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Adaptive strategies destabilise the rock-paper-scissors game but increase the eco-evolutionary performance

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The rock-paper-scissors (RPS) game is a classic model used in evolutionary game theory to explore the dynamics of how multiple strategies interact and evolve over time. The classic RPS game assumes a fixed benefit and cost for each strategy when its player interacts with another player of a specific strategy, while an evolutionary RPS game considers the dynamics of three populations whose fitnesses are influenced by the net payoff of each particular strategy. This may not accurately reflect the complexity of real-world scenarios. In this study, we introduce an adaptive evolutionary game (AEG) that captures simultaneously both the trait-mediated population dynamics, and the adaptive dynamics of traits, with the traits determining the benefits and costs of the payoff matrix in the RPS game through particular kernel functions. We investigate how strategies change through the trait evolution and how such adaptive changes can affect the population performance of each strategy and the presence and stability of Nash equilibrium.

Our study reveals several key findings regarding the adaptive evolutionary RPS game. Firstly, the AEG reaches a steady state (asymptotic phase) more quickly than the evolutionary RPS game, in terms of population dynamics. Additionally, the stable coexistence of all strategies in the evolutionary RPS game is easily destabilised if allowed even small mutation rates in the AEG. We also show that adaptive strategies can enhance the population performance of the RPS game, as measured by average population densities at the steady state. Adaptive dynamics of gaming strategies exhibit diverse attractors in the trait space that depend both on the initial population densities and initial trait

values, as well as parameters. Finally, the evolutionary attractors (i.e., the type of games) emerged in the AEG typically experience greater benefits than costs.

These findings, thus, highlight the effect of adaptive strategies in the RPS game that destabilises the eco-evolutionary dynamics while increases the performance of each strategy.

Keywords: evolutionary games, rock-paper-scissors, adaptive dynamics, traits, interactions

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