Quantum guessing game reveals insight into stronger-than-quantum correlations

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(PhysOrg.com) -- In information processing, physicists are often in search of ways to turn classical strategies into quantum ones, with the implication that the quantum version is somehow stronger, faster, or more secure than its classical counterpart. However, quantum strategies do not always perform better than classical ones. As a case in point, a new study has compared the strength of classical and quantum correlations in a simple number guessing game and found no difference in performance. Further, the physicists found that a third form of correlations - post-quantum correlations - could outperform both quantum and classical forms.

In their study, Mafalda Almeida from the ICFO-Institut de Ciencies Fotoniques in Barcelona and coauthors found that classical and quantum correlations performed equally in a game called “Guess Your Neighbor’s Input.” The game involves a group of players in a ring who each receive an input number of either 0 or 1. The point of the game is that each player tries to guess the number of the person to their right. Of course, players are not allowed to know any information about their neighbor’s numbers before guessing, nor to communicate after having received their numbers. In order to win the game, players are allowed to share physical resources, such as classical or quantum correlations. Importantly, all these resources must be “no-signaling”; that is, they cannot enable instantaneous communication.

The no-signaling principle is fundamental for physicists dealing with the concept of nonlocality. In nonlocality, one object can influence another object at a distance, such as through entanglement. However, this phenomenon cannot be used to send information faster than light, which prevents a direct conflict with Einstein's theory of relativity. Nonlocal correlations, which physicists define as those violating a Bell inequality, are important because they serve as a key resource for quantum information processing.

However, in the game in this study, the researchers found that players gained no advantage at guessing the correct numbers by using quantum resources compared to classical ones. This makes sense, since it seems that players should require signaling in order to improve their guessing accuracy, and neither quantum nor classical correlations involve signaling.

Yet when the physicists looked at what happened when the players use no-signaling correlations (that is, correlations that satisfy the no-signaling principle) that are even stronger than those allowed in quantum mechanics (i.e. they had a higher degree of violation of a Bell inequality), they did find a surprise. No-signaling correlations could actually outperform the quantum and classical correlations, suggesting that quantum correlations obey a stronger version of the no-signaling principle.

"Our study highlights a fundamental difference between quantum correlations and certain post-quantum correlations (that is, correlations stronger than those allowed in quantum mechanics, but which nevertheless obey the no-signaling principle)," Nicolas Brunner, coauthor and a physicist at the University of Bristol, told *PhysOrg.com*. "This is significant because it strongly indicates that quantum correlations could obey a stronger version of the no-signaling principle."

This game is the first that involves entanglement among more than two bits (called "multipartite entanglement") to identify some of the boundary (or gap) between quantum correlations and the stronger no-signaling correlations. However, the results also raise further questions, such as what kind of physical principle might limit quantum non-local correlations? Why do (theoretical) post-quantum correlations seem to not exist in nature? And if they did exist, could these correlations be used for other information tasks? Right now, these questions are likely a long way from being answered.

More information: Mafalda L. Almeida, et al. “Guess Your Neighbor’s Input: A Multipartite Nonlocal Game with No Quantum Advantage.” Physical Review Letters 104, 230404 (2010). DOI: 10.1103/PhysRevLett.104.230404

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