Teaching unselfishness

RHINO

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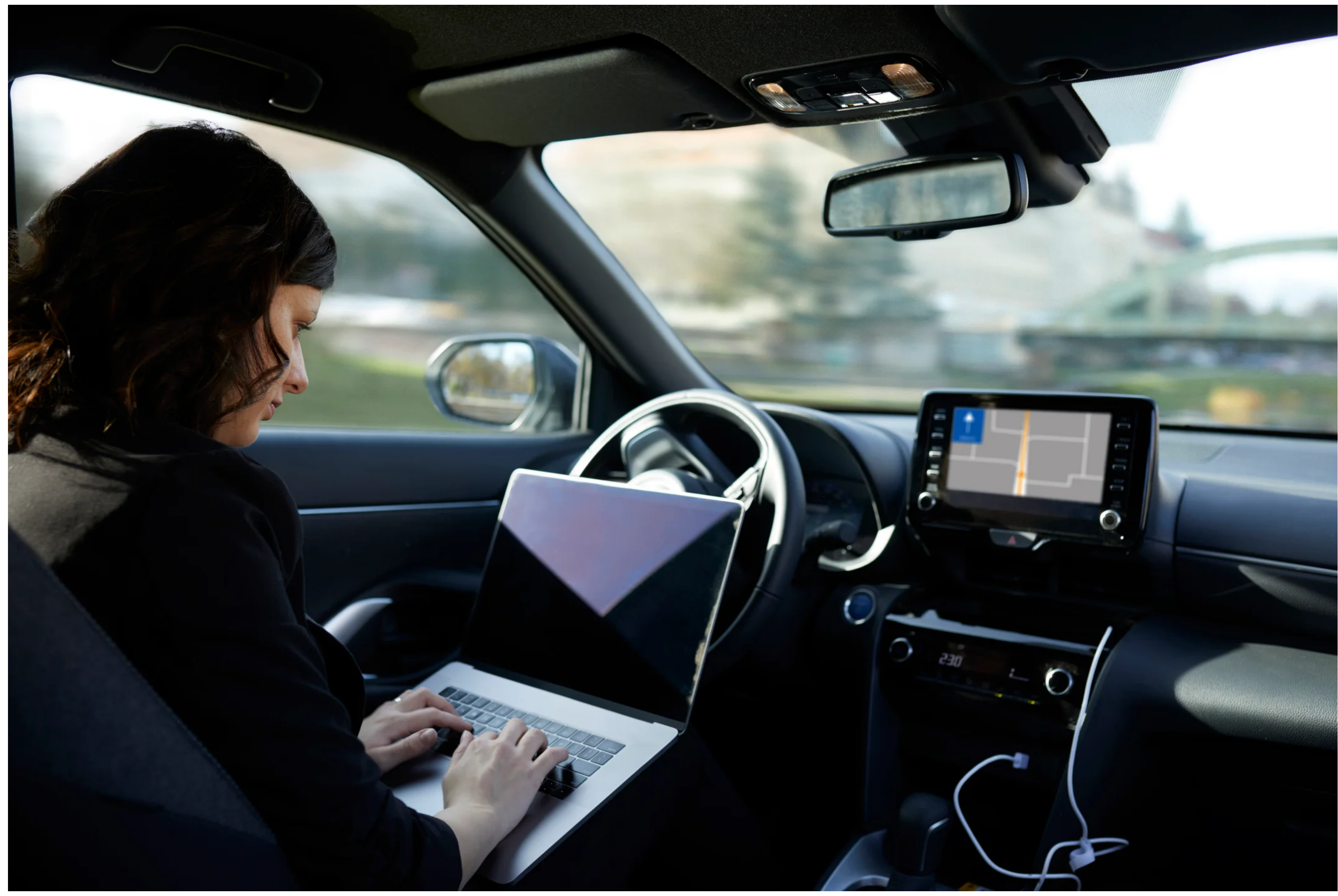
CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

RIKEN

iTHEMS

R-CCS



COOPERATION

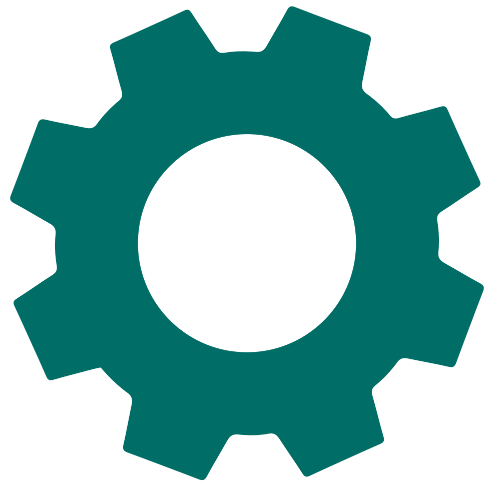
PRISONER'S DILEMMA

$$\begin{array}{ccc} & C & D \\ \begin{array}{c} C \\ D \end{array} & \multicolumn{2}{c}{\begin{pmatrix} b - c & -c \\ b & \boxed{0} \end{pmatrix}} \end{array}$$

Nash Equilibrium

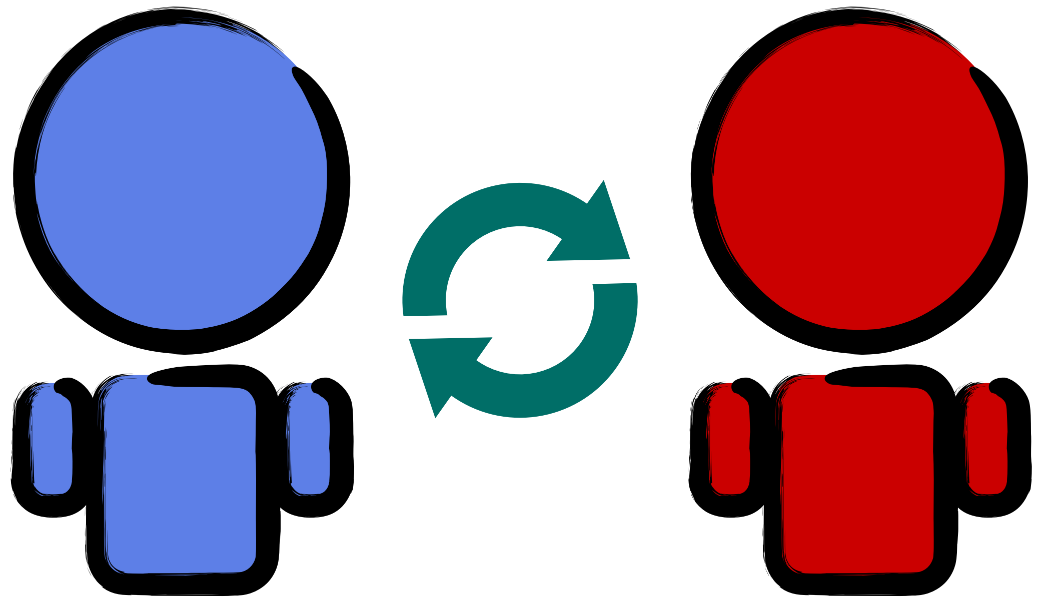
$$b > c > 0$$

RECIPROCITY



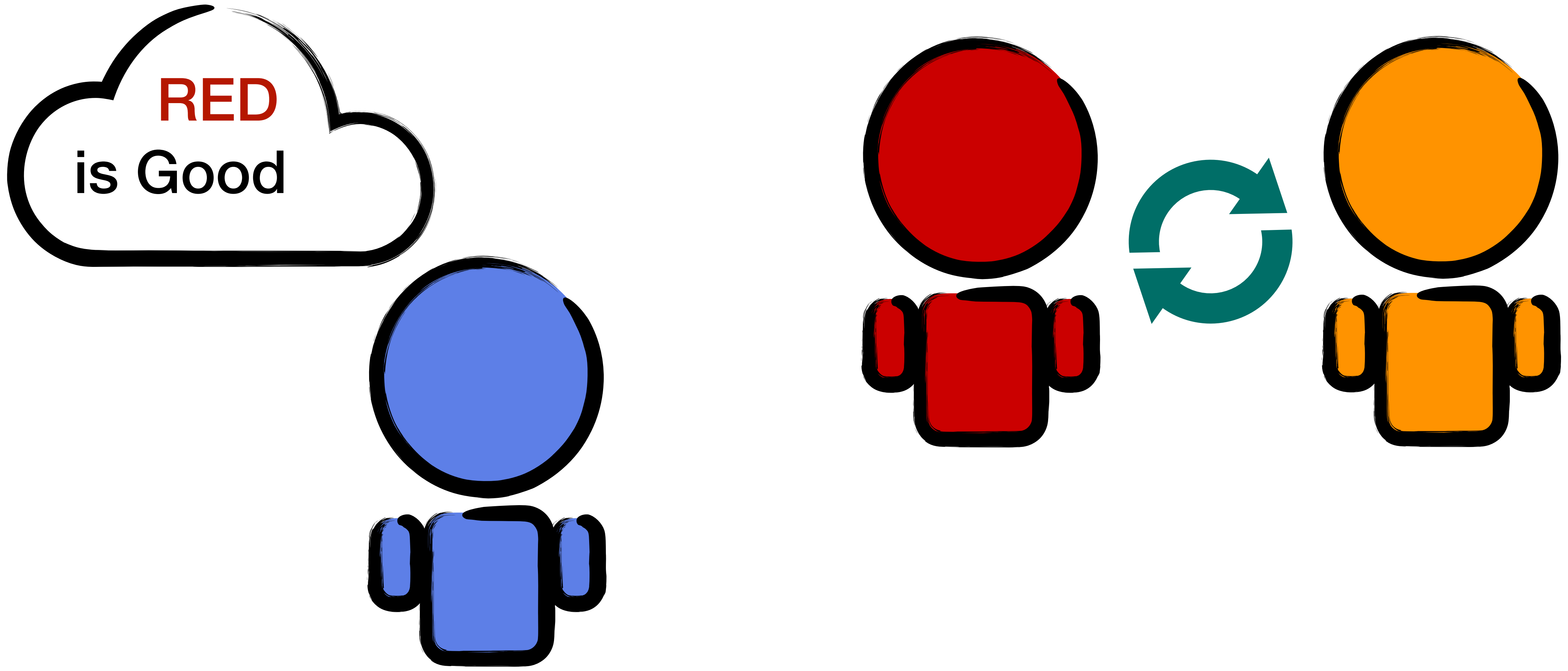
Nowak, M.A., 2006. Five rules for the evolution of cooperation. *science*, *314*(5805), pp.1560-1563.

