Einstein-classicality explains Aspect's experiment and refutes Bell's theorem

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Abstract With Bell's inequality refuted and his error identified [see References], we now explain Aspect's experiment and refute Bell's theorem via what we call Einstein-classicality: the union of true locality (no influence propagates superluminally) and true realism (some beables change interactively). We also remedy many of Aspect's pro-Bell comments; eg, inability to picture in 3-space, hopeless searching, vindicated nonlocality.

1. Introduction

1.0. Einstein argued that EPR correlations 'could be made intelligible only by completing the quantum mechanical account in a classical way,' Bell (2004:86). *So that's what we do* via our truly local and realistic *Einstein-classicality*: with validated (and repeatedly testable) inferences; all in 3-space (since time and gravity are not relevant here).

1.1. Watson 2018J (Bell's inequality refuted) and 2018K (Bell's error identified)—freely available, like most key docs; see References—provide an introduction to our ideas and notation in the context of EPRB. Here we use the experiment in Aspect (2004): denoted by α (honoring Aspect), α also identifies the active source $(\cdot[\alpha]\cdot)$ and the related particle-state, etc: as will be clear from the context.

1.2. As to our worldview: Physical reality makes sense and we can understand it; each beable (Bell's handy term for a physical existent) represented by a math-symbol; each interaction represented dynamically; physical operators represented by mathematical operators; each proven inference displayed and testable. In other words, taking math to be the best logic, we work to let math do the drawings [see (8)-(9), ¶2.4] and the analysis. (For help, etc: Discussion follows Analysis; and there's email.)

2. Analysis

2.0. It is this possibility, of a homogeneous account of the world, which is for us the chief motivation of the study of the so-called 'hidden variable' possibility," after Bell (2004:30).

2.1. Via Bell 1964:(2)-(3) in the above α-context, here's Bell's α-based *impossibility* theorem (1):

$$\begin{aligned}
E(a,b\,|\,\alpha) &\equiv \textstyle\int d\boldsymbol{\lambda}\,\rho(\boldsymbol{\lambda})A(a,\boldsymbol{\lambda})B(b,\boldsymbol{\lambda}) \neq \cos 2(a,b) \text{ [sic]; which is false and refuted as follows:} && (1)\\
E(a,b\,|\,\alpha) &= P(AB=1\,|\,\alpha) - P(AB=-1\,|\,\alpha): \quad \because AB \equiv A(a,\boldsymbol{\lambda})B(b,\boldsymbol{\lambda}) = \pm 1 \text{ only.} && (2)\\
&= 2P(AB=1\,|\,\alpha) - 1: \quad \because P(AB=-1\,|\,\alpha) = 1 - P(AB=1\,|\,\alpha). && (3)\\
&= 2[P(A^+B^+\,|\,\alpha) + P(A^-B^-\,|\,\alpha)] - 1: \quad \because A^+ = 1, A^- = -1, \text{ etc.} && (4)\\
&= 4P(A^+B^+\,|\,\alpha) - 1: \quad \because P(A^+B^+\,|\,\alpha) = P(A^-B^-\,|\,\alpha), \text{via symmetry.} && (5)\\
&= 4P(A^+\,|\,\alpha)P(B^+\,|\,\alpha, A^+) - 1: \quad \because A^+\,\&\,B^+ \text{are correlated via } \boldsymbol{\lambda} \text{ (Bayes Law).} && (6)\\
&= 2P(B^+\,|\,\alpha, A^+) - 1: \quad \because P(A^+\,|\,\alpha) = P(A^-\,|\,\alpha) = \tfrac{1}{2}. && (7)
\end{aligned}$$

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2.2. So we now explain Aspect's experiment and refute Bell by deriving $P(B^+ \mid \alpha, A^+)$ classically. Thus, based on Aspect (2004: Fig.1): (8) shows Alice and Bob spacelike-separated[2] as two photons separate in the α-state and interact with dichotomic polarizer-analyzers that output a number (±1). Each number allows an *If-then inference* to the *post*-interaction state of each particle; see (9).

