# Commonsense local realism refutes Bell's theorem

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**Abstract:** With Bell (1964) and his EPR-based mathematics contradicted by experiments, at least one step in his supposedly commonsense theorem must be false. Defining commonsense local realism as the fusion of local-causality (no causal influence propagates superluminally) and physical-realism (some physical properties change interactively), we eliminate all such contradictions and make EPR correlations intelligible by completing the quantum mechanical account in a classical way. Thus refuting the famous inequality at the heart of Bell's mathematics, we show that Bell's theorem is limited by Bell's use of naive realism. Validating the classical mantra that correlated tests on correlated things produce correlated results without mystery, we conclude that Bell's theorem and related experiments negate naive realism, not commonsense local realism.

## 1 Notes to the Reader

**a. Pre-reading:** EPR and Bell (1964), available on-line, are taken as read; EPR to the start of page 778, Bell to his equation (15). Other texts are also available via hyperlinks in *References.*
**b. Notation:** $(\vec{u}, \vec{v})$ denotes the angle between vectors $\vec{u}$ and $\vec{v}$. $\vec{u}\cdot\vec{v}$ is their inner product.
**c. Results:** All our results accord with the sound experimental findings of others, and no such findings accord with Bell's theorem or related inequalities.
**d. Errors:** Please report errors and typos; correspondence, suggestions, etc., are welcome.
**e. Key words:** equivalencies, operator $Q$, left-to-right precedence.

## 2 Introduction

Embracing commonsense local realism (CLR), the fusion of local-causality (no causal influence propagates superluminally) and physical-realism (some physical properties change interactively), we endorse EPR's (1935:777) condition of completeness: Every element of the physical reality must have a counterpart in our physical theory. But we reject the naive realism in Bell (1964; 2004) and the nonlocality[1] associated with Bell's theorem and his impossibility proof.

> "Indeed it was the explicit representation of quantum nonlocality [in de Broglie-Bohm theory] which started a new wave of investigation in this area [of local causality]. Let us hope that these analyses also may one day be illuminated, perhaps harshly, by some simple constructive model. However that may be, long may Louis de Broglie continue to inspire those who suspect that what is proved by impossibility proofs is lack of imagination," (Bell 2004:167).

Believing that natural physical variables[2] and their local interactions alone account for the correlated results produced by correlated tests on correlated things, we proceed as follows: After

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[1] "Bell's theorem asserts that if certain predictions of quantum theory are correct then our world is non-local," http://www.scholarpedia.org/article/Bell%27s_theorem. NB: We accept that those predictions are correct.

[2] Unlike *observables,* natural physical variables are *beables* – elements of reality, things which exist, their existence independent of *measurement* and *observation* – after Bell (2004:174).

foreshadowing our case against a wholly mathematical version of Bell's theorem, we define our terms in the context of EPRB, our code for the experiment in Bell (1964). We then develop operator $Q$ to formalize the equivalencies and elements of physical reality that we associate with EPRB particle-device interactions. Bell's theorem is then refuted mathematically before we discuss $Q$'s significance and demonstrate $Q$'s utility in a 3-particle setting. We end with firm conclusions.

## 3 Bell's theorem and our foreshadowing

Based on Bell's equations 1964:(1)-(3), (12)-(14), with $\langle AB\rangle$ replacing $P(\vec{a},\vec{b})$ to avoid confusion with other functions, here's a wholly mathematical version of Bell's theorem:

$$\textbf{If } A(\vec{a},\lambda) = A^{\pm} = \pm 1;\ B(\vec{b},\lambda) = B^{\pm} = \pm 1 = -A(\vec{b},\lambda);\ \textstyle\int d\lambda\,\rho(\lambda) = 1; \tag{1}$$
$$\textbf{then } \langle AB\rangle \equiv \textstyle\int d\lambda\,\rho(\lambda)A(\vec{a},\lambda)B(\vec{b},\lambda) = -\int d\lambda\,\rho(\lambda)A(\vec{a},\lambda)A(\vec{b},\lambda) \neq -\vec{a}\cdot\vec{b}. \tag{2}$$