DIRECT



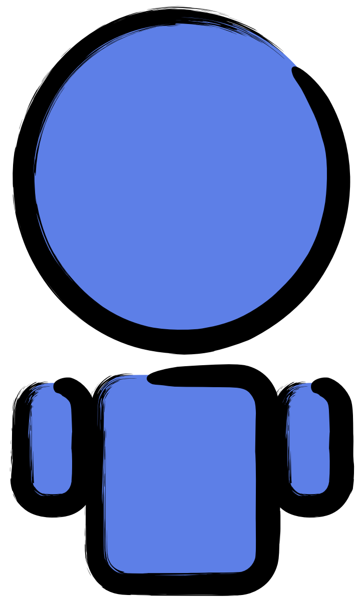
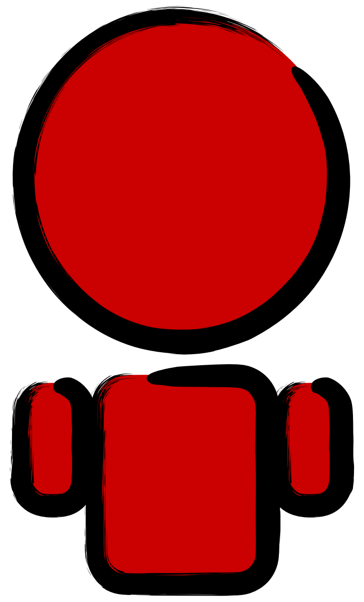
- F. Lesigang, C. Hilbe, N. E. Glynatsi.Can I afford to remember less than you? Best responses in repeated additive games.. 2025. Economics Letters
- N. E. Glynatsi, V. A. Knight, M. Harper Properties of winning Iterated Prisoner's Dilemma strategies. 2024. PLOS Computational Biology
- N. E. Glynatsi, E. Akin, M. A. Nowak, C. Hilbe Conditional cooperation with longer memory. 2024. Proceedings of the National Academy of Sciences
- Glynatsi, N. E., McAvoy A., Hilbe C. Evolution of reciprocity with limited payoff memory. 2024. Proceedings of the Royal Society B

INDIRECT



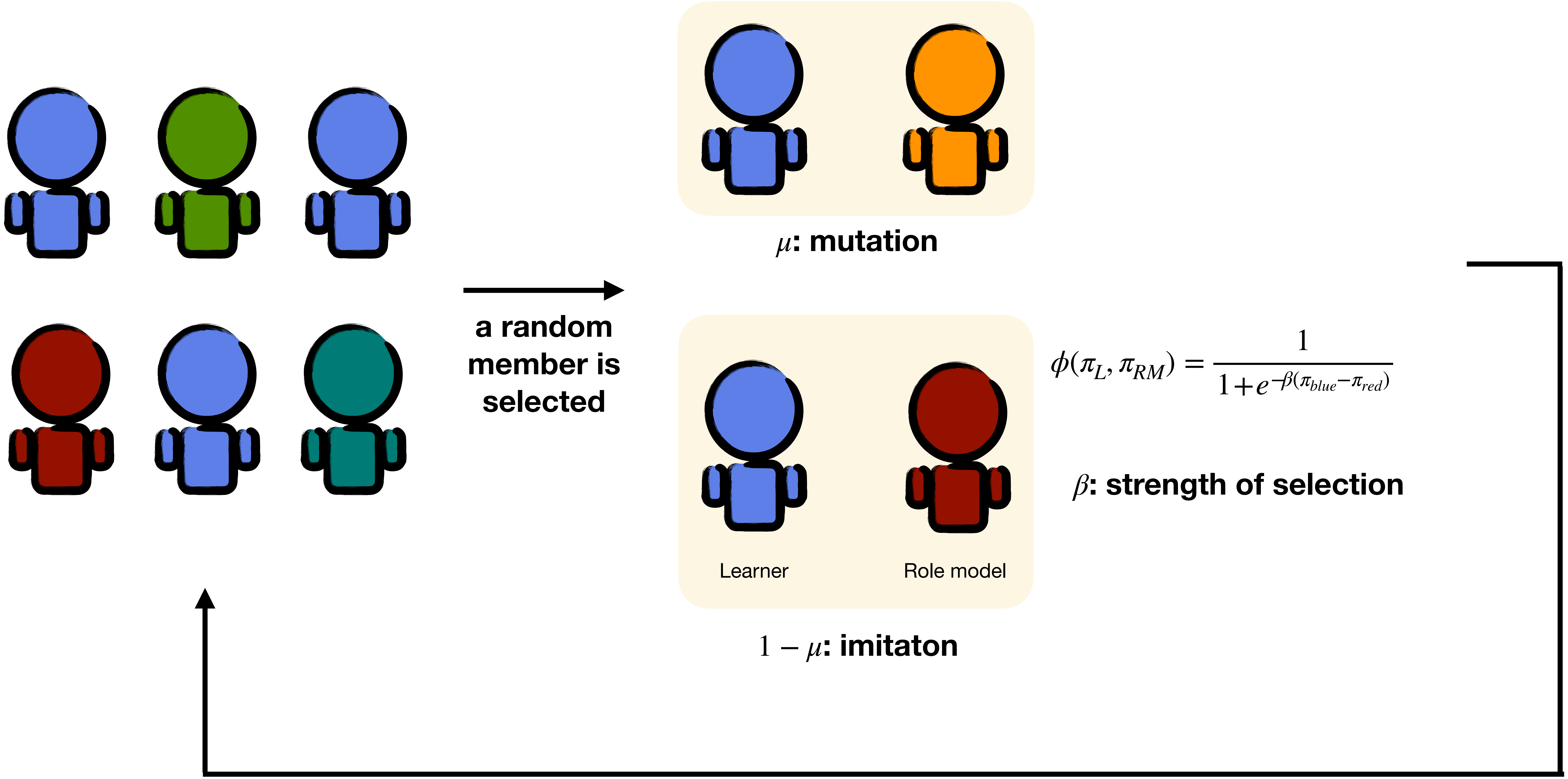
- N. E. Glynatsi, C. Hilbe, Y. Murase .Exact conditions for evolutionary stability in indirect reciprocity under noise.. 2025?. PLOS Computational Biology

DIRECT RECIPROCITY

	1	2	3		n
	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$	$\cdots$	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$
	D	C	C	$\cdots$	C
	D	D	C	$\cdots$	C

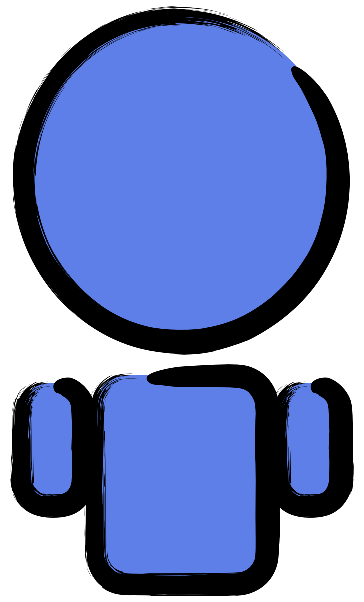
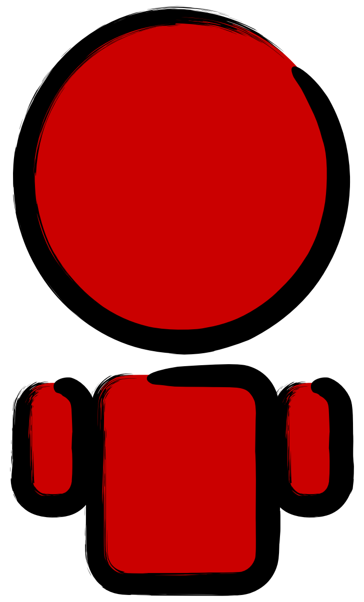
*Folk's Theorem

WHICH NASH EQUILIBRIUM WOULD PEOPLE LEARN?



repeat until a given number of mutants have been introduced

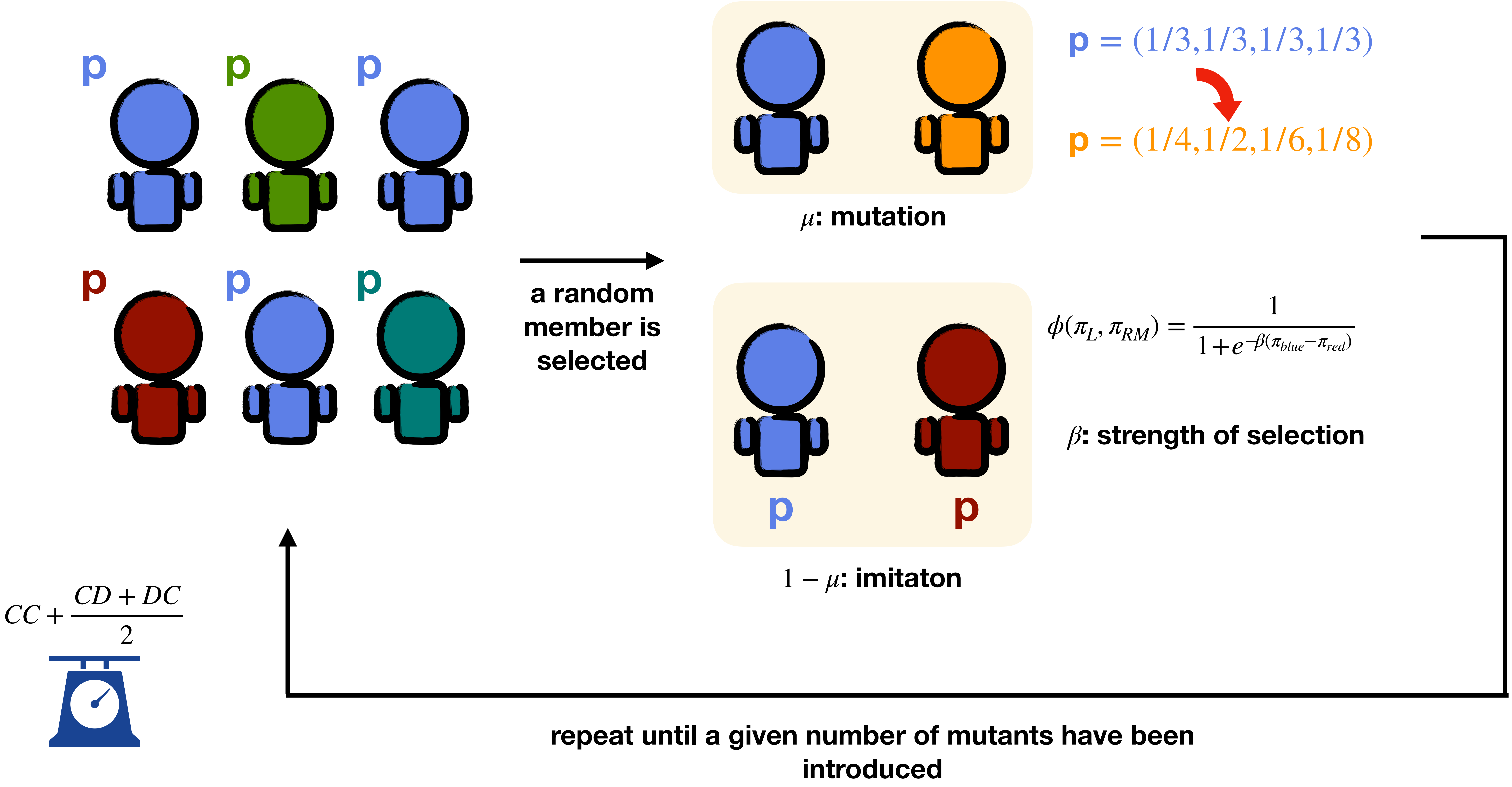
STRATEGIES

	1	2	3		n	$n+1$
	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$	$\cdots$	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$	$\begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix}$
	D	C	C	$\cdots$	C	$?$
	D	D	C	$\cdots$	C	

