Were EPR correct after all; did Bell miss a point?

Abstract

There is still controversy in quantum mechanics over the concept of local reality and entanglement but this concept is, surprisingly, somewhat neglected by philosophy suggesting that philosophy has let slip an opportunity. This paper argues that Bell's inequality theorem overlooks two fundamental but obscure factors that seriously affect his calculations. These show that the bipartite experiments do not fit and cannot be represented by yes-no type calculations of any form. Bell's expectations thus require recalculating whereupon they give the results attained by the tests thus showing that, if anything, they demonstrate that EPR were correct in suggesting something is missing in quantum theory.

Keywords: EPR-Bell, entanglement, local reality, determinism, quantum mechanics.

1. Introduction

Uncertainty in the outcome of an experiment may not seem strange considering the nature of experiments which is to discover what happens under a set of circumstances. But given a set of identical physical conditions one should be able to predict an outcome according to physical laws – at least Einstein thought so. That is, these laws can be expressed mathematically where mathematics is supposed to be truthful to itself with an expected precise outcome every time.[1] However, due to Heisenberg uncertainty, quantum mechanics (QM) only allows probabilities of outcomes so that there is no definite answer to specific inputs. In particular, Einstein, Podolsky and Rosen (EPR) pointed out in 1935 that according to quantum theory two wave-functions each pertaining to a different system can be superimposed, causing the two functions to become 'entangled' at the point of superimposition into a joint wave-function.

EPR complained that this conflicted with what most people would expect from physics, especially if it obeys derived laws. They asked the important questions of any physical theory, is it correct and is it complete?[2] This is, of course, the basic concern of all the literature on the subject. In particular, EPR presumed that to be complete, physical theory should lead to reality (which is a subject in itself, because human senses depend on superficial observation with no certainty that what we see or hypothesize is actually true in a universal context).

They showed that mathematically, given two completely identical experiments – in other words experiments carried out on particles with supposed identical properties and initial conditions governing their motion, momentum or energy, etc – that "*It is possible to assign two different wave-functions to the same reality*". This implied that there could be no exact statement of a *real* underlying situation at

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[1] Brown (2008:2); Hardy (1929:4); Russell (1902:73);Thompson (2024)

[2] Einstein, Podolsky and Rosen (1935:777)

a specific instant, referred to as 'loss of local reality'.[3] Our act of measuring would become the determining factor thus reducing any *a priori* state acquired by the part being measured to having only a chance of affecting the outcome of that measurement. Consequently EPR concluded that the wave-function theory is not complete and that quantum mechanics (QM) needed amending.

In fact Einstein, had always believed in his maxim "God does not play dice with the universe" meaning that Heisenberg's uncertainty principle removed the definiteness of physical predictions. EPR wrote that either: "(1) *the quantum-mechanical description of reality given by the wave-function is not complete or* (2) … *two physical quantities* [with non-commuting operators] *cannot have simultaneous reality*." After all, it would seem logical, according to the human intuition of reality based on the physical laws of the time (1935), that physics should be able to predict with certainty the outcome – much as an engineer knows the rules for designing machinery that will always function a specific way (unless the machine breaks down); or an architect can rely on his mathematical knowledge that his skyscraper will be perfectly safe to live in.

Bohr, Heisenberg, Born and others disagreed that QM was incomplete. Schrödinger, not foreseeing Einstein's objection, having already raised the idea of entanglement between wave-functions which suggest the notion that two entangled points *A* and *B* could be recorded at large distances such that if *A* carried some specific factor, *B* would necessarily be affected by it wherever *B* might be, even a different galaxy. One might then imagine some hidden quantity (called hidden variable or HV by Bohm or instruction set, IS, by Mermin) carried by both particles to account for this feat. This would seem to be at variance with QM's uncertainty principles whereby individual readings depend on which out of many possible inputs interact with those of the recording device. That is, there should be no correlation unless the suggested quantum entanglement is a reality.

In 1961 John Bell calculated a set of statistics known as 'Bell's inequalities' to test the truth, Bell's idea being that if two particles can be entangled in such a way that they have opposite spins or polarisations, they can be used to check EPR's objection against the principles of QM. Specific outcomes could then be calculated for different theoretical possibilities.

Many experiments have been carried out along these lines ostensibly showing that QM beliefs are correct and EPR's objections were wrong. However, I find there are several factors that Bell overlooked and in fact his experiment suggests that EPR's objections are well-founded.

2. Bell's theorem

A problem of all man-made descriptions/theories is whether the factors deduced carry all possible interpretations and outcomes. It is therefore important to search with what I will call 'analytic

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[3] Einstein, Podolsky and Rosen (1935:778)

precision', for unexpected or hidden factors. Apparent superficial or immediate outcomes may sidetrack less obvious possibilities; it is often easy to fall back on mathematical solutions on the basis that mathematics is truthful. But mathematical truthfulness is limited by its formulation and application. As a result it may lull the unwary into a false sense of security.

