Review of: "Bell's theorem is an exercise in the statistical theory of causality"

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Bell's theorem is one of the deepest results of theoretical physics, aiming at solving the important theme of discussion between Albert Einstein and Niels Bohr: Is quantum mechanics our final, complete theory of reality, or is our world compatible with some deeper theory, preferably one that is local, in agreement with relativity theory, and realistic, in agreement with a notion that many people possess? And the corresponding Bell experiment, for which the 2022 Nobel prize in physics was given, may be seen as a final test of this question.

The present article concentrates on the derivation of Bell's theorem. It gives a derivation based on the modern theory of causality, which has close links to statistical theory, but also has a somewhat different basis; see [1]. However, the theory of Directed Acyclic Graphs (DAGs), referred to by the author, can be seen as a purely statistical theory.

The article's point of departure is a model of the well-known Bell experiment, where the settings A and B and the corresponding outcomes X and Y are seen as discrete random variables, and where, given certain hidden variables, fairly obvious independence statements are assumed. A crucial citation is as follows:

'In the theory of graphical models, one knows that such models can be thought of as deterministic models, where the random variable connected to any node in the DAG is a deterministic function of the variables associated with directed links to that node, together with some independent random variable associated with that node.'

Here I miss a concrete reference to the theory of graphical model, and I have a feeling that at least some implicit assumptions are made. One solution might have been to appeal to Definition 1.2.1, page 34 in [1]: It seems that A, B, and the hidden variable are seen as Markovian parents of the outcomes X and Y. This must be seen as a weak assumption relative to the graph given, however.

The article is partly written in response to a series of papers by Marian Kupczynski, and the author claims that it is absolutely clear that Kupczynski's model is of the stated form. This makes the derivation in the article of independent interest.

The derivation itself proceeds by arguing that the model assumptions made imply the well-known CHSH inequality, which can be seen as the basis for the experimental tests of the Bell theorem. Such a derivation is important in the light of the fact that it now seem to be universal agreement that loophole-free experiments have shown violations of this inequality in practice.

The important problem of explaining these violations, remains to be solved. Most physicists seem to land on some sort of explanation assuming non-locality, which may be strange. In my view, there are two alternatives. Bryan Sanctuary has recently [2] advocated for a theory extending quantum mechanics in the sense that, given what he calls hyper-helicity, the spin components no longer take the values -1 and +1. In my own theory [3] I have no extension of quantum mechanics but assume that any observer is limited in the sense that he or she can not have an unlimited number of variables in his or her mind at the same time. This limits the observer in his or her endeavors to put up and verify models that lead to the CHSH inequality, which also includes the models that are discussed in the present article. (Unfortunately, the article [3] contains some errors, which are now corrected in [4].)

References.

[1] Pearl, J. (2009). Causality. Models, Reasoning, and Inference. 2. Edition. Cambridge University Press, Cambridge.

[2] Sanctuary, B. (2023). Spin with hyper-helicity. Preprint.

[3] Helland, I. S. (2022). The Bell experiment and the limitations of actors. Foundations of Physics 52, 55.

[4] Helland, I. S. (2023). On the Foundation of Quantum Theory. The Relevant Articles. Elivia Press. Chisinau, Moldovia. To appear.