Memory-1

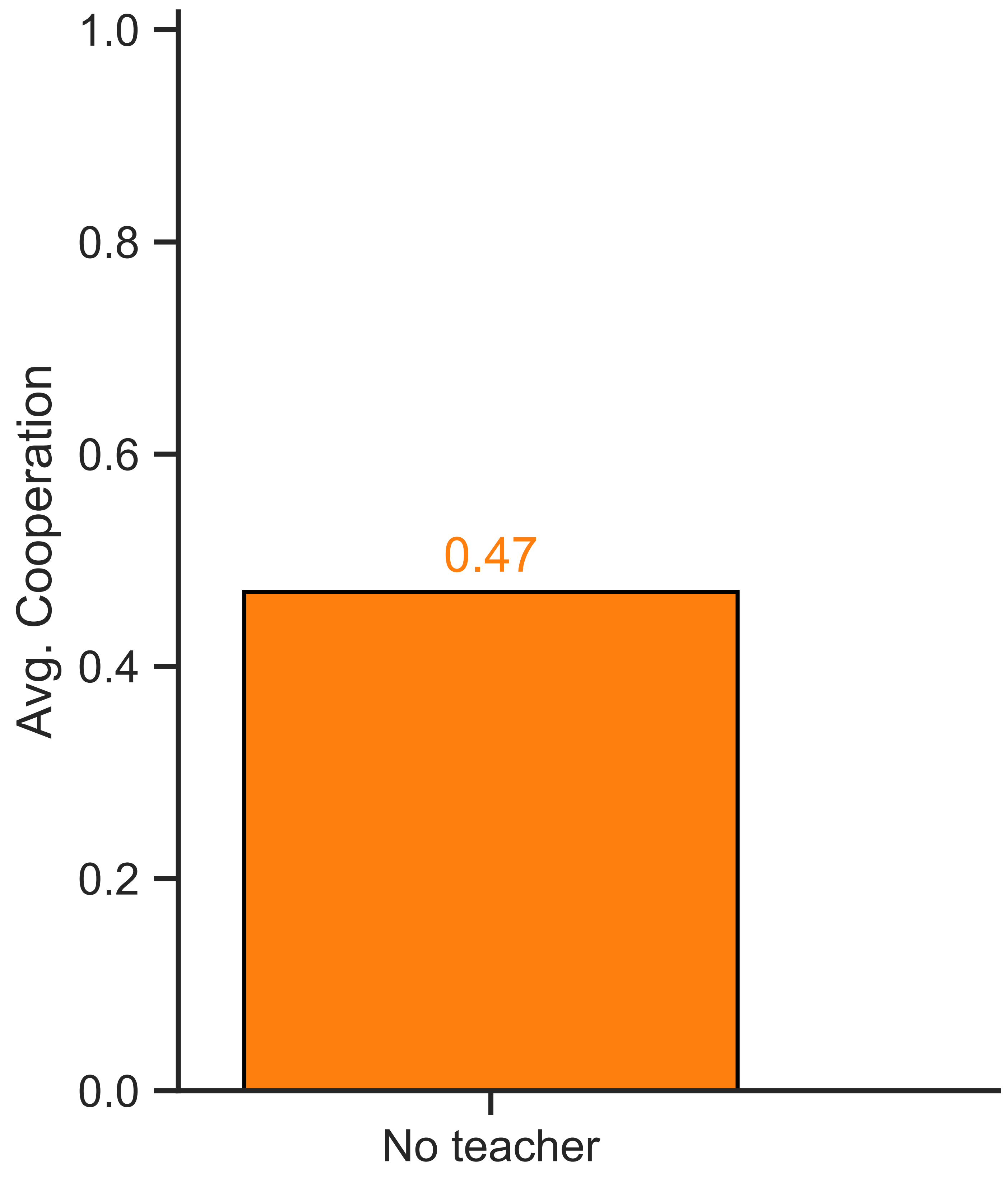
$\mathbf{p} = (p_{CC}, p_{CD}, p_{DC}, p_{DD})$

WHICH NASH EQUILIBRIUM WOULD PEOPLE LEARN?



NUMERICAL EXAMPLE

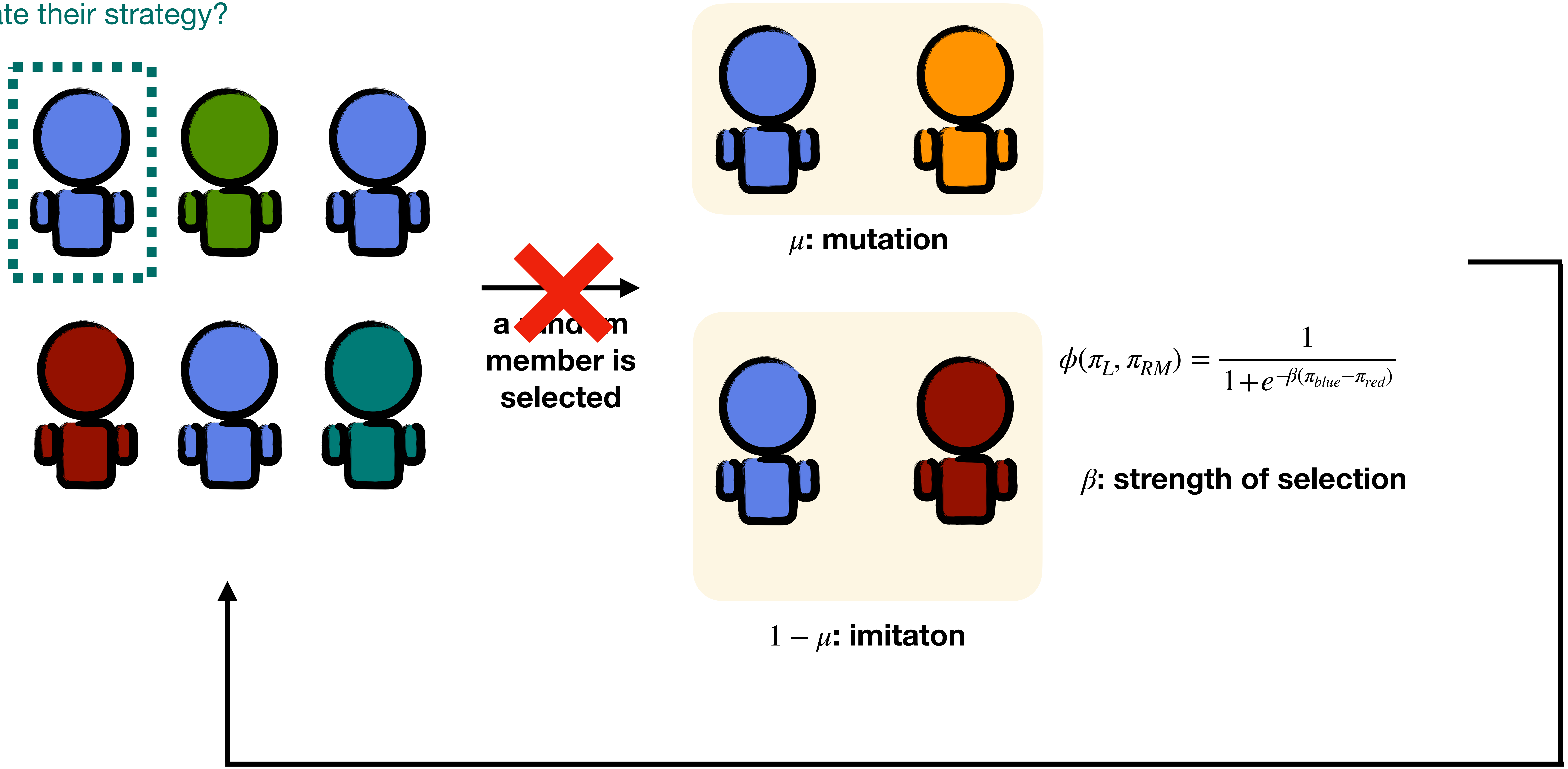
Benefit $(b) = 1$
Cost $(c) = 0.5$
Population size $(N) = 100$
selection strength $(\beta) = 5$
mutation probability $(\mu) = 0.01$
Mutants introduced 10^7



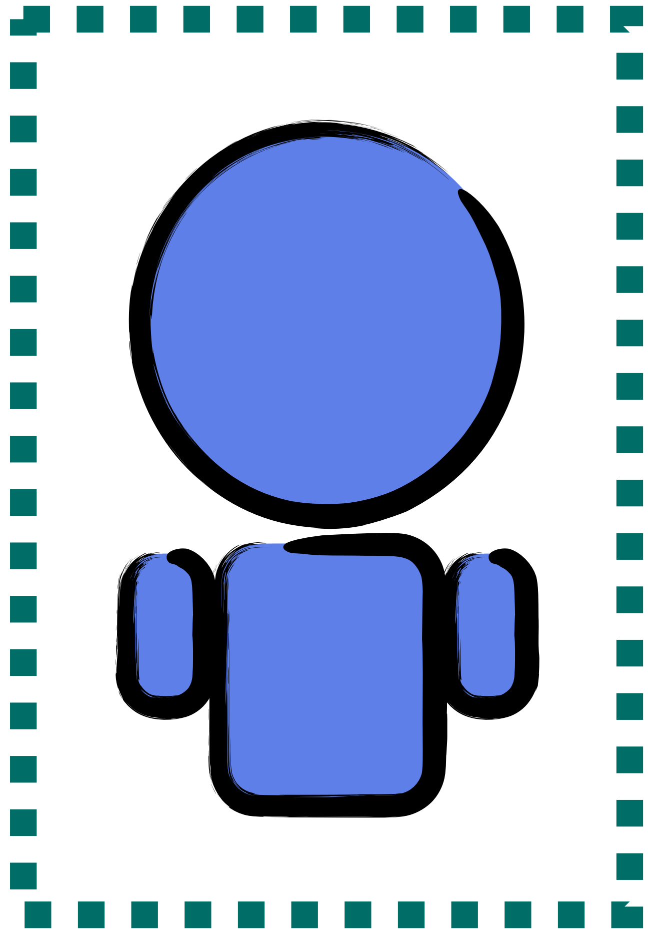
Baek, S.K., Jeong, H.C., Hilbe, C. and Nowak, M.A., 2016. Comparing reactive and memory-one strategies of direct reciprocity. *Scientific reports*, *6*(1), p.25676.

OUR MODEL

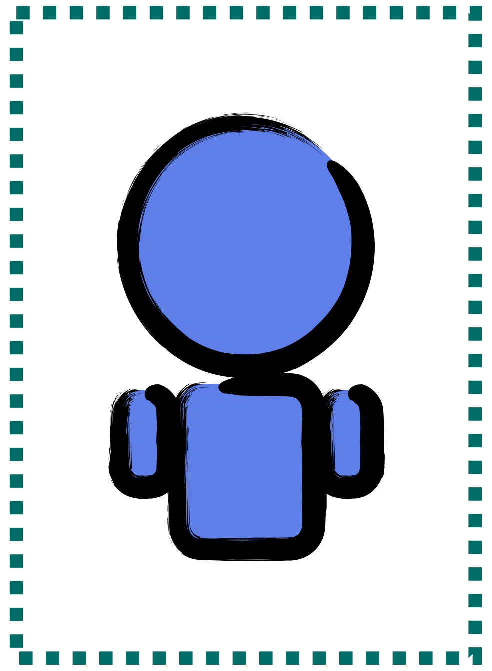
T number of members can never be selected to update their strategy?



TEACHERS



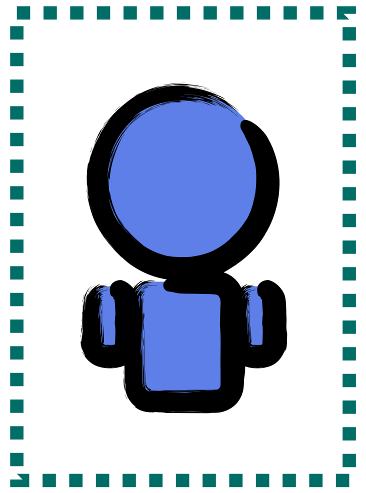
- We call these members “teachers”.
- They can never be selected to update their strategy.
- They can be selected as role models.
- They play the same strategy for the entire evolutionary process.



