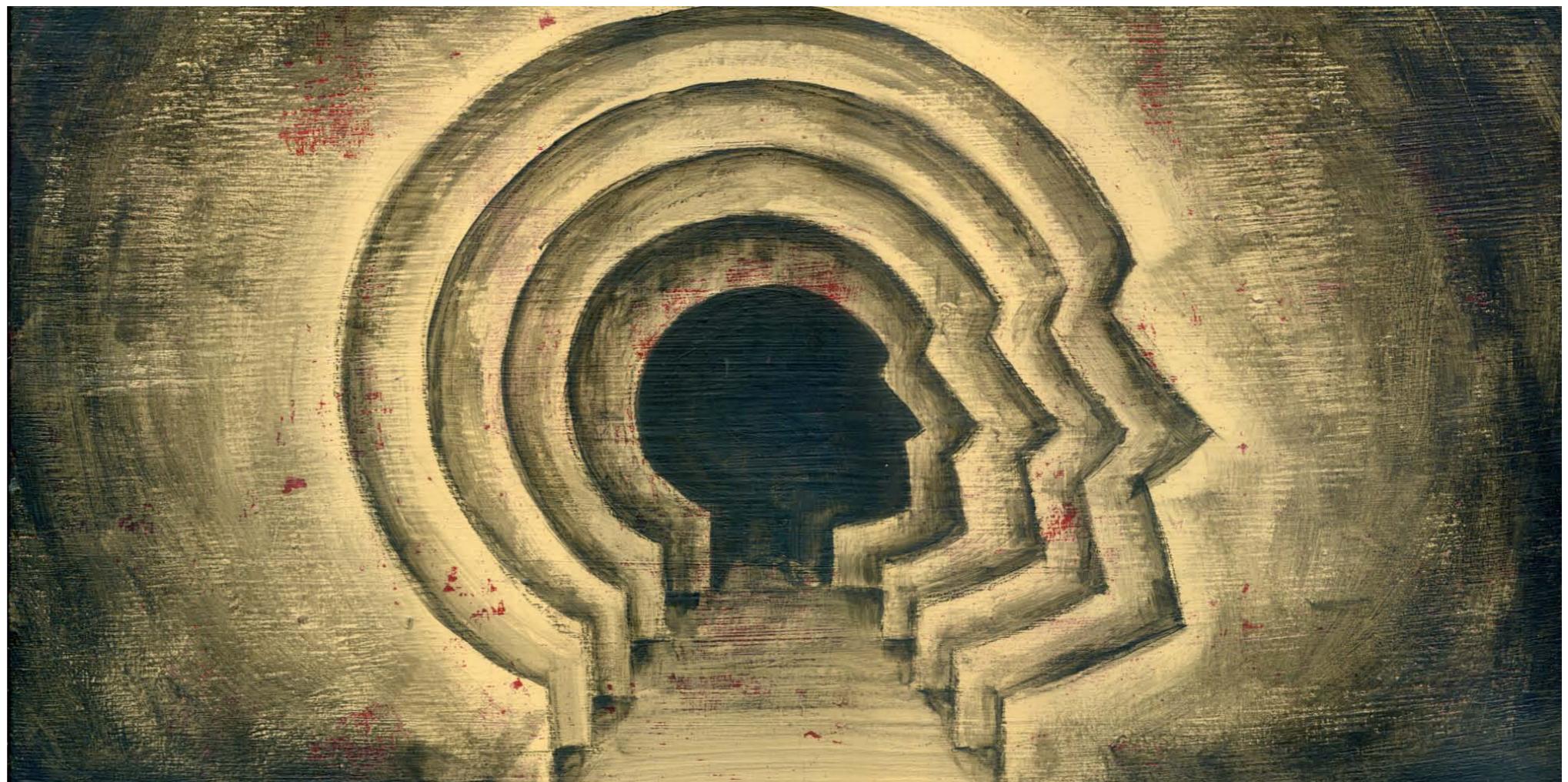


Anxo Sánchez

Computational social science: interactions among people and complex socio-technological systems