In the legal profession the law is not only to lay down with absolute clarity how it is to be perceived and carried out but also to include some leadership in preempting the need for possible unforeseen extensions/problems.[4] Scientific theories should receive the same treatment; EPR-Bell is a classic example. Analysis of the sort I suggest reveals misconceptions that occur when care is omitted to consider the possible existence of obscure factors. Einstein never accepted QM's conflict with reality, nor do I, which as above, leads me to suspect that a closer study of Bell's exposition will find some flaw, not that I think there is any intention to deliberately manipulate the outcome. But I think Penrose's comment on complex numbers can be taken in general to present a mathematical physicist's point of view.[5]

> "But to me it's a very beautiful and satisfying thing—but that's because I'm a mathematician who had been already impressed by the power, elegance and even simplicity of the complex number system before learning about quantum mechanics. In fact, I rather feel that it is the appearance of the *real* numbers that should be regarded as strange, rather than the complex ones, but that is perhaps a particular mathematician's prejudice. To many mathematicians, at least, the system of complex numbers does appear as more natural and beautiful than the system of reals".

The general concept that Bell considers is a pair of particles, *A* and *B*, that at some time, t_o were correlated (entangled in a joint light-cone) for a given property, for example Stern-Gerlach spin or photon polarization. These particles separate far enough that tests can be conducted on them outside their original joint 'light-cone'; that is, a test on particle *A* can be conducted for the given property, followed by one on particle *B* shortly afterwards, but before any information travelling at the speed of light from *A* could have been passed on to *B*. Then the outcome of the separate measurements can be compared, with each measurement being independent of the other. In particular, *A* could be either spin up or down, knowledge of which is unknown until a measurement is performed on *A*. At this stage, according to QM theory, the measurement outcome is determined by an interaction between the measuring equipment and *A* – which is sometimes referred to as a collapse of the wave function;[6] a second measurement follows for part *B* before any information of the outcome of the measurement on *A* could have passed to *B*. Thus it is impossible that the outcome of the measurement of *B* could be fixed specifically by the outcome on *A*, nor could it have been fixed on the *outcome* on *A* *before* the test on *A*. However, Bell theorized, using probability theory, that predictions could be made for the

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[4] Gadamer (2006:xxix)

[5] Penrose (2011)

[6] Muthukrishnan and Roychoudhuri (2009)

outcome of a series of tests based on whether or not there is some correlation between *A* and *B* due to either hidden variables (HV) or an instruction set (IS).

These calculations are divided into two parts. The first determines the probabilities, or expected outcomes, of a set of such experiments on the assumption that the particles are connected by an IS or HV. The second part calculates the expected outcome according to QM theory (no HV or IS) and predicts a different outcome to the first set. Thus experiments can be run to see which probability is reflected in nature: that of QM theory as given in the 'Copenhagen' interpretation, or EPR's concept that the theory is incomplete. If the predictions for an IS/HV are not satisfied then the concept of entanglement must exist.

Three aspects need be explained and explored: the nature of the correlation (hidden variable or instruction set); the physical aspects of the experiments envisioned by Bell;[7] and the bases of the statistical expectations and calculations.

2.1 Bell's statistics

Using the bipartite system described above, Bell arranged his preliminary calculations by basing the statistics on a set of three yes-no type variables such as coin-tosses which he projected should provide different statistic between an HV/IS system and entanglement.

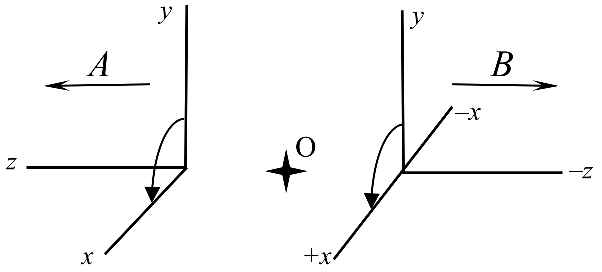

Figure 1. One possible entanglement format; A photon arrives at O and is 'split' to give two entangled parts *A* and *B* which move apart back-to-back as for a reflection.

Some essential problems should be considered, which I contend lead to a necessary reassessment of Bell's inequality in relation to EPR. These are not concerned with details of the experimental evidence but with the fundamental concept of this relationship, which should have been investigated by philosophers in accordance with de Haro.[8] First, I will assume that the experiments can be made free of any 'loopholes'.[9] The equipment can then be assumed to function faultlessly so that there can be no contact between *A* and *B,* or their source of 'entanglement', if it exists, as they travel in opposite directions from the source. This would include that the sum of *A* and *B*'s individual state values, at and

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[7] Bell (1964,1975); and e.g. Preskill (2001 Chapter 4); Gill (2014); Alford (2016)

[8] de Haro (2013:8)

[9] see *e.g.* Shimony ([2009], §4-§5)

after creation, is assumed to be evenly balanced with those of the source at their joint creation, or interaction in the case of other particles. That is, there is no change in the total energy of the system from the instant before interaction until the measurement on *A* is made; and then that this measurement has no effect on the remaining part *B* until *B* is measured – it being understood that the result of these measurements involves only the interaction between the measuring apparatus with the individual part being measured. In other words, the experiment is isolated from external influences except in the measurements. Moreover, if, say, two photons, *A* and *B*, being generated from a common source are to be similar, they must each correspond to equal parts of the original parameters: for example, half the input energy or momentum, as dissimilar energy or momentum could be interpreted as a 'loophole'. That is, due to the uncertainty principle, there could be no certainty that *A* had not changed one or more of its quantum states independently of *B*, or vice versa – the assumption being that any initial HV/IS conditions apply to both *A* and *B*.[10] The same goes for entanglement of particles such as electrons. For photons the entanglement may be through polarization: for, example left or right circular.