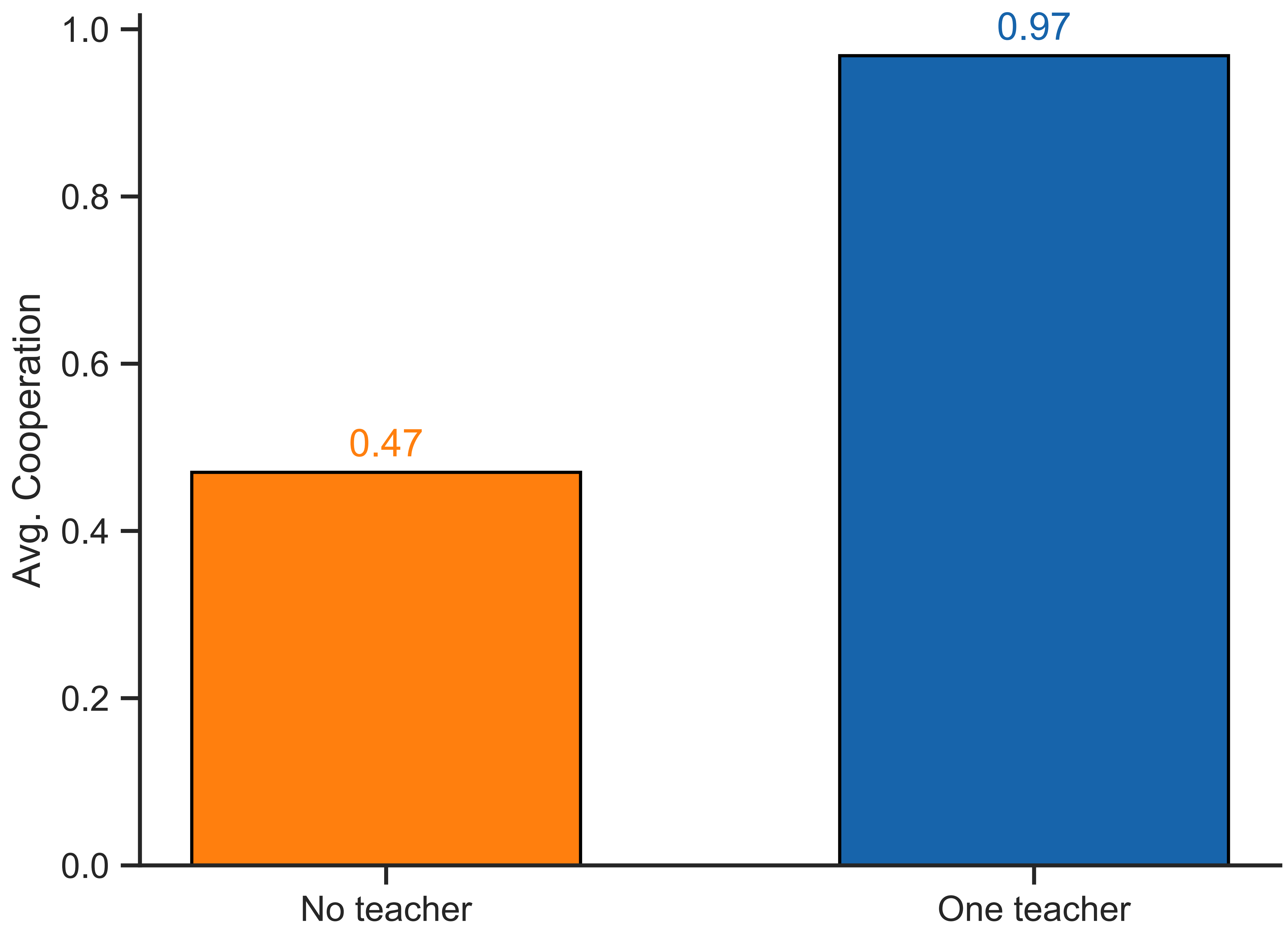
Generous Tit For Tat
(1,0.1,1,0.1)

NUMERICAL EXAMPLE

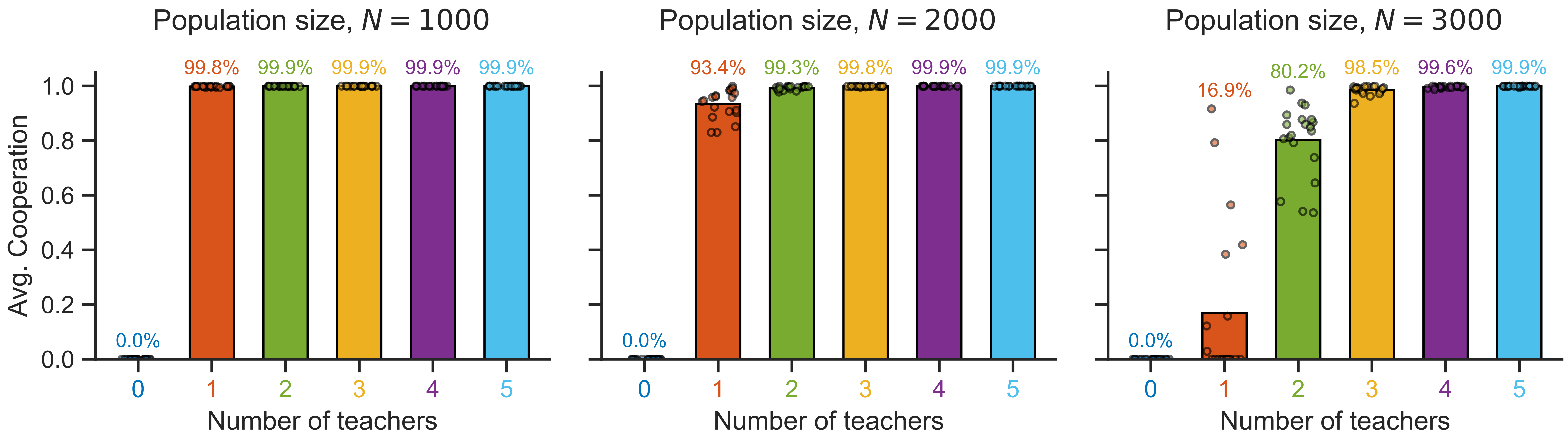
Benefit $(b) = 1$
Cost $(c) = 0.5$
Population size $(N) = 100$
selection strength $(\beta) = 5$
mutation probability $(\mu) = 0.01$
Mutants introduced 10^7
Number of teachers $(T) = 1$



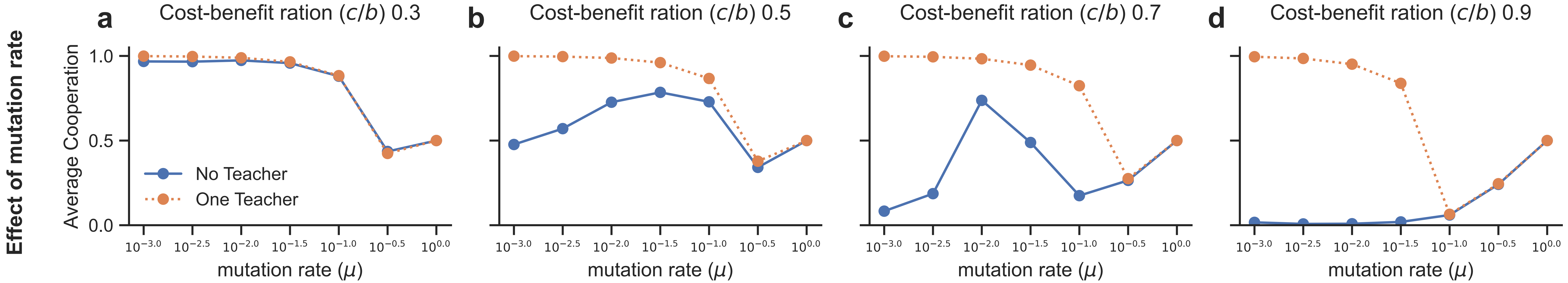
Generous Tit For Tat
$(1,0.1,1,0.1)$



ROBUSTNESS CHECK



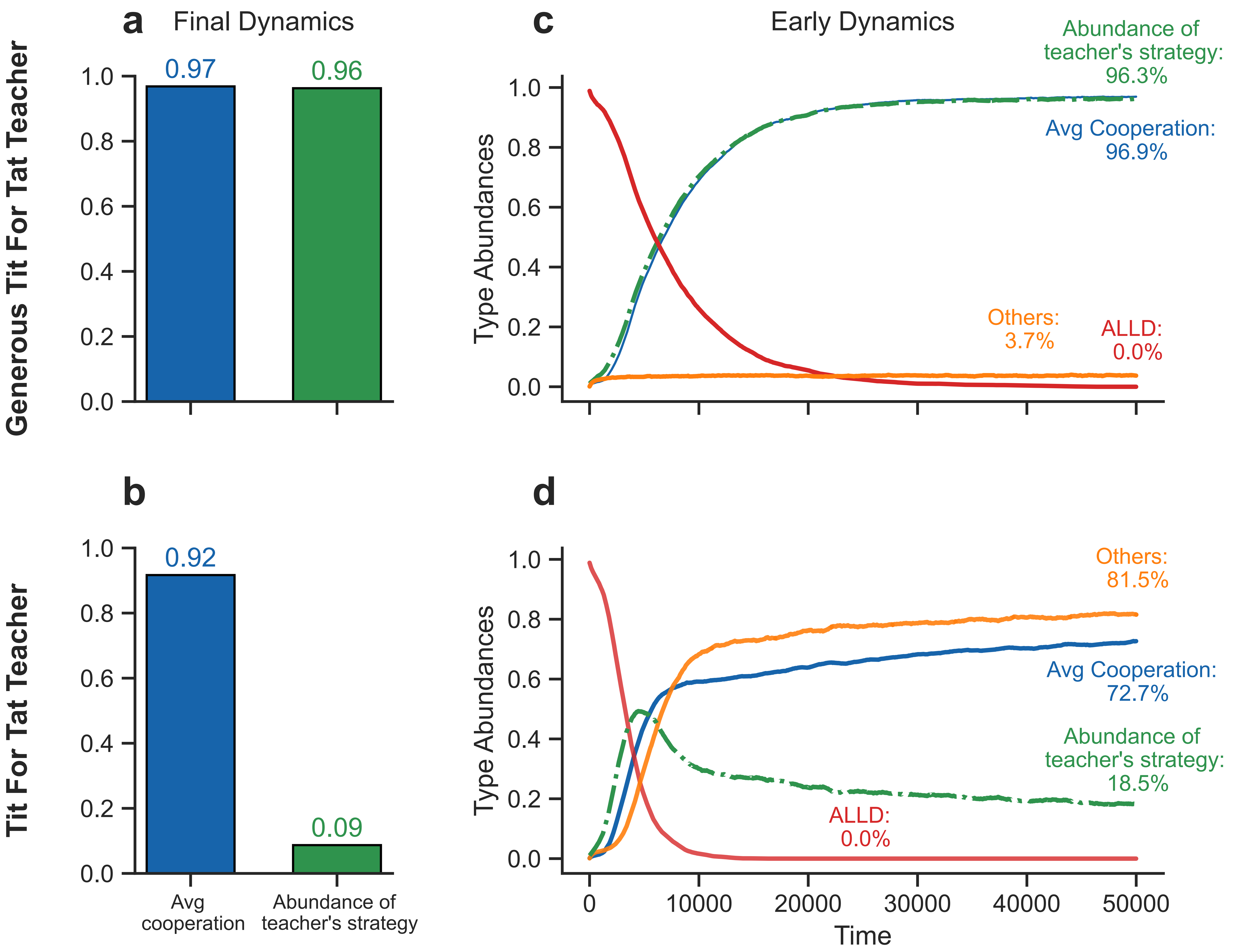
ROBUSTNESS CHECK



HOW DOES IT WORK?

Generous Tit For Tat
(1,0.1,1,0.1)

Tit For Tat
(1,0,1,0)



WHO IS A GOOD TEACHER?

