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EPISTEMOLOGICAL LETTERS
LETTRES EPISTEMOLOGIQUES
EPISTEMOLOGISCHE BRIEFE

Hidden Variables and Quantum Uncertainty
(Written Symposium, 35th Issue)

Variables cachées et indéterminisme quantique
(Symposium écrit, 35ème livraison)

Verborgene Parameter und Quanten-Unbestimmtheit
(Schriftliches Symposium, 35.Heft)

December 1983 Décembre

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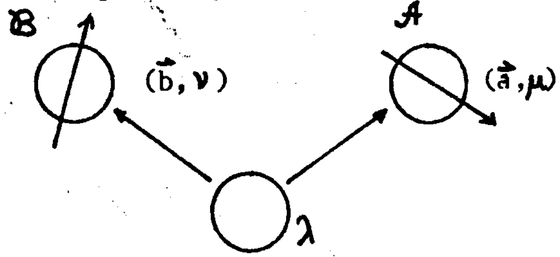
suite au verso !
continuation overleaf !

69.0 N. Hadjisavvas – The Role of the "Hidden Variables" of the Apparatus in Bell's Theorem

It has been frequently argued, at least as a reasonable hypothesis, that if the hidden variables of the measuring devices were taken into account, then one could probably escape from the conclusions of Bell's theorem.*

There exist demonstrations of Bell's theorem that show, explicitly or implicitly, that this is not possible[1]. In this letter we intent to show, as a stronger result, that if one accepts Bell's description of reality and locality, then the hidden variables of the devices can play absolutely no role in the determination of the results of a measurement of Bell's type.

Let us reproduce briefly the description of the experiment used by Bell. A fixed preparation produces pairs of particles (α,β). It is supposed that the quantal state describing a statistical ensemble of such pairs has total spin 0, and is such that α,β "move" in different directions towards two measuring devices $\mathcal{A},\mathcal{B}$, measuring the spin along directions $\vec{a}$, $\vec{b}$ respectively.



For reasons of simplicity, we suppose that the particles α, β and the apparatuses $\mathcal{A}$, $\mathcal{B}$ constitute a closed system. In particular, a , b are constant throughout measurement.

Now we make the following hypothesis:

a) The system of the two particles, at a moment t_o before interaction with the apparatuses, is completely described by an intrinsic state λ (the meaning of "complete description" will appear in hypothesis (c)).

b) At the same time, each measuring device can be completely described by a pair $(\vec{a},\mu)$ (respectively $(\vec{b},\nu)$)

*) See, for instance, the very recent (3).

where $\vec{a}$ (resp. $\vec{b}$) is the direction of spin measurement, and μ (resp. ν) represents a set of values of all other possible parameters, hidden or not. Furthermore we suppose that μ and ν are independent, i.e. the value of μ by no means determines the value of ν.

c) (Determinism + locality). The result A of the spin measurement of a particle α by the measuring device $\mathcal{A}$ is completely determined by the values at time t_0 of λ, $\vec{a}$, μ (λ being the intrinsic state of the pair from which the particle α comes). In particular, A does not depend on the direction $\vec{b}$ chosen for $\mathcal{B}$, neither on its hidden variable ν. It does not even depend on whether the measurement by $\mathcal{B}$ effectively takes place. So we can write $A(\lambda, \vec{a}, \mu)$. In analogy, the result B for $\mathcal{B}$ is only a function of λ, $\vec{b}$, ν, and we can write: $B(\lambda, \vec{b}, \nu)$.

These hypotheses being made, we now assert that the dependance of A and B on μ and ν is illusory. In fact, A and B can only depend on $(\lambda, \vec{a})$ and $(\lambda, \vec{b})$ respectively. In order to prove this, we argue as follows.

Consider an individual pair (α, β), described by the intrinsic state λ. So let the result of spin measurement by apparatus $\mathcal{A}$ be $A(\lambda, \vec{a}, \mu)$. As we said earlier, this result does not depend on what is happening in apparatus $\mathcal{B}$. So if $\mathcal{B}$ were disposed so as to measure the spin of β in the same direction $\vec{a}$, the value $A(\lambda, \vec{a}, \mu)$ would be the same as before. So let $B(\lambda, \vec{a}, \nu)$ be the value of B in this eventuality. Since the statistical ensemble of pairs (α, β) was prepared in a quantal state of total spin 0, one knows (as an experimental result, or as a consequence of Quantum Theory) that for a given pair (α, β) one has

$$A(\lambda, \vec{a}, \mu) = -B(\lambda, \vec{a}, \nu) \qquad (1)$$

Now, if the intrinsic state of $\mathcal{A}$ were not $(\vec{a}, \mu)$ but rather $(\vec{a}, \mu')$, the results of the measurement would be $A(\lambda, \vec{a}, \mu')$. But again, let us suppose that $\mathcal{B}$ were disposed to measure the spin of β in the direction $\vec{a}$, and that its hidden variable is again ν (we can make this hypothesis, since we supposed that ν is arbitrary and does not depend on μ). Then we shall have again

$$A(\lambda, \vec{a}, \mu') = -B(\lambda, \vec{a}, \nu) \qquad (2)$$

A comparison with relation (1) shows that $A(\lambda, \vec{a}, \mu) = A(\lambda, \vec{a}, \mu')$. Thus A is independent of μ, and one can write simply: $A(\lambda, \vec{a})$. Analogously we find $B(\lambda, \vec{b}, \nu) = B(\lambda, \vec{b}, \nu')$ and we can write $B(\lambda, \vec{b})$.

We thus proved our assertion, i.e. that in experiments of Bell's type the variables of the measuring devices can play no role in the determination of the results of the measurement.*) In particular, it is impossible, by introducing a suitable distribution of the perturbations due to the apparatus, to refind the quantum theoretical results, without sacrifying the locality condition. Any dependance on the hidden variables of the apparatus can only destroy quantum correlations, and not create them. This, we think, is a full answer to some questions raised earlier by F. Bonsack ([2], p.8), and to some criticisms made against Bell's theorem.

Nicolas Hadjisavvas,
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(1) J. Bell, in "Foundations of Quantum Mechanics", Proc. Int. School of Physics "Enrico Fermi", Varenna (1971)

(2) F. Bonsack, in Epist. Lett., Livr. 8, 15.0, p.8.

(3) W.M. de Muynck, Phys. Let. 94A, 73 (1983).

*) Note that the result is valid independently on whether or not the directions of spin measurements by $\mathcal{A}$ and $\mathcal{B}$ are parallel. It remains valid even if only the one of the two devices is actually in place.