Note to Wiseman & Cavalcanti (2015): all Bell inequalities are false; the principle of relativity is true and the world is relativistically local

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Abstract 'Experiments violating a Bell inequality [BI] thus leave ['realists'] no option: the principle of relativity is false [sic]. The world is nonlocal [sic],' Wiseman & Cavalcanti (2015). But we show that even high-school math violates a BI; in fact, all BIs—being inadequate for experiments with highly correlated outcomes—are false. Moreover: under the principle of relativity, elementary math shows that wholistic mechanics (WM)—classical mechanics extended to include Planck's constant—also violates BIs. So, with 3 ways to violate a BI—*experiment, high-school math, WM*—*true*-realists find: Bellians are *being rather silly, as Bell (1990) half-expected*; quantum correlations are wholly explicable via WM in our relativistically local world; the principle of relativity is true, nonlocality *false*. Importantly: for STEM teachers, and against popular opinion-pieces about quantum nonlocality, our results require no knowledge of QM. Let's see.

Keywords Bell's inequality, EPR-Bohm, nonlocality, relativistic causality, wholistic mechanics

1 Introduction and Analysis

1.0. (i) 'The realist camp [eg, Dürr, Goldstein, Maudlin, Norsen, Zanghì] has the following credo: Bell's theorem uses only one assumption: local causality (or 'locality' as we usually call it for short). [nb: a view that we *true*-realists also accept.] This is the only reasonable way to apply the principle of relativity for statistical theories. It is essentially what EPR assumed in 1935. They showed that operational quantum mechanics is nonlocal, and Bell showed [sic] in 1964 that adding hidden variables cannot solve the problem. Experiments violating a Bell inequality thus leave us with no [sic] option: the principle of relativity is false [sic]. The world is nonlocal [sic],' Wiseman & Cavalcanti (2015:9). (ii) 'The moral (Bell's theorem): quantum correlations falsify [sic] the hypothesis that, in any laboratory, nature carries the answer to any question which may be put to it, and answers without knowing which questions are being put elsewhere,' Wiseman (2014:469).

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1.1. (i) Against §1.0 above—nb: for the source of each *sic*, see our Appendix—this note is both an endnote and an easy introduction to Watson 2020E. (ii) Honoring David Bohm, let β denote the EPR-Bohm experiment studied by Bell (1964c): which—free-online; see References—is here taken as read. (iii) Further, reserving P for probabilities, let's replace Bell's expectation $P(\vec{a},\vec{b})$ with its identity $E(a,b\,|\,\beta)$. (iv) Then, from Watson 2020E, the underlying theory here is wholistic mechanics (WM): ie, classical mechanics (CM) extended from light-speed to Planck's constant.

1.2. We now present Bell's (1964c) inequality (BI), our related inequality (WI): and a modification of BI (WB); ie, BI-amended to show its limitation. Each is in a format for easy auditing; ie, when tested, a value exceeding zero signals failure and falsity. Thus, from Bell 1964c:(15), here's BI in our terms:

$$\text{BI: } |E(a,b\,|\,\beta)-E(a,c\,|\,\beta)|-1-E(b,c\,|\,\beta)\leq 0 \text{ [sic]}. \tag{1}$$

1.3. Then, from (1)—and with their limits—we have the following expectations:

$$-1\leq E(a,b\,|\,\beta)\leq 1,\ -1\leq E(a,c\,|\,\beta)\leq 1,\ -1\leq E(b,c\,|\,\beta)\leq 1. \tag{2}$$

$$\therefore E(a,b\,|\,\beta)[1+E(a,c\,|\,\beta)]\leq 1+E(a,c\,|\,\beta), \tag{3}$$

$$\because \text{ if } V\leq 1, \text{ and } 0\leq W, \text{ then } VW\leq W. \tag{4}$$

$$\text{So, from (3): } E(a,b\,|\,\beta)-E(a,c\,|\,\beta)\leq 1-E(a,b\,|\,\beta)E(a,c\,|\,\beta). \tag{5}$$

$$\text{Similarly: } E(a,c\,|\,\beta)-E(a,b\,|\,\beta)\leq 1-E(a,b\,|\,\beta)E(a,c\,|\,\beta). \tag{6}$$

