



## The effects of restraint and leniency on the adaptive rock-paper-scissors game

Mmatlou Kubyana<sup>1,2</sup>, Pietro Landi<sup>1,2</sup>, Cang Hui<sup>1,2,3</sup>

<sup>1</sup>Biomathematics Unit, Department of Mathematical Sciences,  
Stellenbosch University, Stellenbosch, South Africa  
[mmatlou@sun.ac.za](mailto:mmatlou@sun.ac.za)

<sup>2</sup>National Institute for Theoretical and Computational Sciences (NITheCS),  
Stellenbosch University, Stellenbosch, South Africa  
[landi@sun.ac.za](mailto:landi@sun.ac.za)

<sup>3</sup>Mathematical Biosciences Group,  
African Institute for Mathematical Sciences, Cape Town, South Africa  
[chui@sun.ac.za](mailto:chui@sun.ac.za)

In a population of competing individuals, better management of shared resources is a form of altruism. Restraint and leniency are two different types of altruistic behaviors: restraint occurs when an individual takes on fewer resources or benefits, and leniency occurs when an individual imposes fewer costs on the opponent. Individuals practicing restraint may suffer relative to less restrained individuals, who exploit more benefits. Similarly, individuals practicing leniency may suffer compared to less lenient individuals, who impose greater costs.

This poses a challenge in understanding how more altruistic behaviors emerge and sustain in populations. While many studies have focused on two-strategy games to elucidate the evolution of altruism, our study delves into a newly developed adaptive three-strategy game of rock-paper-scissors (RPS).

This adaptive RPS game enabled us to explore how restraint and leniency affect the outcomes of games with coevolving traits. Specifically, we investigated the influence of rock becoming increasingly restrained or lenient towards scissors. Using numerical simulations, we found that the dynamics with a more restrained rock counter-intuitively led to an increase in its own density, whereas a more lenient rock showed a significant decrease in density. Furthermore, altruism emerges only when adaptive games lose stability through strategies less prone to extinction. This study highlights the mechanisms by which adaptive traits influence the sustenance of various forms of altruism.

**References**

- [1] M. S. Kubyana, P. Landi, C. Hui, Adaptive rock-paper-scissors game enhances eco-evolutionary performance at cost of dynamic stability, *Applied Mathematics and Computation*, 468:128535, 2024.