(2) is based on treating $\lambda$ as a single continuous parameter (Bell 1964:195), and the $\neq$ in (2) is Bell's famous inequality,[3] introduced via the impossibility-claim in the line following his 1964:(3). This claim, based on his 1964:(15) and its dénouement, brings us to Bell's (2004:147) explanation:

> "To explain this dénouement without mathematics I cannot do better than follow d'Espagnat (1979; 1979a)." Our paraphrase of d'Espagnat (1979:166) follows:
>
> 'One can infer that in every particle-pair [every pair of twins], one particle has the property $A^+$ and the other has the property $A^-$, one has property $B^+$ and one $B^-$. Such conclusions require a subtle but important extension of the meaning assigned to our notation $A^+$ . Whereas previously $A^+$ was merely one possible outcome of a measurement made on a particle, it is converted by this argument into an attribute of the particle itself.'

Concluding that Bell's theorem is based on this restrictive assumption of naive realism, we reject such a restriction when working to understand EPRB. We see no reason to accept that the 'outcome of a measurement' here preexists (ie, exists before) the 'measurement'. On the contrary, we allow that the 'outcome of a measurement' or interaction may reveal the hidden preexisting equivalence class to which the 'system' belongs: thereby revealing the hidden equivalencies of any pristine correlates. Putting it simply: An operation on my twin (even an interview), may reveal something about me; yet I remain unperturbed and unbloodied by the outcome of such interactions.

> For: 'There are no *messages* from one system to the other. EPRB correlations do not give rise to signaling between noninteracting systems. Of course, however, *such correlations allow inferences* from events in one system (eg, $A^+$) to events in the other (eg, $B^-$),' paraphrasing Bell (2004:208) in our terms.

Thus, in our micro-physics here, allowing that there may be "no infinitesimals by the aid of which an observation might be made without appreciable perturbation," after Heisenberg (1930:63), we nevertheless allow that preexisting properties (beables; such as being a member of an equivalence class) may be revealed by such perturbations. So, for us: If a test on a particle reveals an associated equivalence class, then its twin, unperturbed and pristine, is (by birth)[4] a member of a similar class. Thus do we endorse EPR's (1935:777) elements of physical reality, as we will later show.

We now show that Bell's naive inference to naive realism (so different from our own, just given) leads to contradictions. Subject only to our later showing that (2) is false based on (1) alone, but as a consequence of such, we can represent Bell's crucial 1964:(15) thus:

$$1 + \langle BC\rangle = 1 - \vec{b}\cdot\vec{c} \geq |\vec{a}\cdot\vec{c} - \vec{a}\cdot\vec{b}| = |\,\langle AB\rangle - \langle AC\rangle\,|; \tag{3}$$

[3] *Famous* because it is the first inequality in a family of relations collectively known as *Bell inequalities*.
[4] Born, for example, in a spin-conserving decay.

a relation that is certainly false over the range $-\pi/2 < \phi < \pi/2$ if $(\vec{a}, \vec{b}) = (\vec{b}, \vec{c}) = \phi$ and $(\vec{a}, \vec{c}) = 2\phi$.

To derive our (3), his pivotal 1964:(15), Bell goes beyond our (1)-(2) and invokes a third unit-vector $\vec{c}$ in the unnumbered equations that follow his 1964:(14). It can be shown that Bell's theorem is limited to entities that satisfy his unnumbered equations.

So, having foreshadowed our case against Bell, and now on the way to formally refuting Bell's theorem from (1) and LHS (2) alone, we next study EPRB.

## 4 The EPRB context

> "It is a matter of indifference ... whether $\lambda$ denotes a single variable or a set, or even a set of functions, and whether the variables are discrete or continuous," Bell (1964:195). $\lambda$ may denote "any number of hypothetical additional complementary variables needed to complete quantum mechanics in the way envisaged by EPR," Bell (2004:242).

