Classical Explanation of Quantum Entanglement Correlations and Suggested Data Analysis for its Verification

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Abstract –
This article gives a semi/classical, hypothetical explanation of Quantum Entanglement correlations. Then it suggests an analysis on raw experimental data for verification. It does not dispute/conflict probability wave formula $\cos^2(A/2)$, or any other QM mathematics. It explains the anti correlation, and statistical correlation with a hypothetical mechanism of nature, without need of faster than light (FTL) communication. Description of each type of correlation is followed by an explanation of how that correlation can possibly be achieved by nature. Though Bell's inequality in itself is a valid theorem, the hypothesis explains why it is inappropriate to apply Bell's inequality to entanglement. *The article explains entanglement of only spin, but similar logic can be applied to entanglement of other properties.* To demonstrate successful working, and simplicity of the mechanism, I have implemented the mechanism (without using any QM algorithms) as an online Quantum Entanglement Simulator, which can be tried out at latestemail.com by setting detectors in any/random directions. Simulation page does not validate your email address, so you can enter dummy data as long as you remember the entered email and password.

*This article considers superposition as a mathematical concept and not a reality. That is why it describes entanglement of pairs in terms of experimentally measured correlations (irrespective of state) and explains them. Per hypothesis, probability wave combined with conservation laws shape same correlations without superposition being real. Two experiments are listed at the end of the article for its verification. Example considered in this article is – "**Two spin-1/2 particles emitted in opposite directions from the decay of a singlet state with zero total spin**"*

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Measurement

It is necessary to point out that in context of entanglement – "measuring" means we are actually setting-up the spin direction. The probability function actually tells us how likely it is to setup the spin in a particular direction, not the likelihood of what its spin direction was before measurement. The reason to bring up this point will become clear after reading the article in full.

Anti-correlation (real time)

Description - If you measure spin of two particles of entangled pair, in any angle, then their spin will always be found to be opposite. *Real time means* that the anti correlation for every pair is established right at origin (at pair creation) and is valid till you measure them, irrespective of where and when you measure them.

Explanation – This is a direct consequence of conservation of angular momentum. The entangled pair to begin with, has to be created with wave function such that the two particles will always measure opposite spins in any angle you measure them in. This has to be decided right when the entangled pair is created, because, due to conservation of angular momentum, *there is no other option*. Being pre-determined, the anti-correlation does not need any communication at all between the particles, let alone FTL communication. So, there is no **intra-pair** communication.

The particles will show opposite spin at any angle as long as both are measured in same angle. Obviously, we can not tell which one will be up and which one will be down without measuring one of them. The wave functions of two particles are created complementary. Sounds like local variables theory? **Yes for anti correlation. No for statistical**, as explained later.

Note – Distance is not even a factor here, so anti-correlation will be observed even light years away. So, investigation of anti correlation at larger and larger distances, seem pretty pointless.

Statistical correlation

Two types of statistical correlations have been documented among this type of entangled pairs.

1. If you measure spin of particles of numerous entangled pairs, say particle 1 at angle A and that of particle 2 at angle B, then the two particles will show correlated spins (i.e. both up, or both down), $\sin^2((A-B)/2)$ times the total number of pairs measured at these angles. This is same number as predicted by quantum mechanics.
2. If you measure spin of just one particle of numerous entangled pairs at any angle A, then the particles will show up spin 50% of the times, and down spin 50% of the times. This is same number as predicted by quantum mechanics.

It is a **key point** to note that the statistical correlation is between set of pairs as opposed to anti-correlation which is between two particles of same pair. Statistical correlation means outcome will converge towards the predicted values as we measure more and more pairs.

As described below, statistical correlation would not need any communication between particles of same pair. But, it would require a sub c speed communication from already measured pairs to subsequent pairs. Statistics is gathered over a period of time, which would give, sufficient time to communicate from past pairs to subsequent pairs at sub c speeds.