Memory-1

$\mathbf{p} = (p_{CC}, p_{CD}, p_{DC}, p_{DD})$

$\{0, 0.1, \ldots, 1\}$

$\{0, 0.1, \ldots, 1\}$

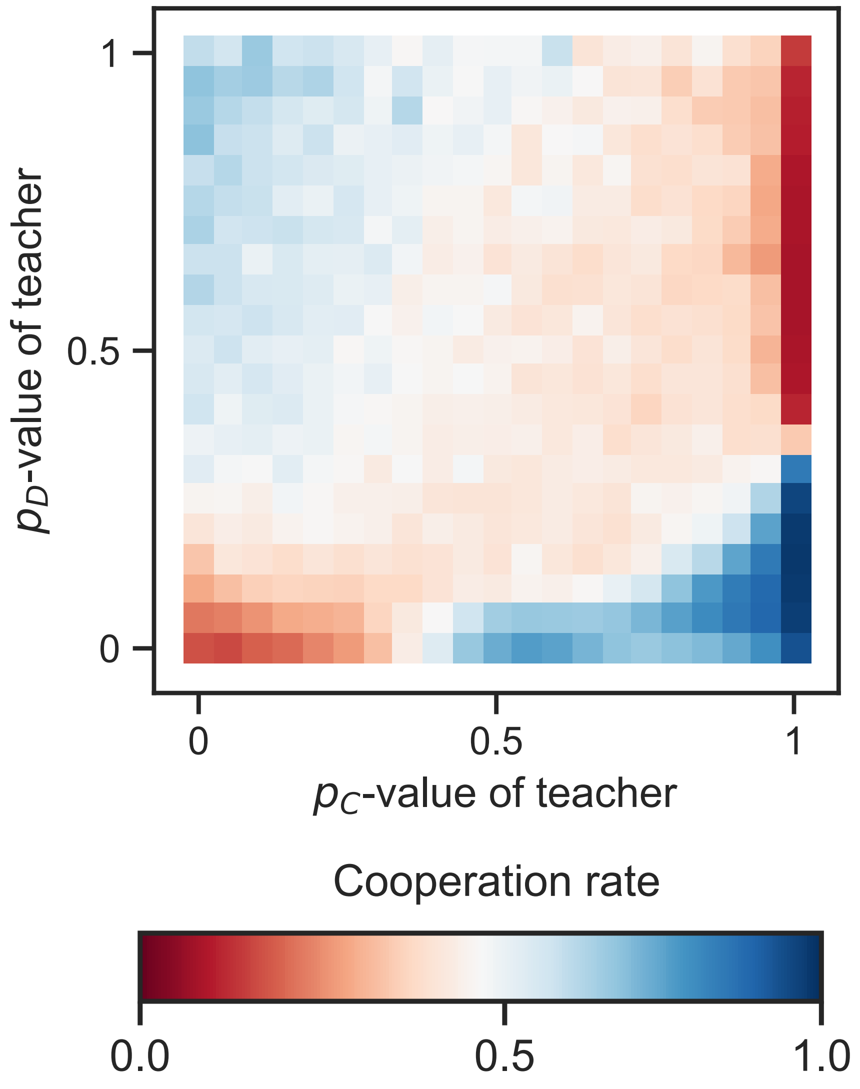
$\{0, 0.1, \ldots, 1\}$

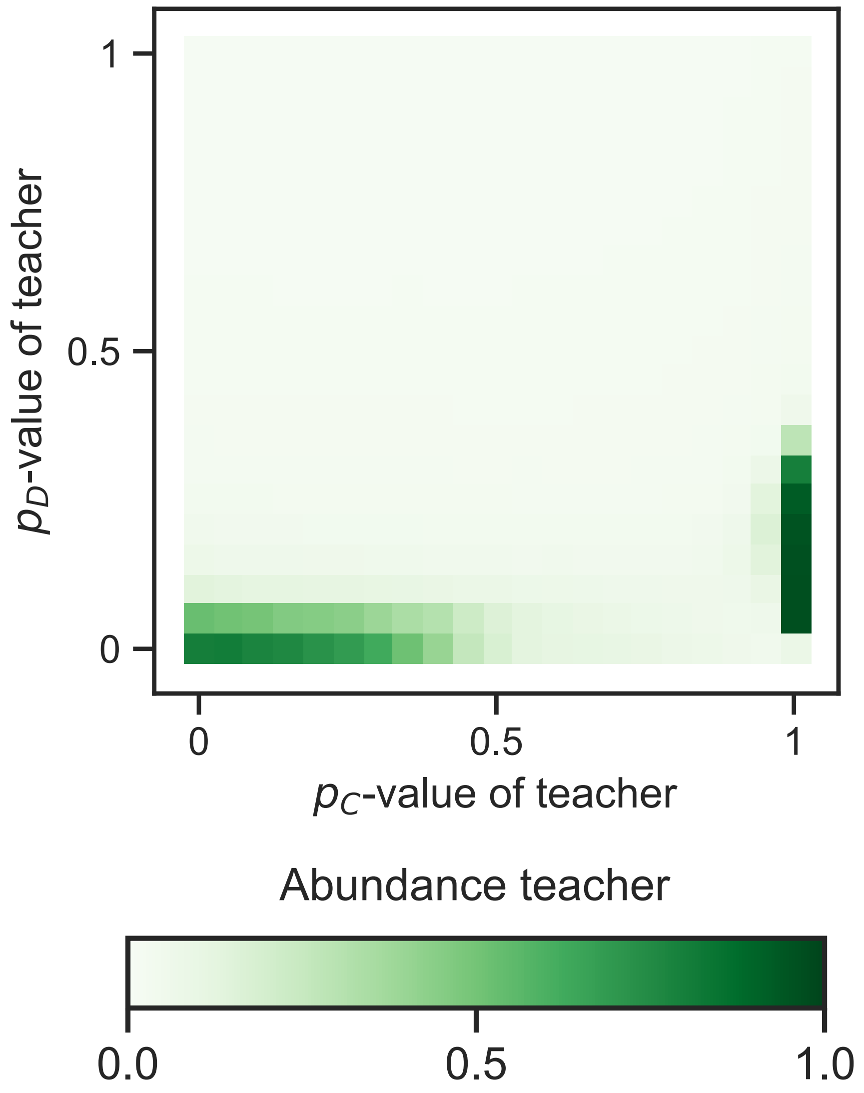
1. Reactive-1 (p_C, p_D, p_C, p_D)
2. Cooperative Memory-1$(p_{CC} = 1, p_{CD}, p_{DC}, p_{DD})$
3. Memory-1 $(p_{CC}, p_{CD}, p_{DC}, p_{DD})$

WHO IS A GOOD TEACHER?

Reactive-1

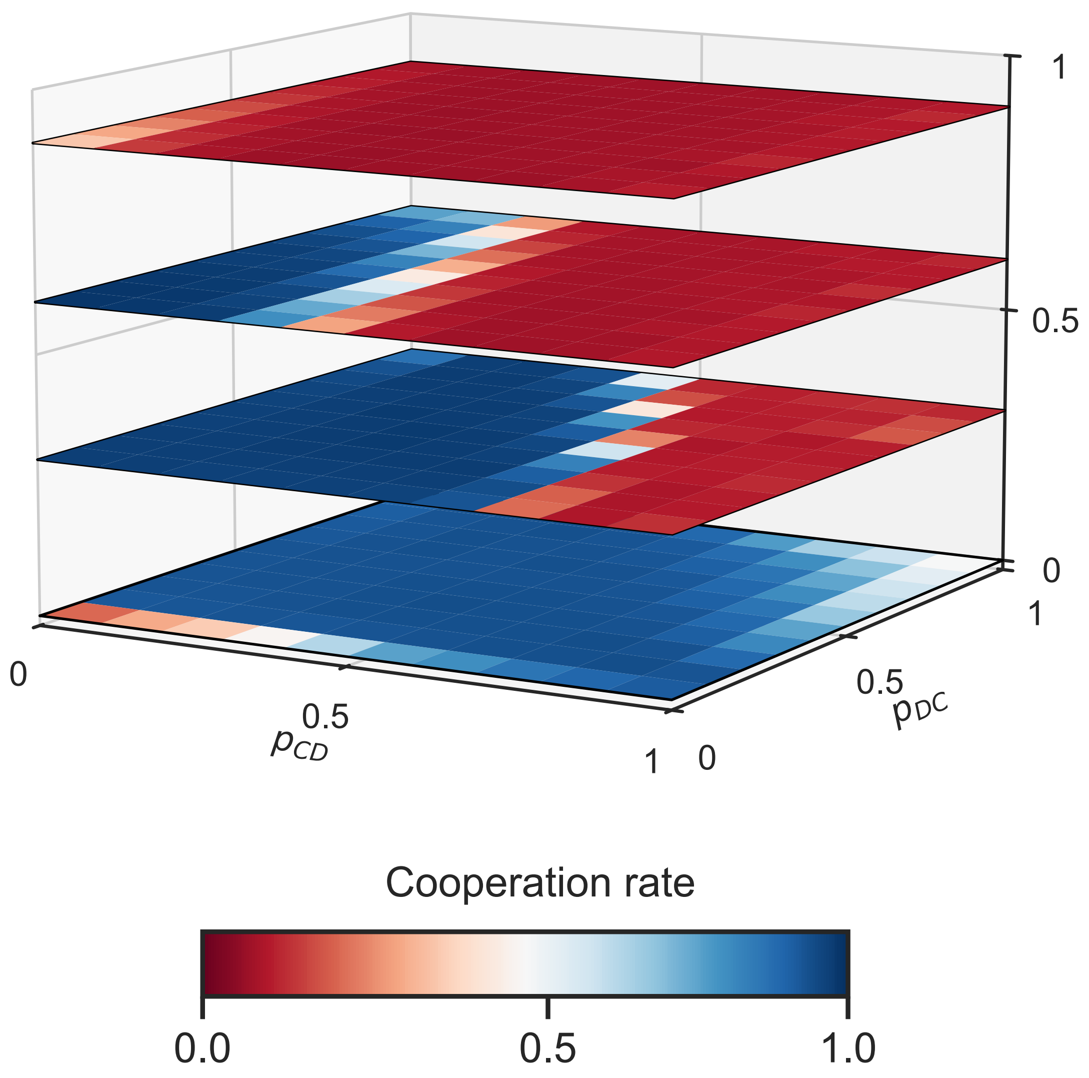
(p_C, p_D, p_C, p_D)