2.3. (i) This polarization-state then allows an *If-then inference* to an equivalence relation ($\sim$, with validation) re a *pre*-interaction state of each particle: for $\sim$ denotes the equivalence relation *has the same output under the same polarizers/operators*. (ii) The operators are the dichotomic linear-polarizers $\partial_a^\pm$, $\partial_b^\pm$: ie, the principal components of Aspect's dichotomic polarizer-analyzers $\Delta_a^\pm$, $\Delta_b^\pm$. (iii) $a = a^+$ is a unit-vector, the orientation of the principal-axis of Alice's polarizer; etc. In EPRB (with spin-$\frac{1}{2}$ particles), a^- is antiparallel to a^+; in α (with photons), a^- is orthogonal to a^+; etc.

$$.\text{Alice} \ ☺ : A \equiv \pm1 \leftarrow \Delta_a^\pm \Leftarrow \tilde{q}(\boldsymbol{\lambda}) \cdot [\alpha] \cdot \tilde{q}(\boldsymbol{\lambda}) \Rightarrow \Delta_b^\pm \rightarrow \pm1 \equiv B : ☻ \ \text{Bob}. \tag{8}$$

$$[A^+ = 1] \leftarrow [a \cdot \lambda] \Leftarrow \tilde{q}(\lambda = a^+) \leftarrow \partial_a^\pm \Leftarrow \tilde{q}(\boldsymbol{\lambda} \sim a^+) \cdot [\alpha] \cdot \tilde{q}(\boldsymbol{\lambda} \sim a^+) \Rightarrow \partial_b^\pm \rightarrow \tilde{q}(\lambda = b^+) \Rightarrow [b \cdot \lambda] \rightarrow [1 = B^+] \tag{9}$$

$$\lfloor \quad \text{Alice's locale, } R_1 \quad \rfloor \qquad \lfloor \text{Source} \rfloor \qquad \lfloor \quad \text{Bob's locale, } R_2 \quad \rfloor \tag{10}$$

2.4. So, reading (9) from Alice's A^+ to Bob's B^+, here is the physical significance of our symbols: and the basis for our inferences, each being testable and consistent with locality, QM, and experiment.

#	Symbol in (9)	Physical significance of symbols and the basis for our inferences
1	$A_i \equiv A^+$	Alice's i-th result, representing $A = 1$.
2	$[A_i = 1]$	The i-th output from Alice's printer (via wifi from Alice's analyzer).
3	$[a \cdot \lambda]$	Alice's analyzer: represented by a convenient indicator-function that converts input polarization $\lambda = a^+$ to the output $A = 1$; etc.
4	$\tilde{q}(\lambda = a^+)$	Polarized photon output from Alice's polarizer $\partial_a^\pm$.
5	$\lambda = a^+$	Equality-relation in #4 inferred from [a$\cdot\lambda$] via $A = 1$.
6	$\partial_a^\pm$	Alice's dichotomic-polarizer; principal-axis a, output-channels $a^\pm$.
7	$\boldsymbol{\lambda} \sim a^+$	Equivalence-relation under $\partial_a^\pm$ by inferring from $\tilde{q}(\lambda = a^+)$.
8	$\tilde{q}(\boldsymbol{\lambda} \sim a^+)$	Pristine photon output from source $[\alpha]$ to $\partial_a^\pm$ in Alice's locale; $\boldsymbol{\lambda} \neq \lambda$.
9	$\cdot[\alpha]\cdot$	Source emitting pristine photon-pairs in the α-state.
10	$\tilde{q}(\boldsymbol{\lambda} \sim a^+)$	Pristine photon output from source $[\alpha]$ to $\partial_b^\pm$ in Bob's locale; $\boldsymbol{\lambda} \neq \lambda$.
11	$\Rightarrow$	Pristine photon, $\tilde{q}(\boldsymbol{\lambda} \sim a^+)$ under $\partial_a^\pm$, flies to $\partial_b^\pm$.
12	$\partial_b^\pm$	Bob's dichotomic-polarizer: principal-axis b, output-channels $b^\pm$.
13	$\tilde{q}(\lambda = b^+)$	Polarized photon output from Bob's polarizer $\partial_b^\pm$.
14	$\lambda = b^+$	Equality-relation in #13 inferred from $[b \cdot \lambda]$ via $B = 1$.
15	$[b \cdot \lambda]$	Bob's analyzer: represented by a convenient indicator-function that converts input polarization $\lambda = b^+$ to the output $B = 1$.
16	$[B_i = 1]$	The i-th output from Bob's printer (via wifi from Bob's analyzer).
17	$B_i \equiv B^+$	Bob's i-th result, representing $B = 1$.

[2] Alice and Bob are independent free-willed investigators. Freely accessible internationally via headphones, they chat freely to facilitate inference-validation, commentary, etc, for all. In (8)-(9), thick arrows ($\Rightarrow$) denote movement toward a local interaction, thin arrows ($\rightarrow$) point to the subsequent output (here, a transformation); etc.