Explanation – Both types of statistical correlations are shaped by nature, in order to keep things in balance. For example, when we measure a particle, we also set/change its spin direction. This change in its natural spin direction creates a spin imbalance in nature, in that particular angle. This spin imbalance accumulates in nature over time with increasing number of measured pairs, it spreads at sub c speed in space and starts influencing the generation of subsequent pairs in such a way, that the imbalance would be cleared when subsequent pairs will be measured at the same angles. At all times, anti-correlation is enforced by conservation of angular momentum. The anti-correlation and statistical correlation do not conflict with one another at all. *If I were to utterly over simplify*, then it is like saying "you keep pouring dirt at one place, and it eventually takes shape of a heap", because nature keeps clearing the imbalances.

Note – Distance is a factor here, because the imbalances need to spread from measuring location to generating location at sub light speed. No experiments have been documented which were conducted at large enough distances where light speed would not suffice for *statistical correlation via **inter-pair** communication at sub c*. It always takes time to measure numerous pairs and that time would be sufficient for the imbalances to spread travelling at sub c speeds.

No wonder Quantum Entanglement experiments must be conducted in pristine environments so that the accumulated spin imbalance is not disturbed by factors external to the experiment. Disturbed spin imbalance means disturbed statistical correlation. *The imbalance accumulation is possible in 3D (a sphere around detector), or 2D (a plane containing line of electron movement and angle of measurement, or in just 1dimension (along line of electron movement).*

Simulation – The described mechanism has been simulated at latestemail.com. Computations are very simple and efficient. The simulation is completely based on mechanism of clearing the spin imbalance. It does not use any of the quantum mechanics algorithms. It uses tools like php and mysql on a shared hosting, is accurate to six sigma levels, and has been tested to generate and measure more than 120,000 pairs per minute. Obviously, nature can be much more efficient.

Bell's inequality (Very general description)

Based upon below two criteria, it computes a minimum statistical correlation percent between numerous entangled pairs.

1. Enumerates all possible combinations of pre-determined spin directions for a pair.
2. It considers all the enumerated combinations **equally likely** while establishing a minimum correlation percent.

Violation of Bell's inequality – Experimental data shows that statistical correlation between numerous pairs is actually less than the minimum established by Bell's inequality. Thus we say that because the Bell's inequality is violated, and so, the spin directions can not be pre-determined.

Why Bell's inequality is inappropriate for statistical correlation

What renders Bell's inequality inappropriate for the entanglement data is "equally likelihood of all enumerated combinations". Due to the accumulated spin imbalance in nature (space), the likelihood of subsequent combinations becomes biased in favor of clearing the imbalance. Subsequent pairs are created with only two restrictions/tendencies: **1)**.anti correlation is always true, and **2)** the spin imbalance accumulated in previously measured angles need to be cleared. These two restrictions/tendencies make the "enumerated combinations", **unequally likely**, thereby rendering application of Bell's inequality to statistical correlation, inappropriate. Loopholes may or may not exist; but it is also an inappropriate use of an otherwise valid theorem. The simulation generates pairs that are always anti-correlated in every direction, at the same time; it maintains statistical correlations in every measured angle exactly as predicted by quantum mechanics.

More scrutiny of statistical correlation and suggested verification

Anti correlation is straightforward, due to conservation of angular momentum. So leave that aside for now.

Statistical correlation must also shape due to conservation of angular momentum in a way. But that is not the important point for now. The important point is that there are two ways statistical correlation can shape.

1. **Independent statistical correlation –** Each pair independently, is capable of contributing to the statistical correlation. Statistical correlation, by definition is among a population of independent outcomes.

   Coin example **–** If you toss a coin, the probability of head is 50% with each toss. If you toss the coin large enough number of times (say N), you will get head ~50% of the times and tail ~50% of the times. We know that each toss individually and independently is capable of contributing to this outcome. Therefore, instead of considering each and every toss, if we consider outcome of only every other toss, we will get the same ~50/50 outcome. If we consider outcome of only every third toss, we will get the same ~50/50 outcome. If we consider outcome of only every nth toss, we will still get the same ~50/50 outcome, provided N/n itself is large enough. This is true because, each toss is independent from the other tosses. Outcome of one toss does not influence outcome of any other toss.

   More scenarios of independence **–** 1) Toss a coin every hour and you will still get ~50/50. 2) You toss a coin number of times and your friend tosses a coin number of times in another country, pick up every nth outcome from the combined result set and you should still get ~50/50. The coin toss is truly independent phenomena.