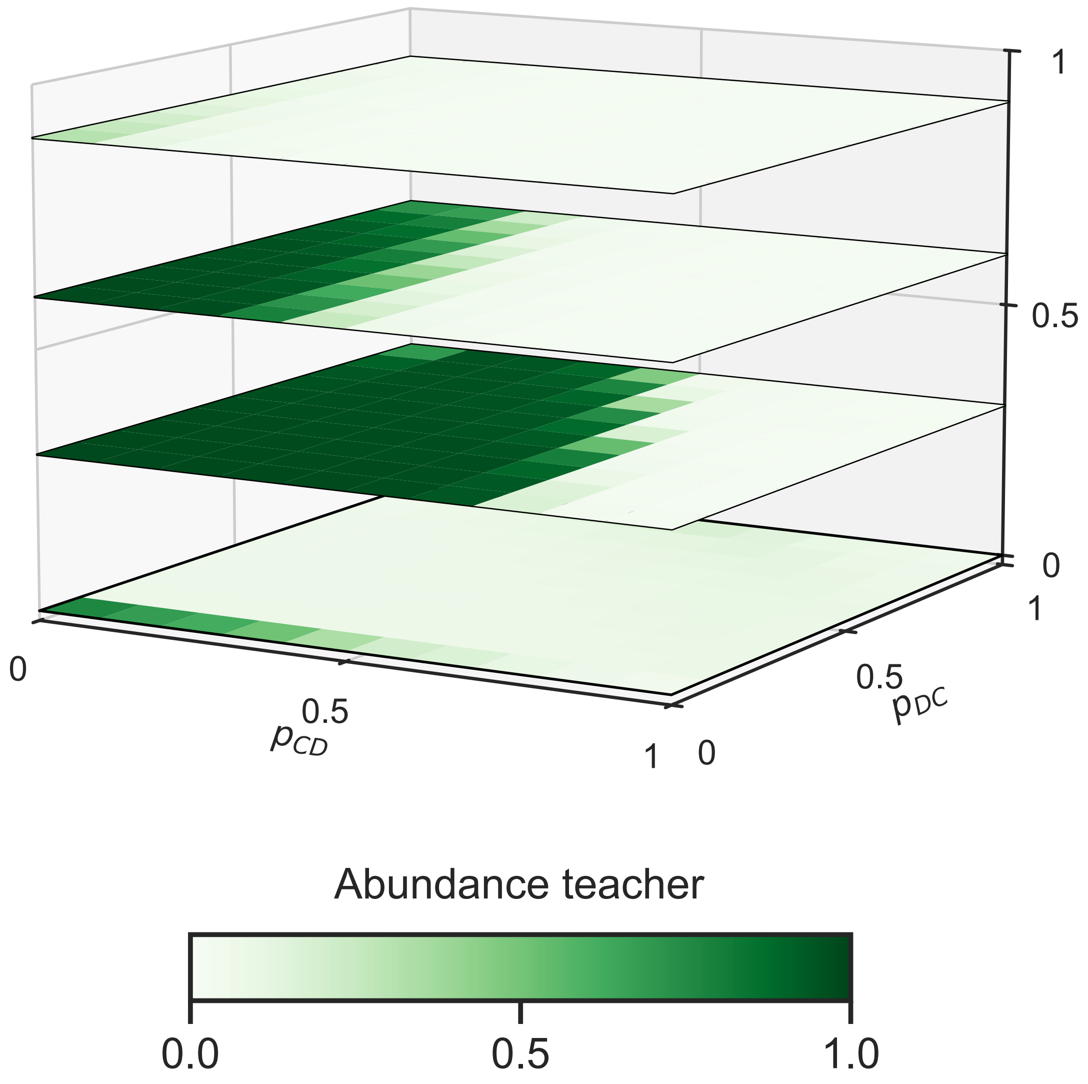




Cooperative Memory-1

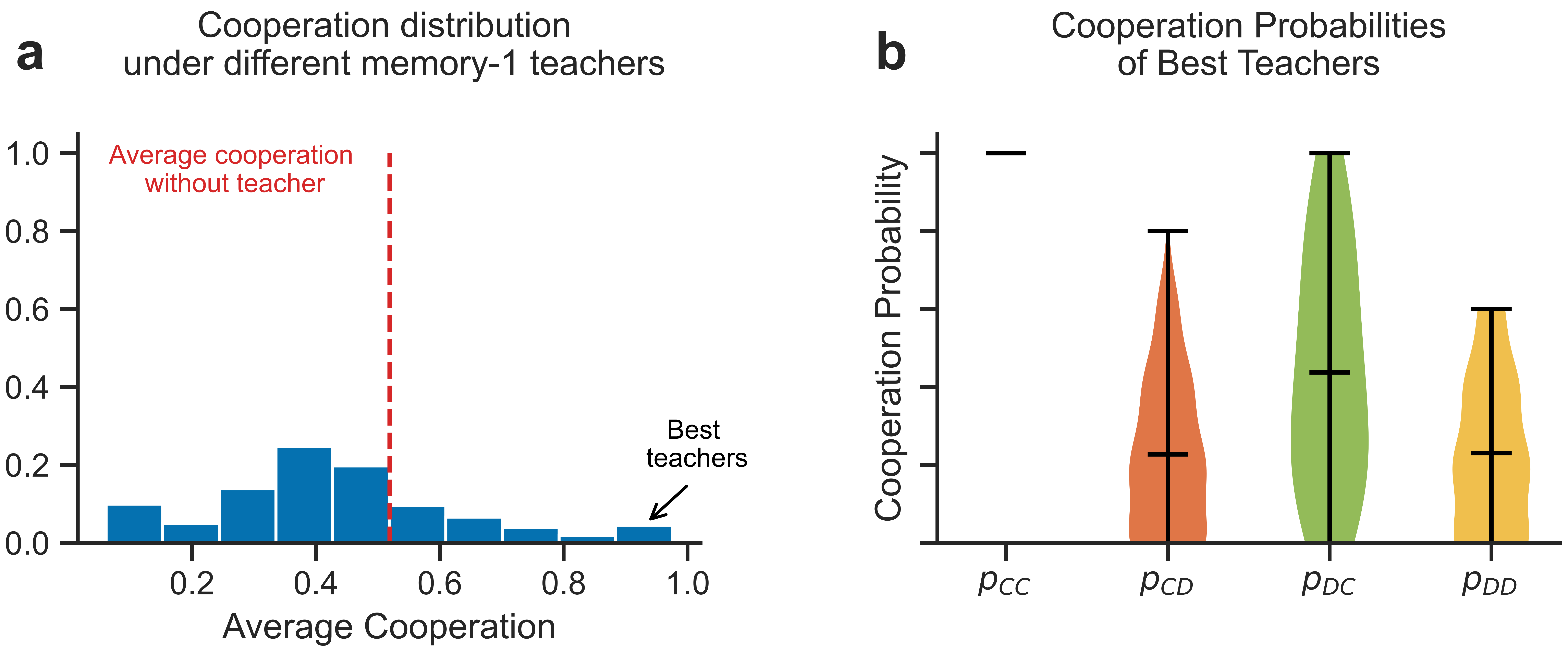
$(p_{CC} = 1, p_{CD}, p_{DC}, p_{DD})$





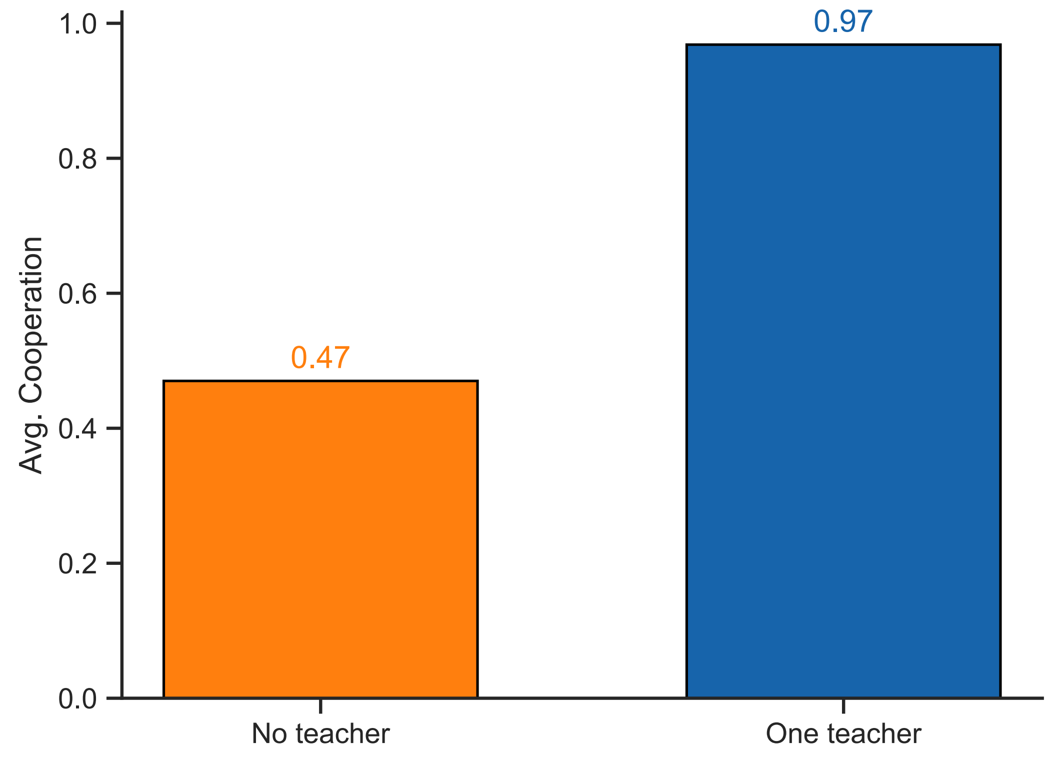
WHO IS A GOOD TEACHER?

Memory-1 $(p_{CC}, p_{CD}, p_{DC}, p_{DD})$

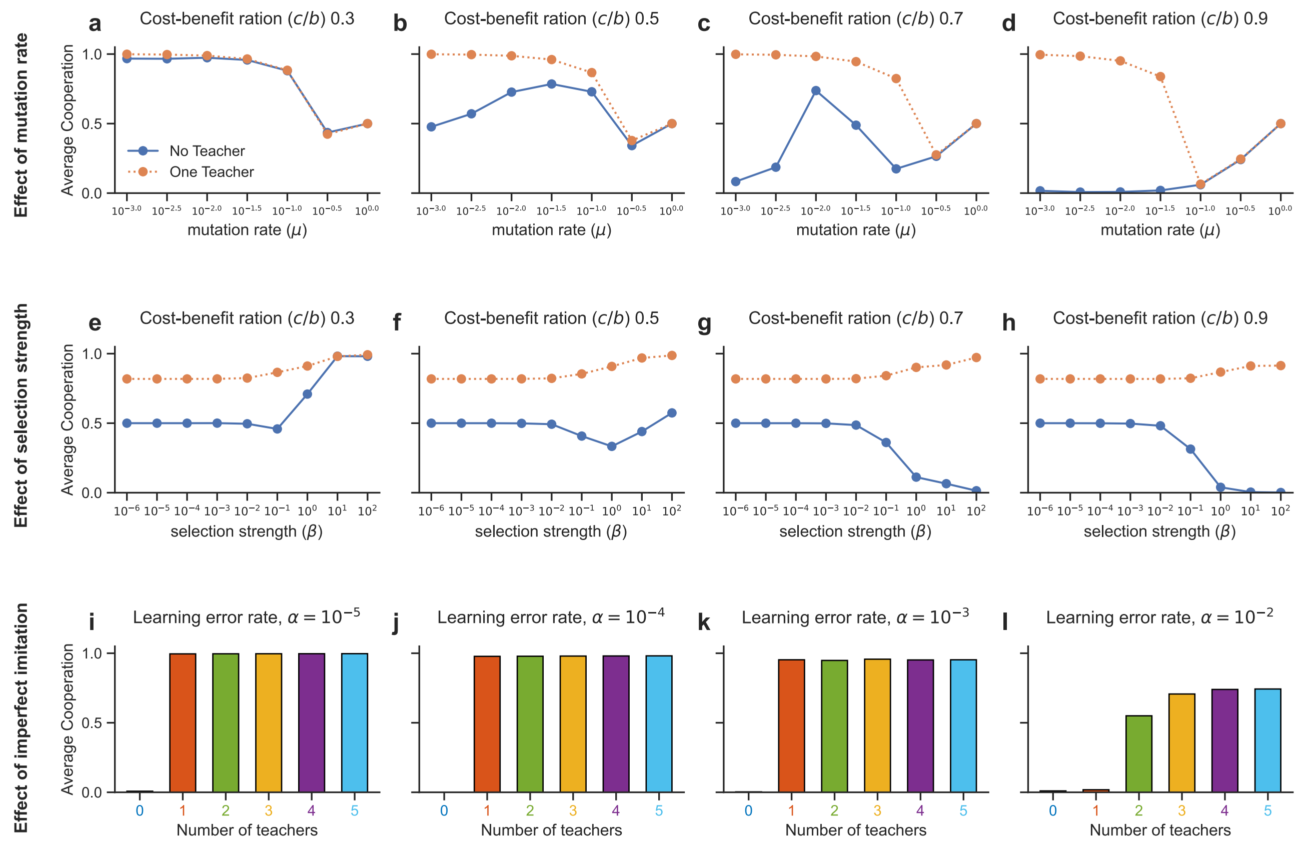


SUMMARY (SO FAR)