2.5. For analytical convenience, we now convert the above *flow*-notation to a more physically significant *operator*-notation: a key component in our mathematics. That is, consistent with the equivalence relations $\sim$ in ¶2.3 and the mathematical consequences of operators: the flow of a photon through Bob's polarizer is replaced by the operation/action of Bob's polarizer on that photon. Thus:

$$\text{Let } \tilde{q}(\boldsymbol{\lambda}\sim a^+) \Rightarrow \partial_b^{\pm} \rightarrow \tilde{q}(\lambda = b^+) \equiv \partial_b^{\pm}\tilde{q}(\boldsymbol{\lambda}\sim a^+) \rightarrow \tilde{q}(\lambda = b^+);\ \text{etc.} \tag{11}$$

$$\therefore P(B^+ \,|\, \alpha, A^+) = P\left(\tilde{q}(\boldsymbol{\lambda}\sim a^+) \Rightarrow \partial_b^{\pm} \rightarrow \tilde{q}(\lambda = b^+) \,|\, \alpha\right) \tag{12}$$

$$= P\left(\partial_b^{\pm}\tilde{q}(\boldsymbol{\lambda}\sim a^+) \rightarrow \tilde{q}(\lambda = b^+) \,|\, \alpha\right) \tag{13}$$

$$= \cos^2(a, b)\text{: our experimentally confirmed inference,} \blacksquare \tag{14}$$

$$\text{based on events in Bob's neighborhood; etc.} \blacksquare \tag{15}$$

$$\text{Therefore, from (7): } E(a, b \,|\, \alpha) = 2\cos^2(a, b) - 1 = \cos 2(a, b);\text{etc.} \blacksquare \tag{16}$$

$$\text{So Bell's theorem (1) is false and refuted; Aspect (2004) explained: QED.} \tag{17}$$

3. Discussion

3.0. We cannot seriously believe in any theory 'that cannot be reconciled with the idea that physics should represent a reality in time and space, free from spooky actions at a distance,' after Einstein (in Born 1971:158). We join Einstein (p.172) as advocates for principle II, the Principle of Local-Action: 'the independent existence of the real state of affairs existing in two separate parts of space R_1 and R_2.' 'For we still cannot find any fact anywhere which would make it appear likely that requirement II will have to be abandoned,' after Einstein (pp.172-173). Or, re (9)-(10): let R_1 be Alice's locale, let R_2 be Bob's: then each real state of affairs exists pairwise-correlatively (via the α-state with angular momentum conserved) and independently (via the Principle of Local-Action).

3.1. As (9) expands on (8), the physical significance of our validated inferences is shown. For, in line with EPR's (1935:777) necessary condition for a *complete* theory: *every element of the relevant physical reality has a counterpart in our physical theory*. Moreover, each particle-pair is pairwise correlated via the conservation of total angular momentum: so each interaction here is pairwise bound by a *determinism* akin to *classical spin, torque, precession*; also see Hecht (1975:104) re the operation of wire-grid microwave-polarizers. Thus $\boldsymbol{\lambda}$ is a classical hidden-variable, the orientation of a particle's total angular momentum (intrinsic and extrinsic). So the particles in (9) have a common property inferred from Alice's result: each particle in this instance may be represented by $q(\boldsymbol{\lambda} \overset{\delta_a^{\pm}}{\sim} a^+)$; or succinctly by $q(\boldsymbol{\lambda} \sim a^+)$, since the operator is clear from the equivalence, here $\partial_a^{\pm}$ from the inferred a^+ via $q(\lambda = a^+)$.

3.2. That is, more formally. In (9)—consistent with Alice inferring $q(\lambda = a^+)$ from $A = 1$—we confirm $\sim$ under $\partial_a^{\pm}$ similarly: (i) polarizing-operators $\partial_a^{\pm}$ deliver this $q(\boldsymbol{\lambda})$ and any $q(\lambda = a^+)$ to the same output; (ii) it is impossible (under idealization) that an interaction with a $\partial_a^{\pm}$ might to deliver this $q(\boldsymbol{\lambda})$ and any $q(\lambda = a^+)$ to two different outputs; (iii) an equivalence relation $\sim$ therefore holds between this $q(\boldsymbol{\lambda})$ and any $q(\lambda = a^+)$ under $\partial_a^{\pm}$: ie, $q(\boldsymbol{\lambda} \overset{\delta_a^{\pm}}{\sim} a^+)$; or $q(\boldsymbol{\lambda} \sim a^+)$ under $\partial_a^{\pm}$ by implication.