1.4. Therefore—irrefutably from (5)-(6), and thus *never false*—here's our inequality (say, WI):

$$\text{WI: } |E(a,b\,|\,\beta)-E(a,c\,|\,\beta)|-1+E(a,b\,|\,\beta)E(a,c\,|\,\beta)\leq 0. \tag{7}$$

1.5. (i) Irrefutable (7) is also derived under WM in Watson 2020E. (ii) And here's WB:

$$\text{WB: } \tfrac{2}{3}\left[|E(a,b\,|\,\beta)-E(a,c\,|\,\beta)|-E(b,c\,|\,\beta)\right]-1\leq 0. \tag{8}$$

1.6. So let's test BI-(1), WI-(7), WB-(8) under β; across (a,c) in two zones for symmetry:

$$\text{Test-settings: } -\pi<(a,c)<0, 0<(a,c)<\pi; (a,b)=(b,c)=\frac{(a,c)}{2}=\frac{x}{2}. \tag{9}$$

$$\text{Test-functions: } E(a,b\,|\,\beta)=E(b,c\,|\,\beta)=-\cos\left(\frac{x}{2}\right), E(a,c\,|\,\beta)=-\cos(x). \tag{10}$$

1.7. (i) (9) is quite general: it allows $(a,b),(b,c)$ and (a,c) to be co-planar at any workable orientation to the line-of-flight axis. (ii) Independent of any theory, (10)'s negative-cosine—an increasing function of x for $0\leq x\leq\pi$—is a natural way to satisfy (2). (iii) However, (10) is also derived via WM under relativistic causality; see Watson 2020E.

1.8. To facilitate discussion, let the 11 unnumbered relations in Bell (1964c) be: (11a); then, below

(14), (14a), (14b), (14c); then (15a), (21a)-(21e), (23). Hereafter, B-(1) denotes Bell 1964c:(1); etc.

1.9. Then, *under* (9)-(10): (i) We can observe irrefutable WI-(7)'s compliant behavior. (ii) And if BI-(1)'s RHS exceeds zero, we can observe where BI is false. (iii) Further, we can see that WB-(8)—unlike BI-(1)—respects its RHS of ≤ 0. (iv) WB-(8) thus shows that the validity of BI-(1) is limited to settings wherein $E(a,b|\beta) \leq -\frac{2}{3}\cos(a,b)$; etc: (v) To be compared with the complete range of relations that WI-(7) accommodates—across spin-half particles and photons—without difficulty.

1.10. To observe such results—noting that && is valid code for *and*—copy and paste the whole of this next expression into WolframAlpha®: free-online; see References.

$$\text{plot}|cos(x) - cos(x/2)| + cos(x/2) - 1\&\&(2/3)(|cos(x) - cos(x/2)| + cos(x/2)) - 1$$

$$\&\&(|cos(x) - cos(x/2)| + cos(x)cos(x/2) - 1), -\pi < x < \pi$$

1.11. Then click [=]. Enjoy! (And, maybe later, continue experimenting: for physics is an experimental science that combines theory and practice as we seek Nature's laws. And WM predicts the results of idealized experiments with certainty.)

1.12. We find, under (9)-(10): (i) WI-(7) and WB-(8) are everywhere true; whereas BI-(1) is everywhere false. (ii) Further, WB-(8)—with its limiting $E(a,b\,|\,\beta) \leq -\frac{2}{3}\cos(a,b)$; etc—now makes the extent of Bell's error *quantitatively* clear, especially for Bellians. QED.

1.13. Finally—via the Appendix—let's study Bell's error with a view to its correction: to thereby provide further support for the *sics* in §1.0.