A further question arises on the nature of the 'split' in the case of photon pairs, which does not appear to have been established in the literature: Are the subparts separate entities or an extension/ development of a holistic system over a period of time? For example, Couteau refers to a single photon split into two, which could make sense since experiments achieve a measurement of each part, *A* and *B*, at different times.[11] But Ashok & Roychoudhuri find the divisibility of a photon an "open question", while Reid *et al.* refer to spatially separated particles.[12] Alford notes that superposition implies that the parts still form a singlet state.[12] On the other hand, according to quantum theory as developed and experimentally tested, entanglement in the QM sense means allowing each part to acquire a conditionally separate existence despite the mathematical superposition. And it also allows that the two parts can be measured separately. Yet, based on the assumption that we are investigating a single whole isolated from any external influences, *A* and *B* must be connected in the sense that each must remain faithful to the original conditions. Without this proviso, tests would be unable to arrive at a firm conclusion on QM conceptualization. Therefore, if the two parts could be recombined, in a thought experiment for example, at any time before measurement of one of them, they would have to give back the original source. It seems, then, that the actual condition of holism versus separation is unimportant, as both (holism and separation) should give the same outcome. Consequently I shall refer to either '*A*' or '*B*', or 'parts' of the (bipartite) system, and proceed without being concerned whether they are separated or part of a whole.

I will also briefly mention the light cone concept used by Bell. If A and B are not correlated then if A is, say spin up, there should be no method by which B should be able to coordinate to A (unless there is an IS/HV present). On the assumption such an IS/HV is absent, the outcome of a test on an

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[10] (given by λ in Bell 1964:195-6)

[11] Couteau (2018:7); Ashok & Roychoudhuri (2015:1); Reid *et al.* (2008:2); Alford (2016:1)

unentangled B should not show any correlation with the results of the test on A. To avoid the possibility of a loophole it is necessary that the test on B should be conducted before any signal from A, at the time of A’s test, could arrive at B. Thus there must be sufficient distance between the tests that the two can be carried out within this light transfer period. I shall assume this to be the case for the experimental results, that is, that no loopholes of this nature exist. In order to ensure the tests cover the possibility of an IS, the randomness of the actual experimental outcomes has to be palpable. This is achieved in Bell’s case (see also Alford, Gill)[12] by calculating the statistics provided by simple yes-no type of outcomes, as for example, the sets of three hidden coin tosses. If an HV or IS is carried by the two parts, these would give a significantly different outcome to the number of up-spins compared to down-spins, or left polarisations to right polarisation, from the expected probability of a half if no IS or HV was present.

A clear and easy analysis of this concept is provided by Mermin (1981 and 85) which has been much lauded (more than 200 citations) because of its statistical simplicity. I use it because this simplicity, on easy analysis, shows up the misconceptions in Bell’s (and Mermin’s!) concept. But before turning to Mermin I will first explain Bell’s calculation using Alford.[13]

With an IS/HV being present the possibilities are HHH HHT HTT TTT (H-heads, T-tails) so that the probability of obtaining the same side up at least once occurs in the first case for all of the three possible arrangements, HHT only for one of the three arrangements and so on for the other two. Statistically this type of operation gives an expectation of obtaining the same side up (two heads or two tails) in 8 out of 12 results. Similar results appear in Preskill, and Gill. If the tests should produce a different result, that will show that there is no IS. For example, a 50:50 out-come will imply QM entanglement without an IS, thus contradicting EPR.

To fit a triple yes-no system Mermin requires “that the various states or conditions of each particle can be divided into eight types:[14] RRR, RRG, RGR, RGG, GRR, GRG, GGR, GGG” to be recorded in corresponding recording equipment. These codes represent a total possible state for each particle, for example, in the case of an electron, state spin-up or down; or, in the case of a photon, left or right circular polarization (LHP and RHP respectively). R and G then refer to a particular condition/ constituent creating that state.

To achieve experimental randomness each recording-device has a switch that can be randomly set to any one of three positions independently of the experimenter. A first measurement can be made for either particle, say the left (*A* in Figure 1), and a second measurement for the right, *B*, some time thereafter. Each particle will trigger either a Red or Green light to flash depending jointly on whether the recorder has been randomly set to position 1, 2 or 3, and whether the corresponding constituent part

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[12] Alford (2016); Gill (2015)

[13] Alford (2016:5)

[14] Mermin (1981:403) amended in 1985.

of its state is represented by R or G. For example, suppose the left device receives its particle first, and was randomly set to switch 2: if it flashes green it is noted as 2G. Similarly, the other recorder flashing later on receipt of particle *B* may give 3R – colour red with switch set randomly to 3. The result is recorded as 23GR. If in Mermin's test system the recorders are both set to the same switch, they always record the same colours,[15] e.g. 22GG where if one constituent G stands for coding spin up or, say, LHP, the other G stands for spin down or RHP. That is Mermin has set his test for ease of reading so that if say, RRG for one particle moving one way stands for spin up, RRG on the other, moving oppositely, is spin down. The trial is run thousands of times and the recordings listed.