In (1), our shorthand $A^{\pm}$ ($B^{\pm}$) denotes the result that experimentalist Alice (Bob) obtains by testing a pristine spin-half particle $p(\lambda)$ $(p'(\lambda'))$[5] with a Stern-Gerlach device[6] $\widehat{A\vec{a}}$ $(\widehat{B\vec{b}})$. $\vec{a}$ $(\vec{b})$, a unit-vector in 3-space, denotes the freely-selected orientation of the principal axis; and, of course, $\vec{a}$ may equal $\vec{b}$. Then, via the spherical symmetry associated with the pair-wise conservation of spin in EPRB, we allow that $\lambda + \lambda' = 0$ prior to any test. Thus Bob's pristine particle $p'(\lambda')$ may also be represented by $p'(-\lambda)$; noting that $\lambda$ and $\lambda'$ are hidden variables.

Let $\widehat{A\vec{a}} \bullet p(\lambda)$ denote the local interaction (disturbance, test, 'measurement') that transforms $\lambda$ to $\pm\vec{a}$; ie, to a concluded transition (post-test orientation) denoting spin-up or spin-down with respect to $\vec{a}$. $\widehat{B\vec{b}} \bullet p'(\lambda')$ similarly. Thus, with the widely-separated $\widehat{A\vec{a}}$ and $\widehat{B\vec{b}}$ correlated by the angle $(\vec{a}, \vec{b})$, and with $\lambda$ and $\lambda'$ anti-correlated at birth by spin conservation, we expect the causally-independent $A^{\pm}$ and $B^{\pm}$ to be correlated, consistent with our classical mantra.

Then, in full accord with reciprocal causal independence and local-causality (ie, no causal influence propagates superluminally), a boundary condition on our analysis is this: $A^{\pm}$ is causally independent of $\widehat{B\vec{b}}, B^{\pm}, \lambda'$; $B^{\pm}$ is causally independent of $\widehat{A\vec{a}}, A^{\pm}, \lambda$. Joining Bell, we are

> "... careful not to assert that there is action at a distance," Bell (1990: 13).

So we move to address the need for a mathematics that delivers the results of local particle-device interactions *and* their equivalencies. We need a mathematical IF ... THEN ... that converts the source of our inferences (*reasoning*) to physically significant consequences (*what follows from that*) via the mathematical transmission of facts: independent of vague words and reasonings.

> "Surely the big $\widehat{A\vec{a}}$ and the small $p(\lambda)$ should merge smoothly with one another? And surely in fundamental physical theory this merging should be described not just by vague words but by precise mathematics?" after Bell (2004:190).

## 5 Operator $Q$

> "One line of development towards greater physical precision would be to have the [quantum] 'jumps' in the equations and not just in the talk – so it would come about as a dynamical process in dynamically defined conditions," Bell (2004:118). "The concept of 'measurement' becomes so fuzzy on reflection that it is quite surprising to have it appearing in physical theory *at the most fundamental level.* ... does not any *analysis* of measurement require concepts more *fundamental* than measurement? And should not the fundamental theory be about these more fundamental concepts?" Bell (2004:117-118).

[5] $p'(\lambda')$ and $\lambda'$ are used to helpfully distinguish Bob's particle from Alice's $p(\lambda)$ and $\lambda$. In EPRB, $\lambda' = -\lambda$.
[6] SGD; a device with a suitable field, detector and printer.

Allowing that a 'measurement' may reveal a once-hidden equivalence class to be a property of the 'system', we take *transformation* to be the concept 'more fundamental than measurement'. So, with $g$ an arbitrary constant, $\delta$ a delta-function (since $A^{\pm}$ and $B^{\pm}$ are discrete), and with $\Lambda$ the space of $\lambda$ and $\vec{a}$, let $Q_a \equiv Q(\lambda \to \vec{a}) = [\lambda \to \vec{a}\}$ be an operator with left-to-right precedence over adjoining operators such that

$$[\lambda \to \vec{a}\}\, g \equiv \int_{\Lambda} d\lambda\, \delta(\lambda - \vec{a})\, g = g; \tag{4}$$

$$[\lambda \to \vec{a}\}\, F(\lambda) \equiv \int_{\Lambda} d\lambda\, \delta(\lambda - \vec{a})\, F(\lambda) = F(\vec{a}); \tag{5}$$

$$[\lambda \to \vec{a}\}\, F(\lambda)\, [\lambda \to \vec{b}\}\, G(\lambda) \equiv F(\vec{a})\, [\lambda \to \vec{b}\}\, G[\vec{a}\} = F(\vec{a})G(\vec{a}). \tag{6}$$

