq 0, \quad \frac{\partial \Lambda_x(\beta)}{\partial \beta} \geq 0, \qquad \ldots. (3)$$

$$\Lambda_x(1) = \infty \qquad \ldots. (4)$$

Condition (2) ensures the invariance of Δx_0 if the two particles are stationary with respect to each other. Conditions (3) and (4), contrary to the Lorentz contraction, prescribe that the spatial dimension of particle B relative to particle A will continually "stretch" with positive β values, approaching ∞ as β approaches 1.

In a theory satisfying the aforementioned conditions, local entanglement becomes feasible even when temporal-locality has been eliminated. It is easy to show that for any distance *d* between A and B, conditions (1)-(4) guarantee the existence of a critical velocity $\beta^*(d)$, above which the *relativistic stretch* of particle B in particle A's reference-frame will be larger than *d*.

The conditions (1)-(4) are in fact satisfied by my recently proposed Information Relativity theory (IR). In IR the length transformation is given by $\frac{\Delta x}{\Delta x_0} = \frac{1+\beta}{1-\beta}$ [13-15]. Thus given a sufficiently high velocity, although distancing from each other, two particles could remain spatially connected. We call this type of locality "spatial locality" to distinguish it from the common use of the term, which concerns only temporal (not faster than light) locality. In recent articles we have also shown that despite being local and deterministic, IR is successful in predicting and explaining several key quantum results, including matter-wave duality, quantum entanglement, quantum criticality and quantum phase transition[14-17]. We have also shown that IR's gravitational version[18] is successful in predicting and explaining the strong force, as well as quantum confinement and asymptotic freedom, two phenomena that are currently predicted only by quantum chromodynamics (QCD)[19-21]. All the above mentioned asserts to us that our conclusion regarding the "spatial loophole" of Bell's inequality and its experimental tests is valid, and that Einstein's stance, as articulated in the seminal EPR paper is correct.

III. Concluding Remarks

We have argued that while Bell's theorem disqualifies temporally-local theories from being candidates for reproducing the results of quantum theory, it cannot equally forbid spatially-local theories. We demonstrated that local realistic relativity theories which predict length extension between distancing particles cannot be dismissed as candidates for explaining quantum entanglement, neither by Bell's theorem, nor by its experimental tests. In addition, we pointed out that Information Relativity theory, which satisfies the aforementioned condition, does in fact predict and explain quantum entanglement, as well as several other quantum phenomena, despite being local and deterministic.

It is worth noting that the conclusion that Bell's theorem cannot forbid local realism was also reached by I. V. Volovich and his colleagues[22, 23]. By using a completely different theoretical approach, they showed that the inclusion in the quantum mechanical formalism of a standard space-time structure might render the theory consistent with local realism.

We conclude by emphasizing that the aforementioned analysis, together with the demonstrated success of Information Relativity in predicting and explaining quantum phenomena, constitute strong indications that entanglement is not nonlocal and that the hidden variable conjectured in the EPR paper is the *spatial dimension of locality*, which, assumingly for different reasons, has went unnoticed by John Bell, Albert Einstein and others.

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