3.3. Moreover, a similar equivalence holds under $\partial_b^{\pm}$. Via Bob observing $B = 1$: the equivalence relation $\sim$ holds between $q(\boldsymbol{\lambda} \sim a^+)$ and $q(\lambda = b^+)$ under $\partial_b^{\pm}$; as in (11)-(13). So, reasoning from the evidence, the experimentally validated inference in (14) follows. And—avoiding confusions between our logical implications and the causation-at-a-distance supposed by others—the correlation in (14) is consistent with the pairwise conservation of angular momentum in each and every pair.

3.4. Thus, via (10) and our insistence on locality and local explanations: the inference in (14) is based on—and explicable and testable by—events in Bob's neighborhood. For Alice and Bob are spacelike-separated: with no relevant influences between the locales; all phone calls being harmless, but handy to coordinate inference-testing, etc. So we do get away with locality: contra Bell (1990:12,13),

> 'I think you're stuck with nonlocality. I don't know any conception of locality which works with QM. So I think we're stuck with nonlocality.' '... I say only that you cannot get away with locality. You cannot explain things by events in their neighbourhood.'

3.5. Further: we accept Bohr's 'disturbance' insight in the context of interactions.

> For, as under an operator: any 'observation of atomic phenomena [may] involve an interaction with the agency of observation not to be neglected,' after Bohr (1928:580). So an interaction may disturb an unpolarized beable [eg, $\tilde{q}(\boldsymbol{\lambda})$; $\boldsymbol{\lambda}$ bold-font]—for the pristine particles are *un*polarized, per Bell (2004:82)—and transform it to a related polarized beable [$\tilde{q}(\lambda)$; λ medium-font]. In general, for us: the pristine (pre-interaction) angular-momentum orientation $\boldsymbol{\lambda} \neq \lambda$, the post-interaction polarization orientation.

3.6. Thus—defining Einstein-classicality as the union of *true locality* (no influence propagates superluminally) and *true realism* (some beables change interactively)—we: (i) affirm the existence of objective (ie, mind-and-theory-independent) properties and values for beables (which properties include equivalence relations under operators); (ii) allow that some beables may be hidden-variables; (iii) allow that beables may change interactively, per (9) and ¶3.5; (iv) reject as naive any brand of realism that negates or neglects (iii).

3.7. In this way we show that naive-realism is no longer tenable. With extreme support, "It was not denied that every observation had some influence on the phenomenon to be observed," Heisenberg (2000:118). With our more general view confirmed, 'The results of observation are not always given prior to and independent of observation,' after Zeilinger (2011:56).

4. Conclusions

4.1. With certainty: Einstein-classicality—defined here as the union of true locality (no influence propagates superluminally) and true realism (some beables change interactively)—explains Aspect's experiment and refutes Bell's famous theorem locally and realistically. Crucially, we show that the correlations in (14) arise from logical (not nonlocal) implications: consistent with true local realism and determinism under the pairwise conservation of angular momentum in each and every photon-pair; such conservation being a logical (not a nonlocal) constraint on all results and probabilities.

4.2. Against Bell: compared to our way of thinking—disproving his inequality algebraically, identifying his error, refuting his theorem—we find this matter best left to Bell's close companion. So here's Bertlmann (2017:54), with his emphasis, on Bell (with Bellian naivety re realism, and puzzlement and doubts that we do not share):

> "John was totally convinced that *realism* is the right position of a scientist. He believed that the experimental results are predetermined and not just induced by the measurement process. Even more, in John's EPR analysis reality is not assumed but inferred! Otherwise (without realism), he said, *'It's a mystery if looking at one sock makes the sock pink and the other one not-pink at the same time.'* So he did hold on [to] the hidden variable program continuously, and was not discouraged by the outcome of the EPR-Bell experiments but rather puzzled. For him *'The situation was very intriguing that at the foundation of all that impressive success* [of QM] *there are these great doubts*,' as he once remarked."

4.3. Against Aspect: en route to refuting Bell's α-based impossibility theorem (1), we provide an antidote to the following claims:

> 'I do not know how to build a picture in our ordinary space', (p.5). '*Bell's discovery is the fact that the search for such models* [nb: with supplementary parameters like ours] *is hopeless*, as we [ie, Aspect and his muse] are going to show now', (p.9). 'Quantum Mechanics conflicts with Local Realism', (p.13). 'It may be concluded that quantum mechanics has some non-locality in it, and that this non-local character is vindicated by experiments [Bell (1980a) cited]', (p.30); from Aspect (2004), with his emphasis.

4.4. We end as we began, with much remaining to be done: including a similar classical analysis of DSE, the double-slit experiment.

5. References

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