That is: The argument $\lambda \to \vec{a}$ denotes $Q$'s transformation of $\lambda$ to $\vec{a}$, there being no requirement that $\lambda = \vec{a}$ prior to $Q$'s action. In (6), in physical terms, $[\lambda \to \vec{a}\}$ has a local physical impact on $F(\lambda)$, thereby revealing a relevant equivalence class. Then, mathematically, $Q$ brings related equivalencies to the value of $[\lambda \to \vec{b}\}\, G(\lambda)$ so that we have, as above, $[\lambda \to \vec{b}\}\, G[\vec{a}\} = G(\vec{a})$. Thus, sequentially, as $Q$'s operation on functions proceeds left-to-right, the first operation represents local physical action on the related function.

Subsequent left-to-right operations then bring related equivalencies to the remaining functions. For $[\lambda \to \vec{a}\}$ is then identifying a beable: the property of 'having an equivalence class' $[\vec{a}\} = \{\lambda \in \Lambda | \lambda \sim \vec{a}\}$ with $[. \to \vec{a}\}F(.)$ well-defined under the equivalence relation $\sim$ on $\Lambda$.

Let $P(X|Z)$ denote the normalized prevalence (the 'objective probability', for some) of $X$ given $Z$; though the term 'probability' can be misleading in a theory devoid of subjectivity. Then the above equivalencies reflect Bayesian-like updating in the expression

$$P[XY|Z) = P(X|Z)\, P(Y|XZ) = P(Y|Z)\, P(X|YZ) \tag{7}$$

when $X$ and $Y$ are causally independent: causally independent in the sense that neither exerts any direct causal influence on the other. However, like the apple and pear crop, we expect a logical connection because of the physical correlation between them. Just as here, with our $Q$, we expect equivalencies because of physical correlations.

Then, allowing that there can be no preferred reference-frame in the study of widely separated tests or disturbances, operator-precedence cannot imply operator preference here. That is, (6) may be reversed to yield

$$[\lambda \to \vec{b}\}\, G(\lambda)\, [\lambda \to \vec{a})\}\, F(\lambda) \equiv G(\vec{b})\, [\lambda \to \vec{a}\}\, F[\vec{b}\} = F(\vec{b})G(\vec{b}). \tag{8}$$

Then, from the symmetry in EPRB, the functions $F(\lambda)$ and $G(\lambda)$ in (6) and (8) must be such that $F(\vec{a})G(\vec{a}) = F(\vec{b})G(\vec{b})$; a clue to the functions that justify $Q$'s left-to-right precedence under the specified conditions. $F(\lambda) = \vec{a} \cdot \lambda$ and $G(\lambda) = \vec{b} \cdot \lambda$ are examples of such functions.

In short: $Q$ reflects our validation of EPR's elements of physical reality, defined as follows:

> "We shall be satisfied with the following criterion, which we regard as reasonable. If, without any way disturbing a system, we can predict with certainty (ie, with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality [a beable] corresponding to this physical quantity," EPR (1935:777).

That is, based on the foregoing: In testing $A(\vec{a}, \lambda)$ in the context of EPRB, let Alice find $A^+$; ie, $A^+ = [\lambda \to \vec{a}\}\vec{a} \cdot \lambda = +1$. Then, without any further disturbance anywhere, Alice can predict with certainty that $B(\vec{a}, \lambda') = B^- = -1$. For we have, modifying (6),

$$[\lambda \to \vec{a}\}\vec{a} \cdot \lambda[\lambda' \to \pm\vec{a}\}\vec{a} \cdot (\lambda') = [\lambda \to \vec{a}\}\vec{a} \cdot \lambda[\lambda' \to \pm\vec{a}\}\vec{a} \cdot (-\lambda) = [\lambda' \to \pm\vec{a}\}\vec{a} \cdot [-\vec{a}\} = -1. \tag{9}$$

So the EPR element of physical reality (the beable) in Bob's test will be $p'[-\vec{a}\}$ via the equivalence class to which the $\lambda'$ in his test belongs. Note that our result is not the result any nonlocality, nor of wavefunction collapse. Rather, our mathematics has properly specified the physically significant preexisting property $[-\vec{a}\}$ of the pristine $\lambda'$ that Bob will test; $p'[-\vec{a}\}$ being the EPR element of physical reality (the beable) that corresponds to the physical quantity $-1$ in units of $\frac{\hbar}{2}$ where $\hbar$ is the reduced Planck constant. (Incidentally, later on, the $1/2$ in the arguments of our prevalence functions is the intrinsic spin $s = 1/2$ of spin-half particles.)