2 Conclusions

> 2.0. 'Nobody knows where the boundary between the classical and quantum domain is situated. ... More plausible to me is that we will find there is no boundary. It is hard for me to envisage intelligible discourse about a world with no classical part—no base of given events, be they only mental events in a single consciousness, to be correlated. On the other hand, it is easy to imagine that the classical domain could be extended to cover the whole. The wavefunctions [not beables in our terms; in agreement with Bell (2004:53)] would prove to be a provisional or incomplete description of the quantum-mechanical part, of which an objective account would become possible. It is this possibility, of a homogeneous account of the world, which is for me the chief motivation of the study of the so-called "hidden variable" possibility,' after Bell (2004:29-30); emphasis added.

2.1. We agree. And with *high-school* math violating BI-(1) so easily here, our 2020E conclusions are reinforced and brought to the title here. For Bell's notions of local causality—as in Bell (1964c); Bell (1975a), aka Bell (1976)—fall to the relativistic-causality in WM; itself based on elementary analysis.

2.2. Now, (unlike naive-realists): true-realists allow [concede, admit the truth] that, even in CM (eg, via Malus' experiments on light-beams in Paris, c1810), some existents change interactively. So measurement interactions may deliver new—*not pre-existing*—values. Thus, via WM and the principle of relativity, true-realists conclude: (i) Quantum correlations are wholly and locally explicable. (ii) Bell's work under β—so readily violated—is *false*. (ii) §1.0, above, is also false.

2.3. We conclude with this note to Wiseman & Cavalcanti (2015): all Bell inequalities—being inadequate for experiments with highly correlated outcomes—are false; the principle of relativity is true and the world is relativistically local. Further, with certainty: Bell *does not* show anywhere that adding hidden variables cannot solve the problem of nonlocality.

3 Appendix: Bell's error and the *sics* in §1.0

> 3.0. 'It's my feeling that all this AAD and no AAD business will go the same way [as the ether]. <u>But someone will come up with the answer, with a reasonable way of looking at these things</u>. If we are lucky it will be to some big new development like the theory of relativity. Maybe someone will just point out that we were being rather silly, and it won't lead to a big new development. But anyway, I believe the questions will be resolved. ... I think somebody will find a way of saying that [relativity and QM] are compatible. But I haven't seen it yet. For me it's very hard to put them together, but I think somebody will put them together,' Bell(1990:9-10).

3.1. Foundational claims require foundational support: backed by experiments. So, to support the *sics* in §1.0, we first return to Bell (1964c): to thereby expose and correct his error.

3.2. With B-(1) denoting Bell 1964c:(1), etc; we find: (i) B-(14) is true under β. (ii) And B-(14b) correctly leads to B-(15); ie, to BI-(1) above. (iii) However, from (7) and §1.9-1.12 above, BI-(15) is *false* under β. (iv) So B-(14b) is also *false* under β. (v) Thus, from the line below B-(14b), Bell's 'use' of B-(1) is the source of his error.

3.3. That is: under β, Bell moves from his *true* B-(14a) to his *false* B-(14b) *using* B-(1) thus:

$$A(b,\lambda)A(b,\lambda) = (\pm 1)^2 = 1. \tag{11}$$

3.4. But Bell's use of B-(1) is bound by the rule—see its introductory sentence in Bell (1964c)—that paired results are correlated *in the same instance*: while Bell, moving from B-(14a) to B-(14b), uncouples and violates such paired-results. We can therefore predict, with confidence, that Bell's analysis will apply to systems less correlated that those under β. Indeed, see §1.12, that's what we find.

3.5. So, (i) we identify Bell's error; (ii) we specify its magnitude; (iii) we demolish all Bell inequalities on the same grounds; (iv) we thus eliminate the basis that Bellians rely upon to justify Bell's theorem. (v) We are consequently compelled to qualify almost every Bellian claim with a *sic*:

> 'Bell showed [sic] in 1964 that adding hidden variables cannot solve the problem. Experiments violating a Bell inequality thus leave us with no [sic] option: the principle of relativity is false [sic]. The world is nonlocal [sic],' Wiseman & Cavalcanti (2015:9). (ii) 'The moral (Bell's theorem): quantum correlations falsify [sic] the hypothesis that, in any laboratory, nature carries the answer to any question which may be put to it, and answers without knowing which questions are being put elsewhere,' Wiseman (2014:469). QED.

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