

ENTANG-LIKE GAME PLAYING WITH THE “QUANTUM ENTANGLEMENT- LIKE” IN PAIRS

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Entang-Like is an interactive game that intuitively illustrates quantum entanglement using bistable images. Designed to make quantum mechanics more accessible, it provides a hands-on analogy for this fascinating phenomenon, turning complex concepts into an engaging and funny experience.

Why a playful exploration of Quantum Mechanics?

Quantum mechanics has long been perceived as an abstract and counterintuitive challenge even for physicists. However, its consequences underpin many technologies that are increasingly becoming an integral part of our daily lives, from quantum computing to ultra-secure communication. Among quantum phenomena, entanglement stands out as one of the most fundamental and at same time more fascinating.

Entanglement describes a peculiar quantum correlation between two or more particles of a quantum system, in which the state of each particle cannot be described independently of the state of the others. Measurements of a physical property affect the system as a whole; a measurement on one particle influences the result of the same measurement on any other, regardless of distance. Einstein

famously referred to this phenomenon as “spooky action at a distance,” highlighting the paradoxical nature of quantum mechanics [1]. Today, entanglement is not just an intriguing scientific curiosity, but it is a key resource for quantum technologies that are revolutionizing computation, cryptography, communication and sensing.

Given its importance, fostering an early understanding of entanglement is crucial. However, conveying such abstract concepts to young learners and the general public requires innovative approaches. This is where Entang-Like comes into play.

The Game Structure

Entang-Like is an interactive game designed to provide an intuitive understanding of quantum entanglement by using bistable images as Rubin’s vase [2]. These images allow two distinct visual perceptions to coexist ●●●



◀ FIG. 1: Cards Z and X with their respective bistable images.

Player 1		Player 2	
measured	inferred	inferred	measured
dog	faces	cats	vase
dog	vase	cats	faces
cats	faces	dog	vase
cats	vase	dog	faces

▲ TABLE 1: Accepted combinations to earn the Entang-Like Medal

••• within a single picture, making them an effective analogy for the superposition of quantum states.

The game aims to make a complex concept such as entanglement phenomenon more tangible and accessible through a hands-on, visual experience. Using bistable images, the game shows how two parts of a quantum system can be connected in ways that challenge classical intuition. It allows participants to experience first-hand the correlations that exist between entangled particles, making, in general, the abstract concepts of quantum mechanics easier to grasp.

The game is structured into three main steps, engaging participants in a sequence of actions and responses, ultimately dividing them into two groups: those who obtain an Entang-Like Medal and those who do not.

Step 1:

- Participants are paired up. Each pair receives a closed box containing two smaller “mini-boxes”, one for each player. Each mini-box contains two covered cards Z and X with two different bistable images on the back fig.1.
- Players of each pair take their own mini-boxes and move far away in opposite directions.

Step 2

- Each player individually observes the image on the back of Z card.
 - Player 1 silently records the picture perceived (e.g. “dog”) and give it to an external observer, that we call Alice, that keeps it secret. We assume it as “measured value”.
 - Player 2 does the same but seals the card with the name of perceived picture in a personal envelope, we name it “inferred value”.
- The players then observe the second bistable image on the back of X and repeat the process.

This time, Player 2 gives his card with the perceived picture to another external observer Bob, who records it (measured value). Meanwhile, Player 1 seals his card, which contains the name of picture he perceived, in a personal envelope (inferred value).

Step 3

- Observers Alice and Bob compare the measured values
- The pair of players can show proudly the Entang-Like Medal, if the measured and inferred values match one

of the accepted combinations, listed in Table 1, no other case unfortunately can get the medal.

By the end of the experiment, two distinct groups emerge: Pairs exhibiting Entang-Like Medal and pairs not exhibiting it.

Interpretation and entanglement analogy

The *Entang-Like* game is inspired by the famous Einstein-Podolsky-Rosen (EPR) gedanken experiment [3] in a form like that presented by David Bohm by using Stern-Gerlach devices, fig. 3a [4,5]. It offers a simplified, playful version of this fundamental experiment in quantum mechanics by using bistable images, fig. 3b.

We strongly note that our game/experiment does not really have a quantum nature since it is performed on a “non-quantum” system and therefore does not claim to be rigorous but is aimed at showing the concept of correlation together with that of non-locality. The characteristic of non-locality is what most distinguishes classical physics from quantum physics, in fact at the beginning of 1900 it was one of the main arguments, supported mainly by Albert Einstein, to show how the consequences of quantum mechanics were paradoxical and therefore the theory was somehow incomplete [3]. Currently, quantum non-locality, as consequence of the phenomenon of quantum entanglement, has been widely demonstrated and the experiments with entangled particles were awarded the 2022 Nobel Prize in Physics.

The first step of the game can be thought of as a preparation of the “quantum system” of two particles, prepared in a so-called “spin singlet state” [6, 7], where the total spin of the system, consisting of two particles, is $S=0$. Spin is an intrinsic form of angular momentum carried by elementary particles and it is quantized, so when we make measurement, it is possible to obtain only discrete values, specifically in the case of electrons with a Stern and Gerlach device, we can measure $1/2$ or $-1/2$ in a direction spin axis. We call the correspondent states $|\text{up}\rangle$ and $|\text{down}\rangle$. In a spin singlet state the particles are indistinguishable, so the system state can be written as a superposition of states in a special Bell state [8]:

$$|\text{Spin singlet state}\rangle = |\text{up}\rangle_{1z}|\text{down}\rangle_{2z} - |\text{down}\rangle_{1z}|\text{up}\rangle_{2z}$$

in the Z direction spin axis

or

$$|\text{Spin singlet state}\rangle = |\text{up}\rangle_{1x}|\text{down}\rangle_{2x} - |\text{down}\rangle_{1x}|\text{up}\rangle_{2x}$$

in the X direction spin axis

A Bell state is, in general, an inseparable state, meaning that it is not possible to describe the state of one particle independently of the other. For this reason, it is considered an entangled state. When the two particles are separated by an arbitrary distance, the Bell state implies that measuring one particle in the state $|\text{up}\rangle$ forces the other to be in the state $|\text{down}\rangle$, and vice versa, regardless of the distance between them. Importantly, in

accordance with quantum mechanics, the state of each particle is not determined *a priori*, before the measurement. In the EPR gedanken experiment with Stern-Gerlach devices (see fig.1a), two observer Alice and Bob, located far from each other, measure the spin of one particle that is part of quantum system prepared in a singlet state.

