Quantum strategy offers game-winning advantages, even without entanglement

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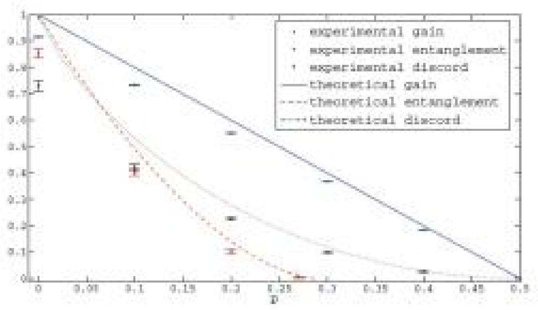

Experimental and theoretical results both show that quantum gain - measured as the difference between the winning chances for classical and quantum players - is highest under maximum entanglement. Quantum gain remains even when entanglement disappears, and approaches zero along with the discord. Image credit: Zu, et al. ©2012 IOP Publishing Ltd and Deutsche Physikalische Gesellschaft

(PhysOrg.com) -- Quantum correlations have well-known advantages in areas such as communication, computing, and cryptography, and recently physicists have discovered that they may help players competing in zero-sum games, as well. In a new study, researchers have found that a game player who uses an appropriate quantum strategy can greatly increase their chances of winning compared with using a classical strategy.

The researchers, Chong Zu from Tsingua University in Beijing, China, and coauthors, have published their study on how quantum mechanics can help game players in a recent issue of the New Journal of Physics.

In their study, the researchers focused on a two-player game called matching pennies. In the classical version of this game, each player puts down one penny as either heads or tails. If both pennies match, then Player 1 wins and takes both pennies. If one penny shows heads and the other shows tails, then Player 2 wins and takes both pennies. Since one player's gain is always the other player's loss, the game is a zero-sum game.

In the classical version of the game, neither player has any incentive to choose one side of the coin over the other, so players choose heads or tails with equal probability. The random nature of the players' strategies results in a "mixed strategy Nash equilibrium," a situation in which each player has only a 50% chance of winning, no matter what strategy they use.

But here, Zu and coauthors have found that a player who has the option of using a quantum strategy can increase his or her chances of winning from 50% to 94%. This quantum version of the game uses entangled photons as qubits instead of pennies. And instead of choosing between heads and tails, players use a polarizer and single-photon detector to implement their strategies. While the classical player can still choose only one of two states, the quantum player has more choices due to her ability to rotate a polarizer 360° before the single-photon detector. The researchers calculated that the quantum player can maximize his or her chances of winning by rotating the polarizer at a 45° angle.

"Each player can apply any operation to their qubit (or coin), and then measure it in computational basis," Zu explained to *PhysOrg.com*. "For a classical player, the operation he can do is to flip the bit or just leave it unchanged. However, if a player has quantum power, he can apply arbitrary single-bit operations to his qubit. But the measurement part is the same for the quantum and classical players."

The researchers found that the quantum advantage depends heavily on how correlated the original photons are, with a maximally entangled state providing the largest gain. The researchers were surprised to find that the quantum advantage doesn't decrease to zero when entanglement disappears completely, since a different kind of quantum correlation - quantum discord - also provides an advantage. This finding may even be the most interesting part of the study.

"There is no wonder that quantum mechanics will lead to advantages in game theory, but the interesting part of our work is that we find out the quantum gain does not decrease to zero when entanglement disappears," Zu said. "Instead, it links with another kind of quantum correlation described by discord for the qubit case, and the connection is demonstrated both theoretically and experimentally."

He added that this finding could potentially be useful for making real-world strategies.

"Our work may help people to understand how quantum mechanics works in game theory (in some cases, entanglement is not necessary for a quantum player to achieve a positive gain)," he said. "It may also give a good example of people making strategies in a future quantum network."

More information: C. Zu, et al. "Experimental demonstration of quantum gain in a zero-sum game." New Journal of Physics, 14 (2012) 033002. DOI: 10.1088/1367-2630/14/3/033002

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