With this formulation it is possible to calculate the probable statistical outcome of the experiment. For example, if the particles carry an 'instruction set' that can be coded RGG, the switch may be set to 1, 2, or 3 so that the result will be, say, 1R from one recorder and maybe 3G from the other. Neglecting the possibility of the sets RRR and GGG for the time being, the possible outcomes of each run (for the set RGG) are 11RR, 12RG, 13RG, 21GR, 22GG, 23GG, 31GR, 32GG, 33GG from which it is easily seen that the probable outcome is 5/9 that each recorder will record the same colours. A similar result occurs for the other mixed colour sets (*e.g*. RRG, GRG etc.). If RRR and GGG are included then the expectation values of same colours being observed in these two cases are 9/9. That is, if both particles *carry the same 'instruction set'* the same numbers will always give the same colours in the experiment, e.g. 1R,1R (see §4 Table 1).

Overall then, Mermin calculates the probability of obtaining these same colour results from the two recorders if an IS exists should be 48/72 or 2/3.[16] The actual experiment over a very large number of runs, yields 'same colour results' very close to ½ , that is 36/72. Thus, according to QM theory, the experimental results using the above type of statistics do not match the theoretical HV/IS predictions implying there is no IS or HV involved. Quantum entanglement is therefore a peculiarity of QM.

3. Some general problems: reflective image and coordinates

If the system under investigation is holistic, this results in the two parts being what I shall call '*reflective images*' of each other as described below in terms of human spatial perception. Equally, if the system consists of two separate photons connected only by the source conditions (*N* in Bell's paper) they must, to maintain the original specifications, also be 'reflective images' of each other.

To see the importance of 'reflective image': looking into a mirror everything we see becomes reversed horizontally with respect to ourselves. If we point our right hand thumb towards the mirror then curling-up our fingers forms a 'right hand (RH) screw'. But the image in the mirror reverses the thumb direction in our view to make it the equivalent of a 'left Hand (LH) screw'. Note that the rotation

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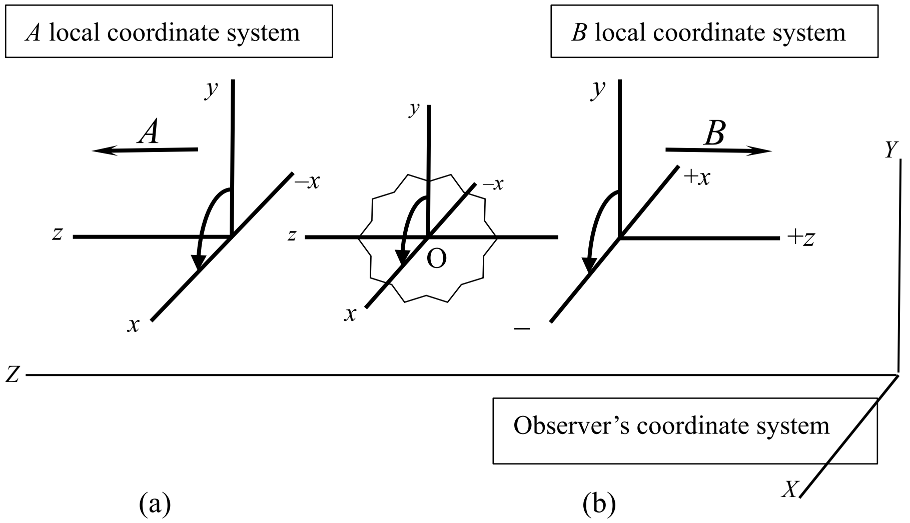
[15] Mermin (1985:46)

[16] Mermin (1981:402)

itself does not change direction, it is only the thumb which points out of the mirror that indicates the LHS condition. Now take the source particle, O in Figures 1 and 2 with, say, LH circular polarization LHP, seen from its direction of travel as anti-clockwise, and let it split. The two parts must rotate in the same direction; that is, one travels along a z-axis in the $+z$ direction in which case it has LH rotation seen as anti-clockwise from its source, O in Figure 1. Then the other must travel with the same rotation but this will be in the opposite, right hand (RH), clockwise direction *as seen from the source*, it travels in the $-z$ direction from the source, as otherwise the actual rotation of one part would have to physically change direction requiring energy to do so. This would require an extra energy input as the source photon split, contrary to the above conservation of energy assumptions. Thus the only difference between the parts and the source is the direction of propagation of the two parts A and B.

To clearly identify the polarization, taking into account the three dimensional nature of human perception (irrespective of any QM ideas), an external (to the bipartite system) and overall observation coordinate system is required, given here as (X, Y, Z) arbitrarily taken in Figure 1 as coinciding with A's local coordinates. A and B then move through this system. Experiments carried out on the two parts can only be carried out according to the experimenter's frame of reference, taken here as the (X, Y, Z) system. From this overall coordinate system, looking along the $+Z$ axis coinciding with the +z axis of the A part, the rotation has not changed. But for each part, in terms of its *local* axis, A 'would see' his rotation (circular polarization) still LHP, and B would 'see' his own rotation RHP. Thus one part appears as a *reflection* of the other. But each looking back to the other would not notice any difference between their rotations – hence my term 'reflective image'.