To be clear, let's complement the EPR criterion with a CLR comment:

> Unsurprisingly, without in any way disturbing particle $p'(\lambda')$ with its beable $[-\vec{a}\}$ — ie, the particle $p'[-\vec{a}\}$ — we can predict with certainty the result $B^-$ of the particle's local interaction with $(\widehat{B\vec{a}})$ and its beable $\vec{a}$.

# 6 Bell's theorem refuted

> Einstein argues that 'EPR correlations can be made intelligible only by completing the quantum mechanical account in a classical way,' after Bell (2004:86). Let's see.

We have $\lambda$ relating to the spin of a pristine unpolarized[7] spin-half particle $p(\lambda)$. As such, $\lambda$ will be perturbed by $p$'s interaction with $\widehat{A\vec{a}}$. Representing that interaction by $\widehat{A\vec{a}} \bullet p(\lambda) \equiv [\lambda \to \pm\vec{a}\}$, $\lambda$ will be transformed to $\pm\vec{a}$ equiprevalently (ie, with equal prevalence) since $\lambda$ is a random parameter. So, expanding (1) in our terms:

$$A(\vec{a}, \lambda) = A^{\pm} = \pm 1 = [\lambda \to \pm\vec{a}\}\, \vec{a} \cdot \lambda, \tag{10}$$

$$B(\vec{b}, \lambda) = B^{\pm} = \pm 1 = -A(\vec{b}, \lambda) = -[\lambda \to \pm\vec{b}\}\, \vec{b} \cdot \lambda, \tag{11}$$

$$d\lambda = |\lambda| d\Omega = d\Omega;\ \rho(\lambda) = \frac{1}{4\pi};\ \int d\lambda\, \rho(\lambda) = \frac{1}{4\pi}\int_0^{4\pi} d\Omega = 1, \tag{12}$$

where $\Omega$ is a unit of solid-angle. Then, inserting (10)-(12) into LHS (2), and recalling (6):

$$\langle AB \rangle = -\frac{1}{4\pi}\int_0^{4\pi} d\Omega\, [\lambda \to \pm\vec{a})\}\, \vec{a} \cdot \lambda\, [\lambda \to \pm\vec{b}\}\, \vec{b} \cdot \lambda = -(\pm 1)(\pm\, [\vec{a}\} \cdot \vec{b}) = -\vec{a} \cdot \vec{b}.\ \text{QED; } \blacksquare \tag{13}$$

Bell's theorem, as represented in (2) above, is refuted. And the anticipated functions arising from the required equality of (6) and (8) are here as $F(\lambda) = \vec{a} \cdot \lambda$ and $G(\lambda) = -\vec{b} \cdot \lambda$.

With (13) being a significant result, we next discuss $Q$'s significance before demonstrating its utility in analyzing multiparticle experiments.

# 7 $Q$'s significance

From (1), the product $AB = A(\vec{a}, \lambda)A(\vec{b}, \lambda) = \pm 1$. So we now move to establish the consequential distribution of $\pm 1$ as a function of $\vec{a}$ and $\vec{b}$. That is, with $Z$ denoting EPRB, we combine (10) with (11) and equate the result to the prevalence relation for such binary ($\pm 1$) outcomes:

$$AB = -[\lambda \to \pm\vec{a}\}\, \vec{a} \cdot \lambda\, [\lambda \to \pm\vec{b}\}\, \vec{b} \cdot \lambda = -(\pm 1)\vec{b} \cdot [\pm a\} = \vec{-a} \cdot \vec{b} \tag{14}$$

$$= (+1)P(AB = +1|Z) + (-1)[1 - P(AB = +1|Z)]. \tag{15}$$

[7] "Each particle, considered separately, *is* unpolarized here," Bell (2004:82).

