

# Homework 3: Reimplementation of a paper.

## General remarks:

**Deadline 27-11-2025 11:59 p.m.**

- You must submit your assignment through GitHub classroom. You **MUST** connect to the link <https://classroom.github.com/a/nggQx4a2> and **push your assignment** to your provided repository **before the deadline**.
- Creating the repository might take some time! If it does not appear to work, refresh the page!
- Provide a single (self-contained) \*.PDF file, named `<Surname>_<Name>_<studentID>_<affiliation>.pdf`. Your name and surname should start with a capital letter (e.g. Wim). If you have two surnames, please separate them with a '-' (e.g., de-Munter).
- Put your name and your affiliation (VUB/ULB) in the document.
- Don't send in photos of your results, scan them, if necessary, but always submit a PDF.
- Any doubts should be emailed to [Elias Fernández Domingos](mailto:Elias.Fernandez.Domingos@vub.be) <Elias.Fernandez.Domingos@vub.be>.

**Note 1:** If these guidelines are not respected, your assignment will not be corrected, and your grade will be 0. Also, you will not be able to push any new changes to your private repository after the deadline.

**Note 2:** For this project we discourage the use of LLMs like ChatGPT. If you decide to use them, please disclose precisely in which scenarios (or which portions of code) you did use them. We will value whether your effort in this assignment was still significant. However, you may use any library you require (e.g., egttools, nashpy, egtplot).

**Note 3:** This is an individual assignment, although we expect that there will be similar solutions, if we notice any deliberate plagiarism, all the students involved will receive a 0 for this assignment!

## Description of the work

In this homework, the goal is to verify that you each are now able to reproduce a result discussed in a paper. We have chosen the paper "[Co-evolution of pre-play signaling and cooperation](#)" written by Santos, Pacheco & Skyrms. The paper is provided in the homework folders on UV and Canvas.

- Your objective is to make a Jupyter notebook that reproduces the **Figures 1, 2, and 4. For Figure 4, you only must reproduce the lines for 1, 2 or 3 signals.**
- Figure 1 shows the stationary distribution with 2 signals.
  - a) Figure 1.a shows how often each signal is present in the population.
  - b) Figure 1.b shows how often each strategy is present in the population.
  - c) Figure 1.c shows how often defection of cooperation is present in the population

**To calculate a) and c)** you can use the stationary distribution you will compute for **b)**. That is, the proportion of time each signal is present corresponds to the expected presence of each signal. This means  $p_\sigma = \sum_s p_s \delta(\sigma_s - \sigma)$ , where  $p_\sigma$  is the probability of signal  $\sigma \in \{0,1\}$  (for this figure),  $p_s$  is the probability of strategy  $s$ ,  $\sigma_s \in \{0,1\}$  is the signal used by strategy  $s$ , and  $\delta(\sigma_s - \sigma)$  is a delta function that takes the value 0, unless  $\sigma_s = \sigma$ , when it is 1. In other words, to calculate the stationary distribution of signal 0, you just need to sum the probabilities of the strategies that use signal 0. The process

is similar for c), albeit slightly more complex. We leave it as an exercise to the students to figure out how to compute this, based on the information in the paper. Please email the TA if you get stuck here.

- Figure 2 shows the invasion diagram for 2 signals.
- Figure 4 shows the frequency of cooperation in the population for different number of signals. You only need to reproduce the lines of 1, 2 and 3 signals.

The paper is not always clear at reporting all used parameters. You may assume that  $\beta = 0.05$  in all figures. However, we will value positively that you **investigate the effect of other values of  $\beta$** , particularly when you reproduction does not coincide with the paper.

Finally, **write a paragraph (max 300 words) providing a critical overview of the paper and your reproduction.**

## Deliverables

PDF of the notebook and the notebook itself.