This connection between the two parts, I suggest, then forms an instruction. That is, this instruction is merely the quantum 'beables' or state of the original particle *before* the bipartition because it is *unaltered by partition*.



(a) (b)

Figure 2. O has circular polarization along its *z*-axis at the instant it 'splits' into two parts *A* and *B* which separate parallel and anti-parallel to O's *z*-axis. These are shown with *local* coordinates according to each frame of reference. The directions of the axes are compared to an overall observer's coordinate system *XYZ*. Hence we see for *B* that $-z$ corresponds to *Z*, *y* corresponds to *Y* and $-x$ to *X*. Note that this diagram is only an arbitrary representation as *A*'s polarization is unknown until a measurement is made, and this measurement only gives the result of the measuring interaction in accordance with the observer's coordinates.

It is clear from this form of reflection, or reflective image, that a coordinate system is essential to evaluate the experiment.[17] Indeed Preskill refers to coordinates although Bell and Mermin among others do not. [18] The mere act of 'splitting' the system into two parts travelling in different directions creating LHP and RHP requires a different spatial description for each. Describing one as 'up' and the other as 'down' does not distinguish between the two because we cannot be ertain that the one is not merely the other upside down – a form of Mach's problem where a third reference point is required. For a particle being 'split', measurements made of either part, *A* or *B*, can produce nothing more than its state at the time of measurement. Such a measurement cannot reveal the state of the original particle either before, or even at the time of its 'split' because we do not know whether *A* or *B* actually carries the same polarization (or other testable property) as the original particle – I only assume it is *A* for the sake of presentation. The entanglement can then only make sense within the ambit of the actual 'split'. Measurements made later, as in the tests, are subject to the interaction with the measuring process, and therefore QM claims that Heisenberg's uncertainty principle (a) applies to the possibility of the measurement determining the outcome – that is determining, for example, the measured polarization of a *possibly* causal (in the sense of local reality, determined, or *a priori*) state for each part; and (b) it causes an uncertainty about the states of *A* and *B* before they are measured. Therefore, it is doubly essential to consider a coordinate system when calculating how the 'beables' relate to the tests.

And here we have a QM 'smoke-screen'. According to Heisenberg's uncertainty principle only one beable/observable can be measured at any one interaction. Therefore according to QM, if one coordinate is known (is measured) then the others become uncertain; if, for example, x_A is valued, y_A and z_A would be unknown.[19] But, as one must remember, QM *is only a supposition* and therefore y_A and z_A cannot be dismissed out of hand. A supposition cannot be proved by a supposition; proof requires

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[17] In this respect I refer to Gill (2015:2-5) in which he takes a single vector to distinguish between polarizations/ spins. Since we are dealing with a polarization it is essential to know the direction of travel. Thus two dimensions are required to establish his plane and a further dimension to establish the direction, since a $\pi/2$ rotation of the plane about its π-axis turns a positive polarization vector into a negative. Thus a 3-dimensional coordinate system is required. I should add, in case the reader is aware that Mermin obviously picked this up because in his original paper (1981) he makes no mention of this problem, but in 1985 page 9 he does mention "north" and "south" spin directions. He then changes his second recorder to allow for this so that when the two particles are spin up and spin down both record the same colours. I will come back to this after the following expansion on the problem because Mermin does *not* change his calculation system to register this change. Thus: *the two systems no longer correlate*. The following paragraphs clarify the full extent of the problem.

[18] Preskill (2001:24-25)

[19] See e.g. Bohm and Aharonov (1957:1070)

confirmation from some *external* source. This type of uncertainty is clearly irrelevant because rotation, or circular polarization, or ‘up’ and ‘down’ is spatially orientated so that if the coordinates are unknown, so too must be the handedness of the polarization and the direction of travel. Therefore the only uncertainty is the direction of the polarization for *A* and *B* until measurement is made, whereupon the polarization determines the coordinates, or equivalently R or G (and with it our 3-dimensional perceptions). Furthermore up and down polarisation, which on the face appears to be ‘either-or’ cannot be decided, even in terms of the direction of *A* and *B*’s travel. For who can say if *A* is up and *B* is recorded as down, that it is not that *A* and *B* are identical with *B* merely equivalent to A upside down? It needs a third condition for *each* part to distinguish there is a difference. That is, once again, a coordinate system, as in the reflective image of Figure 1, is an absolute requirement to create probability calculations; these have no effect on an actual experiment which records only what *nature* produces. In other words, straight yes-no statistics do *not* fit the experimental statistics which require *three* factors.