In our game (see fig.1b), the two particles are represented by the two players of a pair. Each player, as part of the whole pair, may perceive one of the two images with a certain probability, such perception, that we assume as “state”, is not determined *a priori*. We can define a “singlet-like” state for those pairs that perceive opposite images, this state can be written as: $|\text{Singlet-like}\rangle = |\text{Dog}\rangle_{1z}|\text{Cats}\rangle_{2z} - |\text{Cats}\rangle_{1z}|\text{Dog}\rangle_{2z}$ in “Z direction”

or $|\text{Singlet-like}\rangle = |\text{Vase}\rangle_{1x}|\text{Faces}\rangle_{2x} - |\text{Faces}\rangle_{1x}|\text{Vase}\rangle_{2x}$ in “X direction”

We will assume a completed measurement, when the player looks at the bistable image and gives a card to an external observer on which he has marked the perceived picture. Before the measurement the player is in a superposition of possible perceptions.

The two bistable images represent, in the game, two perception measurement apparatuses “in Z and X directions”. We assume that the perceptions along these two directions are incompatible. The concept of incompatibility of quantum measurements arises from Heisenberg’s uncertainty principle, which states that certain pairs of physical quantities, cannot be simultaneously measured with any precision. In our case, this assumption is completely arbitrary and was made only for the purpose of playing, keeping the analogy with quantum mechanics. However, we observe that the Heisenberg uncertainty principle is not violated because we only measure the state of each particle in Z direction or in X direction but not on both directions at the same time.

▼ FIG. 2: Entang-Like Medal



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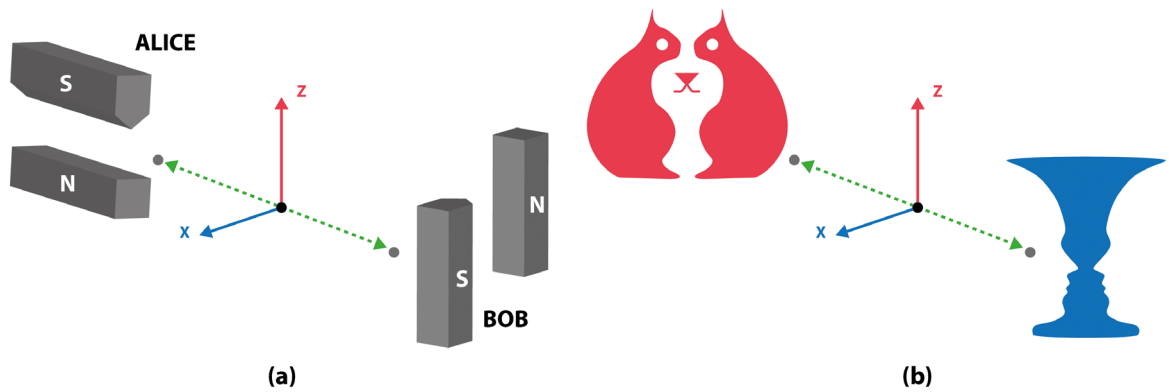
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► FIG. 3: a) Einstein-Podolsky-Rosen (EPR) gedanken experiment in a form like that presented by David Bohm by using Stern-Gerlach devices, b) EPR scheme with bistable images.



This playful experiment provides an intuitive representation of quantum entanglement; we emphasize that in the real world there is no quantum correlation in the pictures perceived by two players looking at identical bistable images [9], so this hypothesis is also totally invented to make the game happen and has no correspondence in the reality.

Educational and Societal Impact

Far beyond simply entertaining, the gaming approach stimulates scientific curiosity and fuels critical thinking. Interactive learning tools like Entang-Like help bridge the gap between abstract physics and intuitive understanding, making quantum mechanics less intimidating and more engaging for students. In a world increasingly shaped by quantum technologies, providing future generations with a solid understanding of these concepts is not just helpful, it is essential to gain skills to tackle broader and deeper issues [10].

This game has been shown as a demonstrator at scientific outreach events such as the European Research Night (ERN) 2024 and “Futuro Remoto” in Naples 2024, where it aroused the curiosity of both general attendees and a younger scientific audience, introducing them to the wonders of quantum mechanics.

We highlight that game-based quantum science and technology dissemination is an emerging field. Many quantum-inspired games have also been developed to improve public understanding of quantum mechanics, such as *QTris*, *Quantum Tic-Tac-Toe*, *Entanglion*, *Quantum Race*, etc. [11, 12, 13, 14]

Entang-Like, by conveying quantum mechanics into a playful and immersive experience, disruptively demonstrates how games can serve as powerful educational tools. As society moves toward a quantum-driven future, initiatives like this can inspire curiosity, break down conceptual barriers, and cultivate the next generation of quantum innovators.

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Maria Parisi is a researcher, focusing on the study and manipulation of quantum light states. She is involved in various projects related to the development of quantum

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