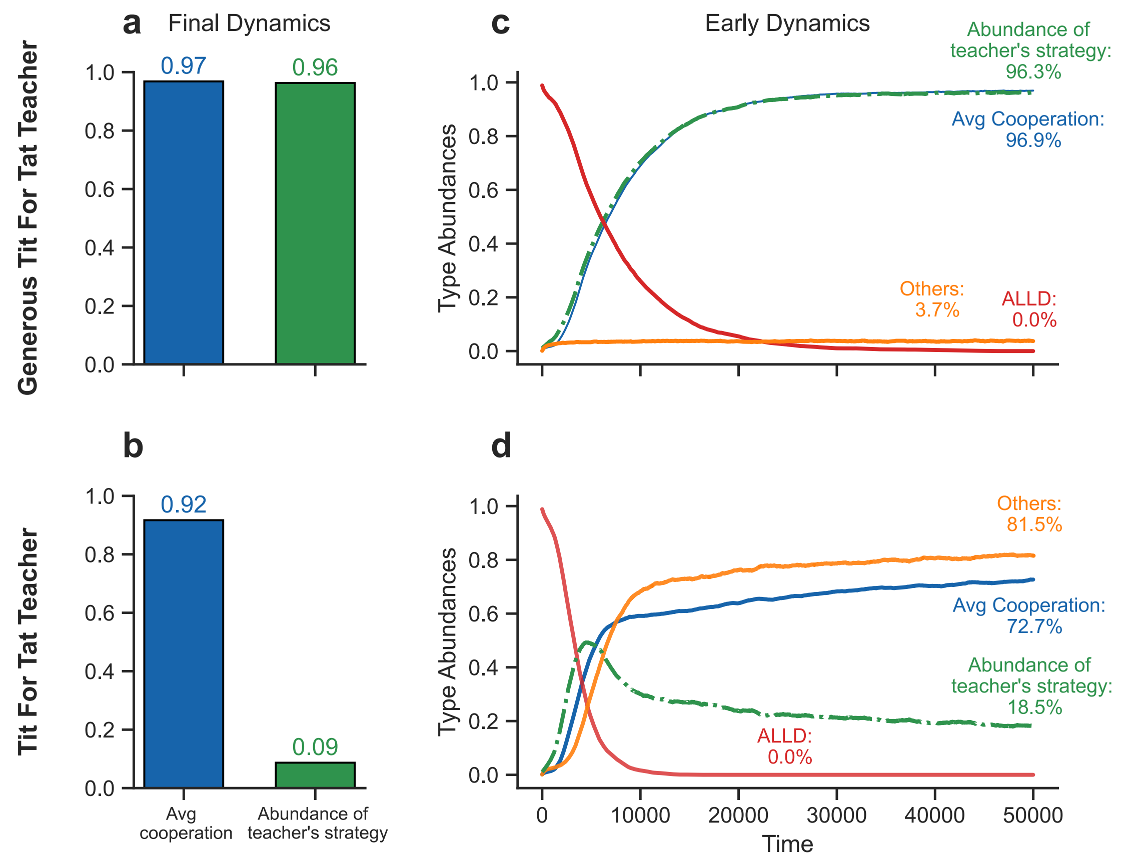
The basic theory



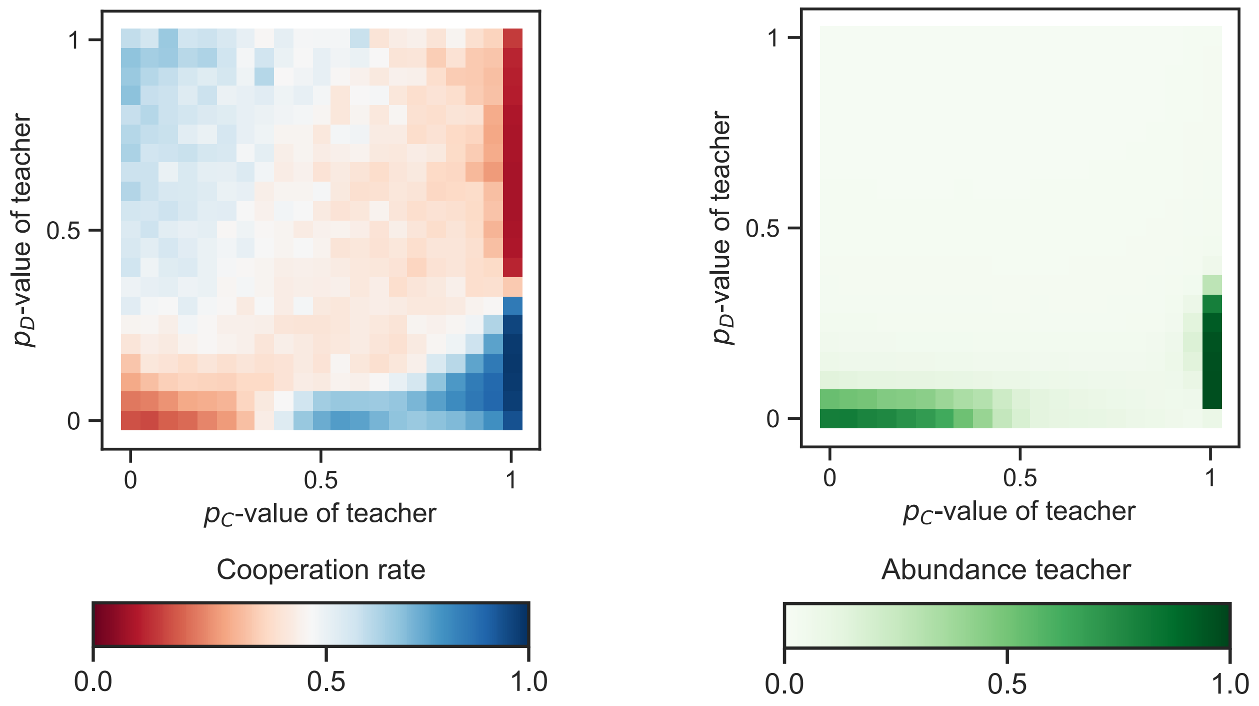
Robustness



The mechanism of teaching



Which strategy should teacher's adopt?



OTHER GAMES

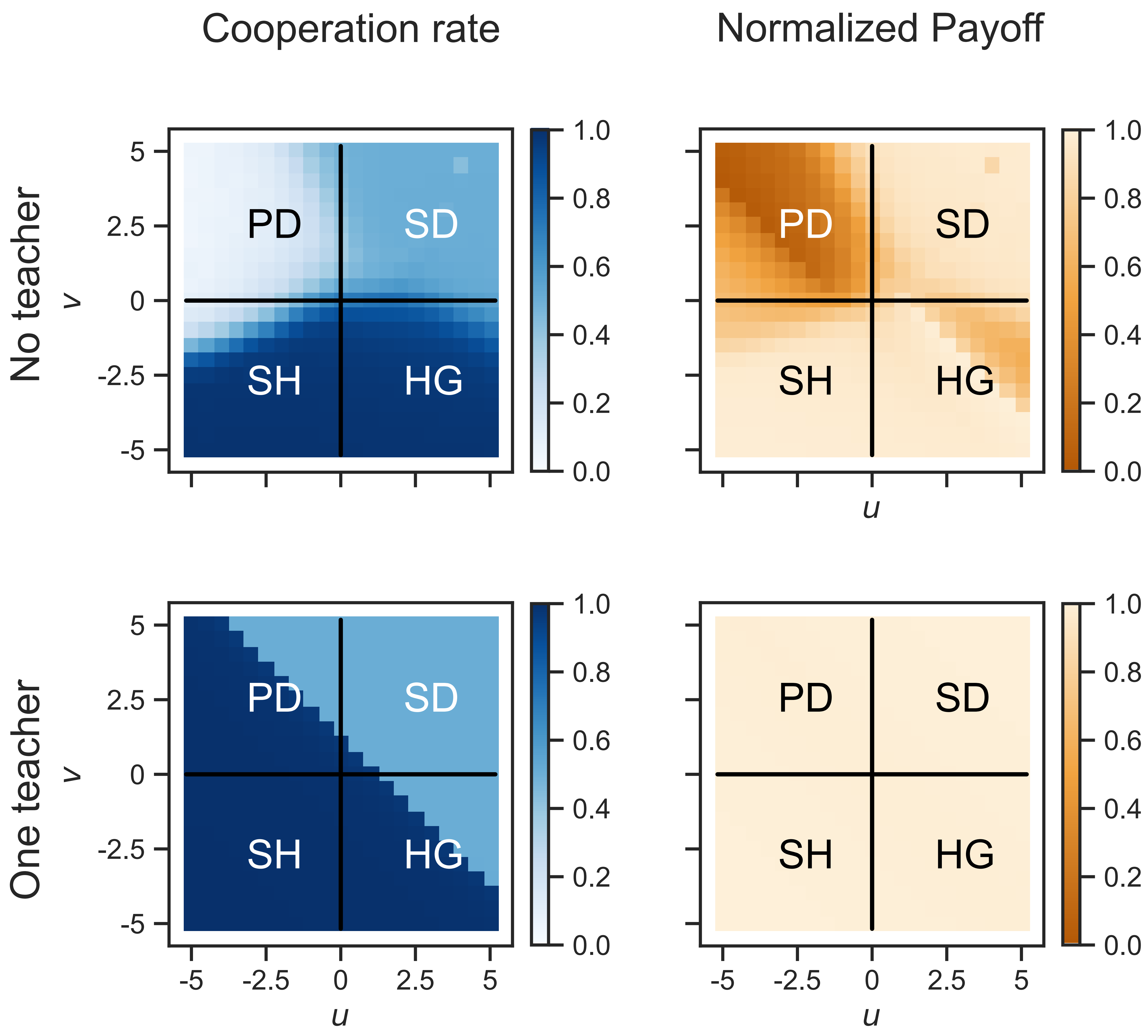
$$\begin{array}{c c} & \begin{array}{cc} C & D \end{array} \\ \begin{array}{c} C \\ D \end{array} & \begin{pmatrix} b-c & -c \\ b & 0 \end{pmatrix} \end{array}$$

Donation game

$$\begin{array}{c c} & \begin{array}{cc} C & D \end{array} \\ \begin{array}{c} C \\ D \end{array} & \begin{pmatrix} 1 & u \\ 1+v & 0 \end{pmatrix} \end{array}$$