4. Reassessment of Bell-Mermin

Consequently this seems to be where the oversights arise. The experiments themselves need no investigation. The measurements of *A* and *B* are made in the experimenter’s (observer’s) frame of reference, which frame must be exactly equivalent for both recorders. Thus *A*’s and *B*’s local coordinate systems must conform to that of the experimental frame. In terms of their local axes (as in Figure 1), *A*’s rotation is in the sense of a point on *A*’s *y*-axis rotating anti-clockwise (as seen from the origin) towards the *x*-axis – and thus agrees with the overall *XYZ* system whereas in terms of *B*’s local coordinate system, a point initially on *B*’s *y*-axis rotates towards *B*’s –*x*-axis (clockwise as seen from O) which in the recording frame’s (*X*, *Y*, *Z*) coordinate system would be the same as a point initially on *B*’s +*x*-axis rotating towards the *y*-axis, (*i.e.*, *y* to –*x*) see Figure 3. Thus, for the ‘reflective image’ in terms of the (*X*, *Y*, *Z*) system the –*z* coordinate corresponds to *Z*, *y* corresponds to *Y* and –*x* to *X*.

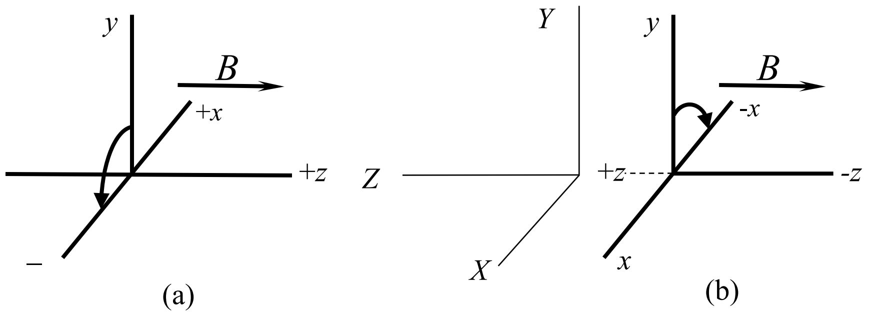

Figure 3. Diagram (a) compares *B*’s local system in the experimenter’s *XYZ* frame of reference. Converting *B* to the *XYZ* frame gives diagram (b) representing the opposite circular polarization to part *A*. The y/Y axis does not change sign but the other two axes do.

In the case of the ‘entangled reflective image’ with change of circular polarization, any IS or HV as proposed by Bohm should be considered in terms of the spatial differences caused by the ‘split’. That is, it becomes synonymous with the expression of the coordinate systems derived above. An IS/HV ‘knowing’ beforehand that it must produce different properties for the two parts for a possible experiment seems absurd. It must, as previously stated, be balanced between the two parts so that *as a whole* it corresponds to the properties of the original particle.

As, for this analysis, only the limiting values of the probabilities are considered the experimental difficulties are of no importance. The equipment is assumed to function faultlessly so that there can be no contact between the two particles or their source of entanglement as they travel in opposite directions from the source. As in section 2.1 the sum of their individual condition values, at and after creation, is assumed to equal the same values of the source of their entanglement, without any change in the total energy of the system from the instant before entanglement until the measurements on both particles have been completed. Because their parameters are correlated, if one particle is measured the other will subsequently be found to have the opposite state.

According to this formulation it is possible to calculate the probable statistical outcome of the experiment. For example, as above if the particles carry variables RGG the switch may be set to 1, 2, or 3 so that the result will be say, 1R from one recorder and maybe 3G from the other. As in section 2 and Table 1, ignoring the possible sets RRR and GGG for the time being, the probable outcome of each run is 5/9 that each recorder will record the same colours for any form of mixed colours, for example RRG, GRG et cetera. If RRR and GGG are included then the expectations of same colours for these two cases are 9/9. Overall the probability of obtaining same colour results from the two recorders is then 48/72. The actual experiment over a very large number of runs, and repeated with different methods always yields same colour results very close to ½ , that is 36/72 for Mermin’s thought experiment. Mermin claims that there is no other possible view of the experiment if the photons follow this coding system.

I shall now show that, for several reasons, Mermin’s and thus all equivalent predictions are falsely constructed. For, example Mermin states that his colours can stand for any distinguishing feature of the bipartite states of A and B. From previous comments it is clear that a coordinate system is required and therefore it seems to me obvious that this will conveniently fit the triple coin-toss or Mermin’s system. Thus we can take say R as a positive coordinate and G as its opposite/negative.

To complete his system he arranged each of the two recorders to flash *the same colour for opposite states*. For example if A records RRR this could represent left polarisation in which case RRR for B would mean right polarisation. While this choice was obviously made to use ‘same colour’ for ease of comparison, although the RRR-RRR coding seems plausible, it is, in fact, misleading in 3-dimensional space as Figure 1 repeated below demonstrates.

I will only consider Mermin’s RRR version because it is the easiest to see the problem; my comments would apply to any other instruction set, for example GGR. Thus suppose part *A* shows left-polarisation (LHP) or spin state-up or spin as RRR.[20] Then if *B* also recorded RRR, because Mermin treats the same colours in the second part, *B*, as representing opposite conditions, he would claim *B* is a state-down particle or right polarisation (RHP).

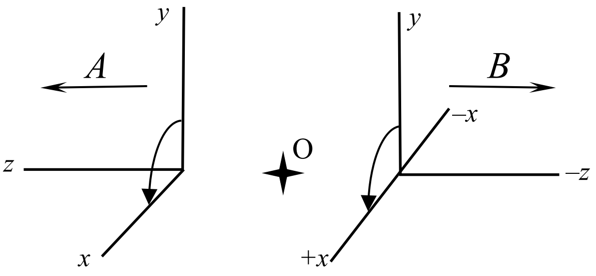

Figure 1 repeated.