$$\therefore P(AB = +1|Z) = (1 - \vec{a}.\vec{b})/2 = \sin^2 \tfrac{1}{2}(\vec{a}, \vec{b});\ P(AB = -1|Z) = \cos^2 \tfrac{1}{2}(\vec{a}, \vec{b}). \tag{16}$$

The $\pm 1$ distributions for $AB$ and $\langle AB \rangle$ are thus:

$$P(AB = +1|Z) = \sin^2 \tfrac{1}{2}(\vec{a}, \vec{b}) = P(\langle AB \rangle = +1|Z); \tag{17}$$

$$P(AB = -1|Z) = \cos^2 \tfrac{1}{2}(\vec{a}, \vec{b}) = P(\langle AB \rangle = -1|Z). \tag{18}$$

In this way we resolve the concern of many about the opinion of Bell and others – eg, Bell (2004:243) and Bell's move there from his (9) to his (10) – that *causal independence* should equate to *statistical independence*, seen as a consequence of *local causality*.

> "One general issue raised by the debates over locality is to understand the connection between stochastic independence (probabilities multiply) and genuine physical independence (no mutual influence). It is the latter that is at issue in 'locality,' but it is the former that goes proxy for it in the Bell-like calculations. We need to press harder and deeper in our analysis here," Arthur Fine, in Schlosshauer (2011:45).

Derived from first principles, (17)-(18) deliver: $P(A^+B^+|Z) \neq P(A^+|Z)\,P(B^+|Z)$; etc. Thus *statistical independence* does not equate to *causal independence* under *local causality*, given such physical correlations as those in EPRB; nor with pear and apple crops. Rather, like the apple and pear crop discussed above, there is a physical correlation and hence a mathematical relation between them. Just as, with our $Q$, we have physical correlations and consequent equivalencies.

Comparing (14) with (13), we see that Q henceforth eliminates the need for the normalizing integral in expressions like (13); for $Q$ is a normalized operator when, as here, its arguments are normalized. We next expand the order of operations in (13) to demonstrate $Q$'s correlative power and its Bayesian-like updating:

$$\langle AB \rangle = P(B^+|ZA^+) - P(B^-|ZA^+) - P(B^+|ZA^-) + P(B^-|ZA^-) \tag{19}$$

$$= \tfrac{1}{2}\sin^2 \tfrac{1}{2}(\vec{a}, \vec{b}) - \tfrac{1}{2}\cos^2 \tfrac{1}{2}(\vec{a}, \vec{b}) - \tfrac{1}{2}\cos^2 \tfrac{1}{2}(\vec{a}, \vec{b}) + \tfrac{1}{2}\sin^2 \tfrac{1}{2}(\vec{a}, \vec{b}) = -\vec{a}.\vec{b}. \tag{20}$$

Or, reversing the operations in (13), and then expanding them:

$$\langle AB \rangle = \langle BA \rangle = -[\lambda \rightarrow \pm\vec{b}\}\,\vec{b} \cdot \lambda\,[\lambda \rightarrow \pm\vec{a}\}\,\vec{a} \cdot \lambda = -(\pm 1)(\pm\,\vec{a} \cdot [\vec{b}\} = -\vec{a} \cdot \vec{b} \tag{21}$$

$$= P(A^+|ZB^+) - P(A^-|ZB^+) - P(A^+|ZB^-) + P(A^-|ZB^-) \tag{22}$$

$$= \tfrac{1}{2}\sin^2 \tfrac{1}{2}(\vec{a}, \vec{b}) - \tfrac{1}{2}\cos^2 \tfrac{1}{2}(\vec{a}, \vec{b}) - \tfrac{1}{2}\cos^2 \tfrac{1}{2}(\vec{a}, \vec{b}) + \tfrac{1}{2}\sin^2 \tfrac{1}{2}(\vec{a}, \vec{b}) = -\vec{a}.\vec{b}. \tag{23}$$

Similar analysis delivers the correct results for GHZ (1989), GHSZ (1990), CRB (1991), so we next demonstrate $Q$'s utility via a related 3-particle experiment.