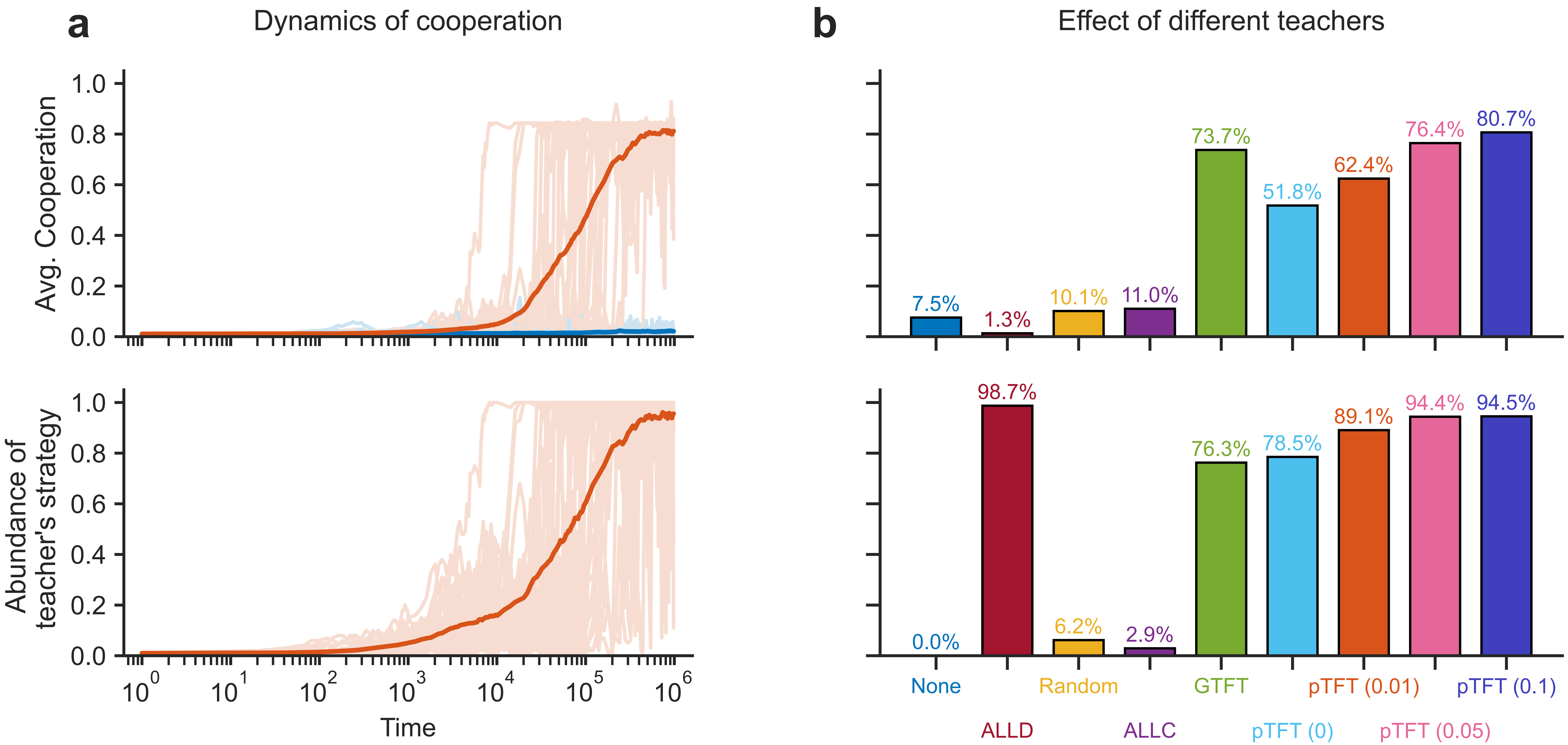
2×2 games

OTHER GAMES



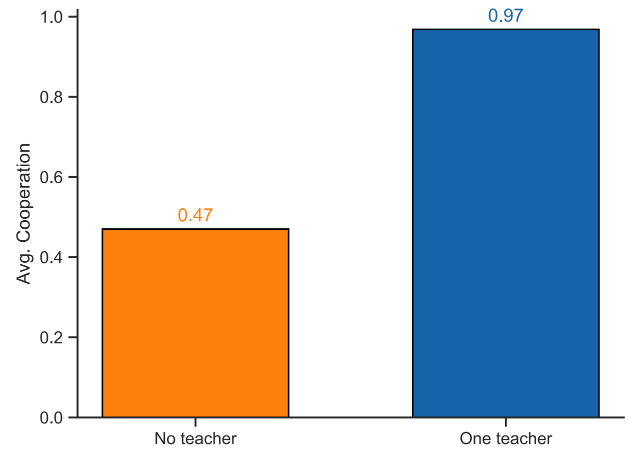
Cooperation rate
Normalized Payoff
No teacher
One teacher
PD
SD
SH
HG
v
u
5
2.5
0
-2.5
-5
1.0
0.8
0.6
0.4
0.2
0.0

PUBLIC GOODS GAMES

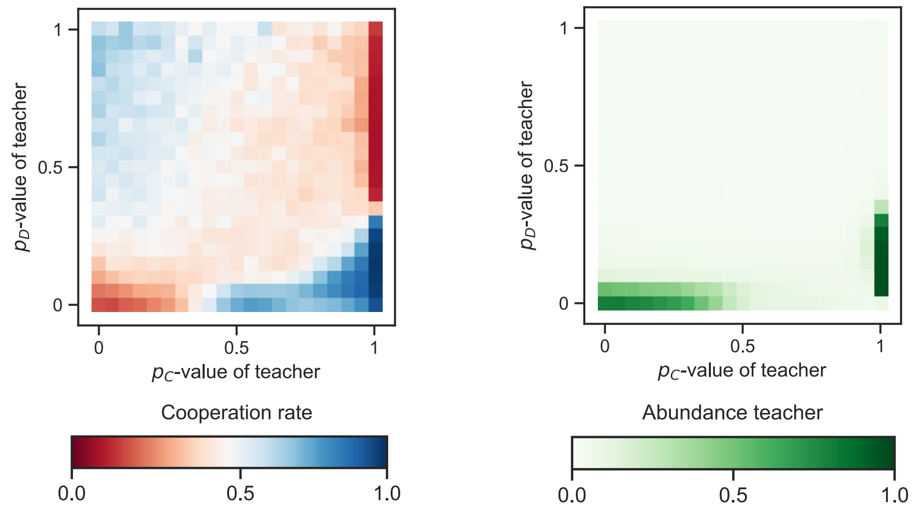


SUMMARY

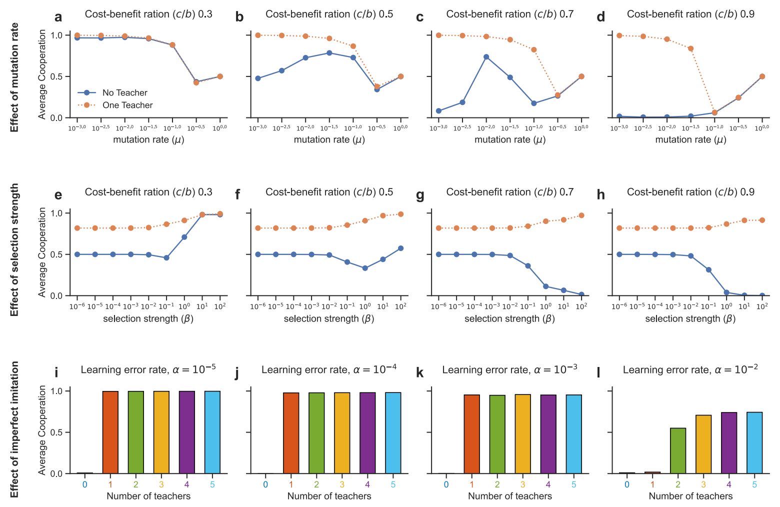
The basic theory



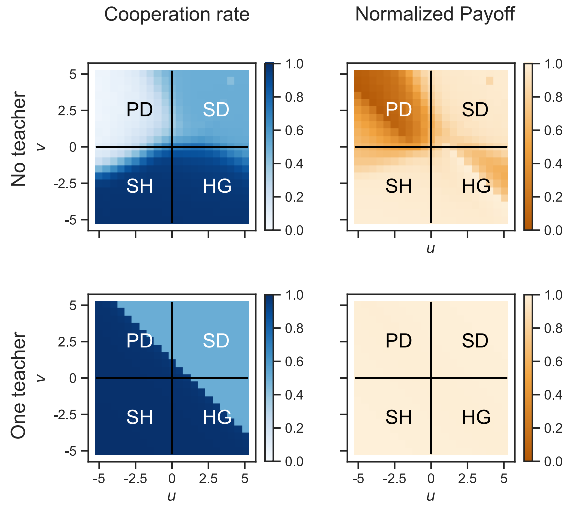
Which strategy should teacher's adopt?



Robustness



2×2 games

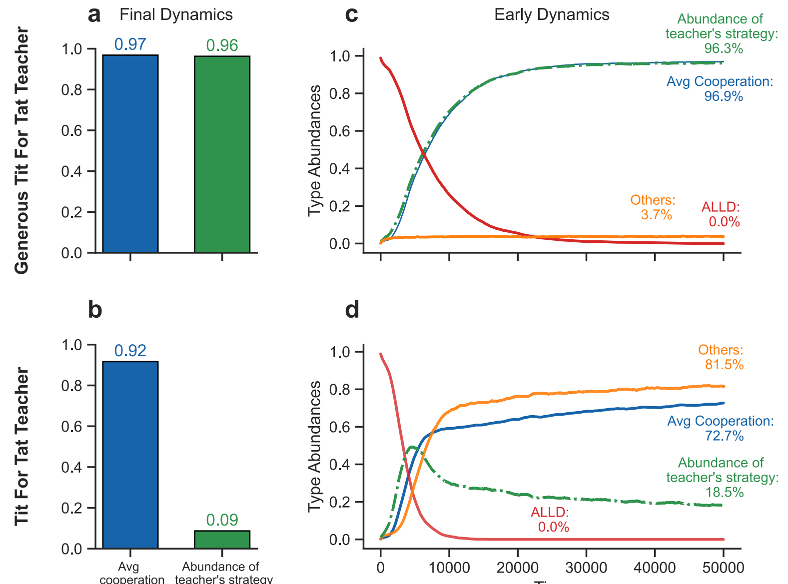


Nikoleta-v3

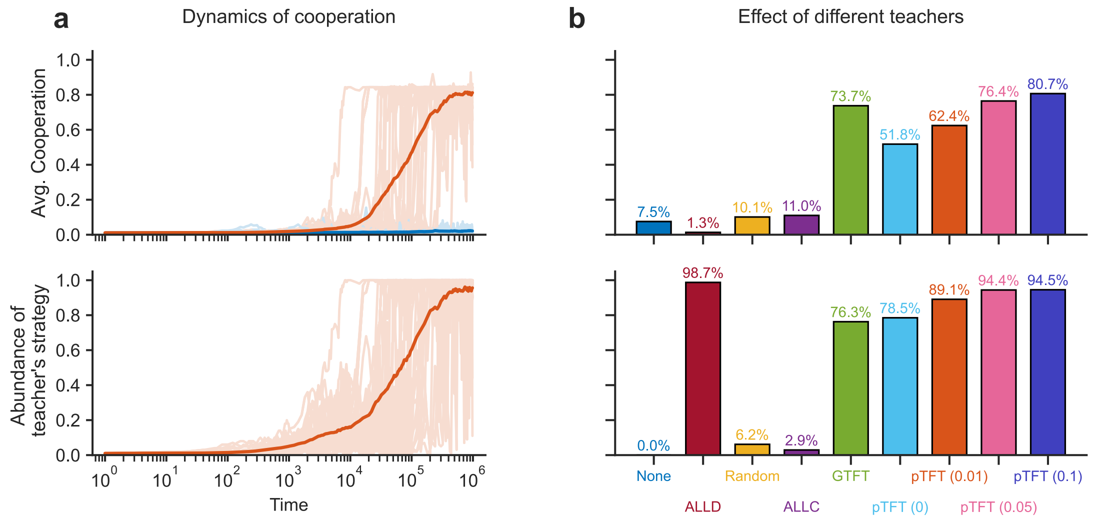
@NikoletaGlyn

http://nikoleta-v3.github.io

The mechanism of teaching



Multiplayer games



THANK YOU!

TEACHING TIME