Using a coordinate system to obtain RRR, Figure 1 shows that R corresponds to a positive coordinate leaving G to be the opposite, or negative coordinate. Hence it is immediately clear that *B* moving in the opposite direction, thus having opposite spin ***from B's point of view*** has coordinates (+x,+y,–z) which engender colour codes RRG and **not** RRR. Thus Mermin, by basing his statistical calculations on opposite spins or polarisations having the same codes, produces an incorrect statistical interpretation. This is clearly shown in Table 1 using Mermin's colour coding which could refer equally to Bell's and Alford's statistical calculations.

Put another way, at the separation of A and B (Figure 1) RRR for *A* is equivalent to (+*x*, +*y*, +*z*) and for B the relevant coordinates are (+x,+y, –z) or RRG where G stands for either 'not R' or –z. If the system records (in separate runs) 1R 1R; or 2R 2R; or 3R 3R; such pairs do not necessarily correspond to LHP and RHP pairs.

Before introducing Table 1, I will briefly return to Alford's statistics derived in section 2.1. On the basis that the experiment testing for an IS is set to give a completely random outcome for the coin toss statistics, for which Alford demonstrated an outcome of 8/12, one should accept that the experiment itself will *include* the possibility of the spins/polarizations – which for an IS under the coordinate extension have a probability of producing coordinated spins of only 4/12. Therefore, in calculating the expected outcome this additional statistic must be added in, giving a probable outcome of 8/12* plus 4/12* gives 12/24* (* the / sign means 'out of' not divide) for correlated spins. So again Bell's inequality fails; his mistaken reasoning is given later.

I have laid out Mermin's calculations as a table, the second and third rows of which give his concept based on the two parts being one spin-up and the other spin-down producing the same colours in his recorders. The lower part of the table corrects this idea in terms of the true state of affairs using the three-dimensional coordinate system.

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[20] Here I consider spin either as firmly found in Thompson 2024, or in Dirac's case designated by a matrix (spinor) both of which require two different constituents to distinguish their 'direction'.

Table 1. Mermin's calculation sets. (Again, interpret / as meaning 'out of').

If Mermin includes the 3-dimensional possibilities for opposite polarization or spin up/down, his same colour expectation will become ½ in line with the comment just made for Bell as follows:

Second row: the state RRG for different settings in Mermin's thought experiment with the top and bottom settings (RRG and RRG) producing the same colour combinations (RR) in columns 1 and 2, and different in column 3 (RG), *etc*. Similar sets can be obtained for the other 5 possible colour options RGR, RGG, GRR, GRG, GGR giving an overall probability of 'same colour occurring' of 6 lots of (5/9) = 30/54.

Third row: GGG and GGG or RRR and RRR will always give same colour combinations.

Fourth row: the probability for obtaining the same colours from RRG/RGG accoding to a coordinate system is only 4/9 or 24/54 for all similar sets.

The fifth row compares the remaining possibility of RRR with GGG.

States	1 1	1 2	1 3	2 1	2 2	2 3	3 1	3 2	3 3	Total for all
Same RRG Different RRG	1 1	1 2	1 3	2 1	2 2	2 3	3 1	3 2	3 3	6 of (5/9) =30/54
GGG & GGG RRR & RRR	Same	Colour	for	All						9/9 9/9
Same RRG Different RGG	1 1	1 2	1 3	2 1	2 2	2 3	3 1	3 2	3 3	6 of (4/9) =24/54
RRR & GGG	Different		for	All						9/9

Total for same colours (Mermin's probabilities) + RRR/RRR + GGG/GGG = (30+18)/(54+18)

Total for same colours (Corrected probabilities) + RRR/GGG + GGG/RRR = (24 + 0)/(54+18)

To cover all possibilities, those that Mermin excluded through his prescription must be included. These are those in which the negative coordinates unexpecedly appear. They make up the fourth and fifth rows. Thus the average for all sets is (48 +24)/144 = 1/2 as found in experiment. (The 2/3 probability correctly reflects the yes-no or triple hidden coin toss statisitics which is shown not to be applicable to particle spins or polarization).

I will add one further observation on coin-tosses versus reflection.

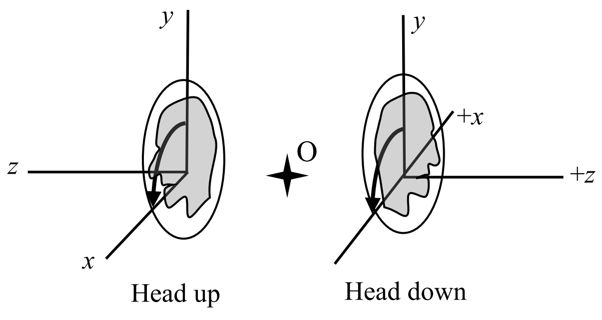

Figure 4. Comparison of the effect of turning a coin upside down in relation to the reflection of spin. The coin does not change its axes. If the right coin is turned round the axes and coin will

match the left side exactly. The particle spin of Figure 11.15 is shown by the arrows. They will be in opposite directions if the same change of axes as for the coin is made.