   The point is – if the individual events are truly independent, then in a given experiment, it would not be possible to find a consistent pattern such that the outcomes of the pattern itself violate the expected statistics.

   Applying this reasoning to entangled pairs, the statistical correlation $\sin^2((A-B)/2)$ has to hold good in the same manner described in the coin example. I.e. just consider only the nth outcome, and the statistics should still hold good. *This kind of analysis is absolutely necessary to solve the mystery of quantum entanglement*. If we are able to mine the raw experimental data for a consistent pattern that itself violates the rule $\sin^2((A-B)/2)$, then it means the outcomes are not truly independent, which takes us to the next point. And that is exactly the essence of this whole article.

2. **Balancing statistical correlation –** Statistical correlation is shaped up because, the individual events are not truly independent. I.e. the outcomes of various pairs are not independent, and there is some sub c speed feedback mechanism which shapes up the correlation over a large number of events. Means the outcomes of already measured pairs influence the generation of subsequent pairs in such a way that statistical correlation shapes up *(without violating the anti correlation).* This balancing happens exactly as predicted by quantum mechanics, because, the QM predictions are correct and lead to a balanced state.

   Truly *independent statistical correlation* of entangled pairs, especially with anti correlation as a given, makes it very complex (if not impossible) to explain. Even though, the mathematics may be able to explain the complex observation, nature would operate with simplicity, not with complexity. Presence of a sub c speed feed back mechanism makes the explanation of statistical correlation very-very simple, as demonstrated in the simulation.

Statistical correlation is due to conservation of angular momentum, over a range of space (time), while anti correlation is due to instantaneous conservation of angular momentum at the time and place of pair creation. There is no point in beating the anti correlation to its death. It is the statistical correlation that needs to be scrutinized.

Anti correlation is a direct consequence of conservation of angular momentum, while statistical consequence is indirect consequence of conservation of angular momentum. It is indirect because the spin imbalance needs to accumulate before it starts influencing the subsequent pairs. Spin imbalance is cleared as per QM laws. Due to this difference, it should be harder to shake the anti correlation as compared to shaking the statistical correlation. An experiment based upon this difference is suggested at the end of the article.

Suggested data analysis for verification of concept

a) Data Collection:

1. For simplicity sake, the scenario is - we have a source of entangled pairs. The entangled particles depart in opposite directions (left and right). There is one detector on left side that is set at 0 degree. The second detector is on right side and is set at 60 degrees. Each detector measures the spin of all the particles that are headed in its direction. The distance between the source and detectors is not important for initial investigation. Two detectors can be at same or different distance from the source.
2. Pairs are generated and measured one at a time, pair1, pair2, pair3, .. pair#. Each pair = 2 particles P1 & P2.
3. Raw data is recorded in sequence and the sequence is retained in recorded data for further analysis.
4. Every measured pair records 5 values – Pair#, angle1, outcome1, angle2, outcome2.
5. Angle1 is left side measurement angle, and angle2 is right side measurement angle.
6. It is important to record results in sequence. We do not need pairs in trillions – we can stop at few millions pairs after the correlations starts shaping up. It would be difficult to check the correlation at the time of recording data, so we can start with 50 million pairs, stop, check correlation, and then increase the limit if needed. Main goal is – record the outcomes in sequence, even if the pair generation has to be slowed down to achieve this goal.
7. Only measured pairs need to be recorded and all measured pairs need to be recorded. The pairs that are not measured need not be recorded as they are not expected to contribute to the accumulation of spin imbalance.

The data will look like below table – Outcomes listed are just examples, they need to be real values. The angles are listed in the table just in case the detector angles are not fixed at (0, and 60) and are changed randomly and so that we record the complete raw data.