# 8 $Q$'s utility

We consider Mermin's (1990, 1990a) 3-particle variant of GHZ. Respectively: Three spin-1/2 particles with spin parameters $\lambda, \mu, \nu$ emerge from a spin-conserving decay such that

$$\lambda + \mu + \nu = \pi. \tag{24}$$

Any parameter may thus be correlatedly represented in terms of the other two. The particles separate along three straight lines in the y-z plane to interact with three SGDs that are orthogonal to the related line of flight. Let $a, b, c$ denote the azimuthal angles of each SGD's principal axis relative to the positive x-axis; let the test results be $A, B, C$; and let $\oplus$ denote xor. Then extending (6), (10), (11) and using (24)[8], we have:

$$A(a,\lambda) = A^{\pm} = \pm 1 = [\lambda \to a \oplus a + \pi\} \cos(\lambda - a), \tag{25}$$

$$B(b,\mu) = B^{\pm} = \pm 1 = [\mu \to b \oplus b + \pi\} \cos(\mu - b), \tag{26}$$

$$C(c,\nu) = C^{\pm} = \pm 1 = [\nu \to c \oplus c + \pi\} \cos(\nu - c). \tag{27}$$

$$\langle ABC \rangle = [\lambda \to a \oplus a + \pi\} \cos(\lambda - a)[\mu \to b \oplus b + \pi\} \cos(\mu - b)[\nu \to c \oplus c + \pi\} \cos(\nu - c) \tag{28}$$

$$= [\mu \to b \oplus b + \pi\} \cos(\mu - b)[\nu \to c \oplus c + \pi\} \cos(\pi - [a\} - \mu - c) \oplus - \cos(-[a\} - \mu - c) \tag{29}$$

$$= [\nu \to c \oplus c + \pi\} \cos(\pi - [a\} - [b\} - c) \oplus - \cos(-[a\} - [b\} - c) \oplus - \cos(-[a\} - [b\} - c)$$

$$\oplus \cos(-[a\} - [b\} - c - \pi) \tag{30}$$

$$= \cos(\pi - [a\} - [b\} - c) \oplus - \cos(-[a\} - [b\} - c) \oplus - \cos(-[a\} - [b\} - c) \oplus \cos(-[a\} - [b\} - c - \pi) \tag{31}$$

$$= \cos(\pi - a - b - c \oplus - \cos(-a - b - c) \oplus - \cos(-a - b - c) \oplus \cos(-a - b - c - \pi) \tag{32}$$

$$= - \cos(a + b + c). \; QED. \blacksquare \tag{33}$$

This is the correct result for the subject experiment; with Mermin's (1990a:733) 'crucial minus sign' properly delivered: For, from (33), $\langle ABC \rangle = -1$ when $a + b + c = 0$.

# 9 Conclusions

We conclude that Bell's theorem and related experiments negate naive realism, not commonsense local realism; noting that prevalences may be derived from such beables as our equivalence classes.

Making EPR correlations intelligible by completing the quantum mechanical account in a classical way, our commonsense local realistic theory also corrects the view – eg, Bell (2004:243) and Bell's move there from his (9) to his (10) – that *causal independence* should equate to *statistical independence*, seen as a consequence of *local causality*. Rather: A left-to-right chain of equivalence based on physical correlations, not causal influences, links the causally independent outcomes in (1) and in (10)-(11) and in (25)-(27) to the appropriate local-realistic expectations $\langle . \rangle$.

Working from first principles to show that Bell's work is limited by his use of naive realism, we also eliminate the source of Bell's discomfort (expressed in Bernstein 1991:84). We therefore appropriate and rephrase Bell's words:

> Perfect quantum correlations demand something like the 'genetic' hypothesis: like the triplets linked by $\lambda, \mu, \nu$ in (24). It's so reasonable to assume that the particles carry with them programs, correlated in advance, telling them how to behave. This is so rational that when Einstein saw that, and the others refused to see it, he was the rational man. The others were burying their heads in the sand. So it's great that Einstein's idea of a classical locally-causal reality works. The reasonable thing works.

Thanks to John Bell.

[8] Used in the move (28)-(29) to allow precedent operators to act on relevant variables.

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