To clarify the inaccuracy of coin-tosses, the arrows of Figure 1 appear in Figure 4 as they immediately show the difference between the coin toss and particle spin, or what is the same thing, between reflection and a reversed coin. A reflection of the coin would turn a left facing head to right facing; two coins with opposite facing heads would be *different* from each other. If we did not know which coin was being tossed then the probabilities of finding a left facing coin heads up would not be the same as if all coins were left facing. As shown in Figure 4, coin tosses, and similar, do not belong to the set of reflections. A coin does not change its instruction set/hidden variable from toss to toss. If it originally faced left ($+x$,$+z$) it always faces left. It only changes from head up to down, or vice versa. 180-degree rotation still has head facing the same direction as always. Thus we can see that from this view that Bell's, Gill's, Alford's and similar type of statistics would give a different expectation to the experimental results if coin toss statistics are used. This perhaps should not be surprising because, if the universe is not mathematical in construction, mathematical theories created by humans cannot *define* how the universe itself might function.

Finally, it is worth noting that Figure 3b agrees with Caltech's QM lecture notes by Preskill.[21] who, unlike Bell, is specific about coordinate axes. Preskill just did not make the connection between the coordinates and Bell's λ for the HV factor as in section 5.

5. Summary

Bell's papers are divided into sets of equations (1964 equations 1-12, 1975 equations 1-16) describing theoretical calculations for the experimental expected outcomes of a HV theory; and thereafter a proof (Bell's equations 13-22 and 17-24, respectively) showing the result does not agree with QM's expected outcomes. I refer to Preskill's presentation, as his is coordinate specific whereas Bell's is not.

According to both Bell and Preskill, the hidden variable λ is taken as deterministic for the fundamental local reality system applying to the bipartite state. λ is therefore expected by them to be the same for both parts A and B. Section 3 above, together with the figures, suggest on the contrary that λ should be taken, not as a hidden variable in the case of the bipartite state, but as specifying the coordinate system between the reflective images (or reflections as the case may be) of the two parts. Consequently, returning to the standard QM concepts, as expressed by the second part of Bell's papers, Preskill's *defined* travel direction for the photon is $\pm z$ with polarization in the xy plane giving the coordinate structure (x, y, z) for A and $(-x, y, -z)$ for B.[22] This is the same formulation as in Figure 3.

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[21] Preskill (2001:24-25)

[22] Preskill (2001:11)

Thus λ should be given different corresponding coordinate signs when referring to A or B and should not be treated the same for both A and B when referring to *opposite* polarizations.

These observations suggest that the theory behind the *experimental tests* is *not* complete: (1) it has been created to test only the case of identical supposed instruction sets (that is, the instruction set is considered identical *after* the 'split' instead of being taken *before* the 'split'. (2) Irrespective of adopting the quantum beable concept of a spinor, state-up and state-down cannot have the same instruction set because they are not identical; (3) it has not taken into account the possible nature of an instruction set; and (4), nor has it considered the role of the coordinate systems in determining how the calculations should be applied.

This again shows how mathematical theory can twist ideas and miss subtle differences that might arise, especially where insufficient care has been taken over analyzing its methodology to the limit.

6. Conclusion

Greater analytic precision seems, therefore, to lead to at least two possible objections to Bell's analysis. Even if a coordinate system is not used it should be clear that left polarization is different to right polarization so that, if an instruction set is carried, left handed polarization will have a different set of identities to right handed polarization. On the other hand, in a coin toss the coin does not change whether it is heads up or down. The IS for a coin is the same whether it is head up or tail up. But for, say, an electron, LHP must have a different IS to RHP. Similarly for yes-no statistics, a reflection is not entirely 'no' or 'yes'. Therefore the statistics for yes-no or coin tosses are different to the statistics for particle polarization. Consequently polarization, or spin-state-up and spin-state-down cannot be likened to tossing coins, or rather the statistics for yes-no or coin tosses.

The so-called instruction set, or hidden variable,, if it were to exist, would be merely the original set of predetermined physical *and spatial* properties of the particle *before* splitting. The spatial properties are always relevant so that the bipartite split determines two sets of *spatially* differentiated properties. A standardized coordinate system is therefore a necessity for determining the theoretical correlated expectations of a bipartite entangled EPR system. Consequently doubt must also be cast, in this case, on the acceptability of treating polarization as a 'beable' in the QM sense so that it only requires one of Mermin's three colour codes, thus avoiding a 3-dimensional system to express polarization and spin. This implies that correlation between the coordinate system and the test quantum states should also have been applied to Bell's theoretical calculations through his factor λ.

Consequently there must be doubt about the efficacy of Bell's test and thus also its rejection of EPR's objection to QM. It depends on whether the 'reality' of a 3-dimensional causal space-Time should be supported or the peculiarities of a non-causal (non-deterministic) QM.

What *is* demonstrated is the necessity for paying more attention to Persson's question: do we understand what mathematics is producing. This is clearly a precision factor. Allowing that the above has been a valid objection to QM indeterminacy and loss of reality, it also seems reasonable to recall de Haro's (2013:8) statement on the task of philosophy as analyzing the ideas of physics.

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