Pair#	Left side angle	Left side Outcome	Right side angle	Right side outcome
1	0	UP	60	DOWN
2	0	DOWN	60	DOWN
3	0	UP	60	UP
…..	..	..	..	..
N	..	..	..	..

b) Data Analysis:

1. Raw data should be analyzed for various symptoms that would indicate a presence/absence of a balancing mechanism.
2. Analyze the data as described in the coin example under section "Independent statistical correlation". I.e. analyze data by creating different subsets by including/excluding certain outcomes in a consistent pattern. For example only consider first 5 outcomes, skip next 5, and consider next five and so on. This is a consistent pattern and if the pair outcomes are really independent phenomena, the subsets should also follow the predicted correlations as long as the subsets are also large.
3. Analyze the data to check (after measuring how many pairs), the statistical correlation starts shaping up. If the pair outcomes are truly independent, then the correlation should start shaping pretty early, otherwise an accumulation lag should be noticed. I.e. the correlation should start shaping up say after 500000 pairs have been measured.
4. If an accumulation lag is noticed, then it should be investigated further whether the lag goes up if the distance between detectors and source is increased.
5. The basic idea is to investigate **inter-pair** influence as opposed to most experiments that investigate **intra-pair** communication. **Inter-pair** influence would not require FTL communication because it has got enough time.
6. Per hypothesis, anti-correlation does not need any investigation as it is a direct consequence of conservation laws.
7. If raw data is provided to me, I can do in-depth analysis myself and provide the results.
8. Applying the imbalance hypothesis, the correlation observed from any source (say even star light) can be explained. But such examples do not enable us to rule in/out the **Inter-pair** influence. For that verification the suggested analysis is necessary.

Superposition vs. hypothesis (spin imbalance):

The article considers probability wave to be a reality, it considers superposition just a mathematical concept and not a reality. That is why it describes a pair entanglement in terms of experimentally measured correlations and explains them. Experiments give same results as predicted by mathematical superposition, but (probability wave + conservation laws) can also shape same correlations without superposition being real. Below are two verifications as possible proof of this.

a) Superposition vs. spin imbalance – Simplest verification possible (with sequencing of pairs):

1. Per QM explanation, the anti-correlation and statistical correlations are both caused by same phenomena – the superposition. Therefore, if one of the correlations shows up, then both should show up.
2. Per imbalance hypothesis, the cause of anti-correlation is conservation law, which is more restrictive as compared to the cause of statistical correlation - spin imbalance.
3. Therefore, if hypothesis is true, then it may take some time into the experiment for the statistical correlation to shape up. On the other hand, per QM explanation, the superposition is there from the beginning and the statistical correlations must start shaping very early into the experiment.
4. If positive, this test will confirm imbalance hypothesis. If negative, it will not necessarily disprove the hypothesis and in-depth data analysis would be necessary.

b) Superposition vs. spin imbalance – Simplest verification possible (sequencing of pairs not necessary):

1. Suppose we conduct the entanglement experiment in a not so ideal environment. That means the correlations will deviate from the predicted values.
2. Per QM explanation, the anti-correlation and statistical correlations are both caused by same phenomena – the superposition. Therefore, if one of the correlations deviates, then both should deviate.
3. Per imbalance hypothesis, the cause of anti-correlation is conservation law, which is more restrictive as compared to the cause of statistical correlation - spin imbalance.
4. Therefore, if hypothesis is true, then, it should be possible (not guaranteed) to create a non-ideal experimental environment in which statistical correlation will be disturbed but anti correlation will remain intact.
5. The sequencing of pairs is not necessary in this case because we do not need to analyze data based upon sequential outcomes. We just need to verify whether or not statistical correlations fail without affecting anti correlation in the same environment.
6. If positive, this test will confirm imbalance hypothesis. If negative, it will not necessarily disprove the hypothesis and in-depth data analysis would be necessary.

Conclusions (pending verification)

1. The anti correlation between particles of each pair is always enforced by conservation of angular momentum at origin. Two particles of same pair do not influence outcome of one another in any way. Distance not a factor.
2. Statistical correlation is shaped-up by nature over time in order to clear the spin imbalance accumulated due to past measurements. Light speed suffices for this purpose.
3. Application of Bell's inequality to statistical correlation is not appropriate.
4. **Inter-pair** influence needs to be investigated as opposed to popular **intra-pair** investigations.
5. Pattern analysis on real data is critical to establish whether the pairs over a period of time stay independent or not.
6. Simulation at latestemail.com demonstrates simplicity of logic - at any combination of angles, randomly, without using any QM algorithms.

References: No references, it is a hypothesis that needs to be verified.