Can one see entanglement?

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Entanglement is one of the most fascinating aspects of quantum mechanics as it is far removed from our everyday sensory experience. It is an interesting question to see whether this is a fundamental limitation of our senses, or whether experiments can be designed to bring us closer to the quantum world.

To answer this question we consider what is probably the most sensitive Human "measurement device": the eye, capable of seeing a number of photons as low as 100. It has been shown [1] that macroscopic superpositions of this size can be in principle achieved by strongly amplifying (cloning) a photon from an entangled pair.

In earlier work [2,3] we have shown theoretically that one can violate a Bell inequality using these states, i.e. the choice of measurement basis can be done after amplification. However particular care must be taken when interpreting results of such experiments. To illustrate and to better understand what can be inferred from these results we perform an experiment where the amplification is provided by a "Black Box". We show that it is indeed possible to experimentally violate the Bell inequality with human eyes (or by standard threshold detectors) by selecting the basis after the amplifying "Black Box".

Surprisingly this is the case even when the black box in question is entanglement-breaking (in our case a measure and prepare cloner). Indeed any detection method with finite efficiency, such as threshold detectors does open up the detection loophole, explaining these results.

In fact entanglement can only be inferred if one assumes that what is measured is a qubit, i.e. one can only demonstrate the entanglement between the two initial photons.

Finally we present our measurements of both the retinal and post-retinal contributions to the human threshold of vision, and conclude that with finite efficiency threshold detectors, such as linear photodiodes or human eyes, it is impossible to distinguish a macroscopically entangled state from a classical one.

[1] De Martini, F., Sciarrino, F. and Vitelli, C. Entanglement Test on a Microscopic-Macroscopic System. Phys Rev Lett 100, 253601 (2008).

[2] Sekatski, P., Brunner, N., Branciard, C., Gisin, N. and Simon, C. Towards Quantum Experiments with Human Eyes as Detectors Based on Cloning via Stimulated Emission. Phys Rev Lett 103, 113601 (2009).

[3] Sekatski, P., Sanguinetti, B., Pomarico, E., Gisin, N. and Simon, C. Cloning entangled photons to scales one can see. Phys Rev A 82, 053814 (2010).