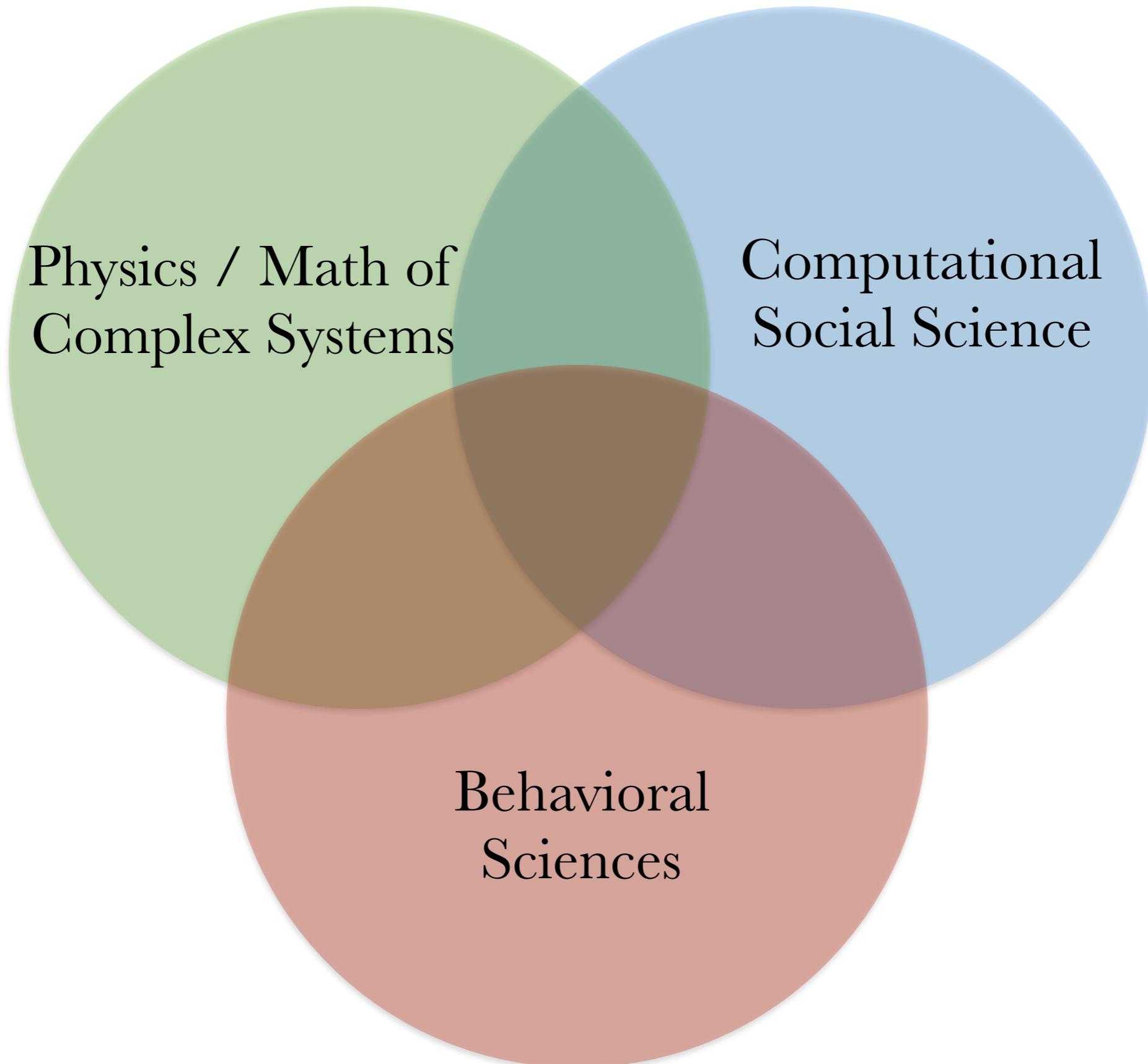


Grupo Interdisciplinar de Sistemas Complejos (GISC), Departamento de Matemáticas & Institute UC3M-BS of Financial Big Data (IfiBiD), Universidad Carlos III de Madrid



Instituto de Biocomputación y Física de Sistemas Complejos (BIFI), Universidad de Zaragoza

The interactions-based approach



Living on the edge



Nature (Special Issue) 525, 305
(17 September 2015)

To solve the grand challenges facing society — energy, water, climate, food, health — scientists and social scientists must work together.

Social physics



Adolphe Quetelet
(1796-1874)

Astronomer,
mathematician,
statistician,
and sociologist

Frame: Adam Smith (1723-1790), David Ricardo (1772-1823), Thomas Malthus (1766-1834)

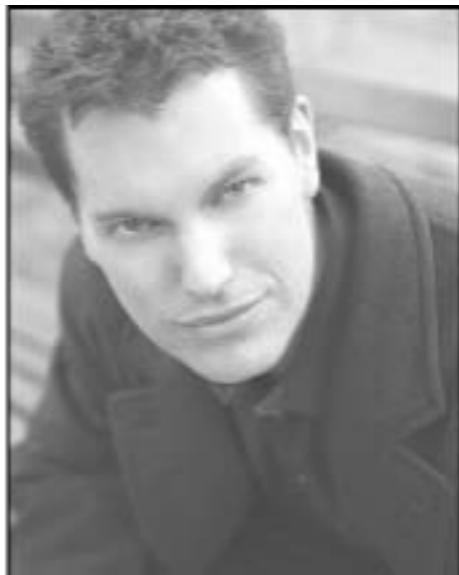
Social physics



Quetelet was keenly aware of the overwhelming **complexity of social phenomena**, and the many variables that needed measurement. His goal was to understand the **statistical laws underlying such phenomena** as crime rates, marriage rates or suicide rates. He wanted to explain the values of these variables by other social factors. These ideas were rather controversial among other scientists at the time who held that it contradicted a concept of freedom of choice.

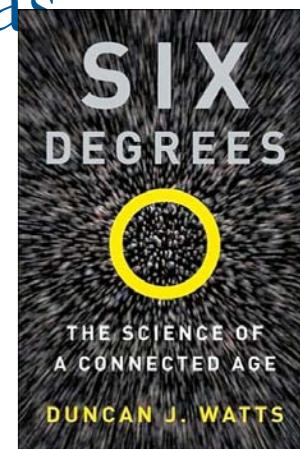
His most influential book was *Sur l'homme et le développement de ses facultés, ou Essai de physique sociale*, published in 1835. In it, he outlines the project of a social physics and describes his concept of the "**average man**" (*l'homme moyen*) who is characterized by the mean values of measured variables that follow a normal distribution.

Physicists and interdisciplinarity



DUNCAN J. WATTS

Physicists, it turns out, are almost perfectly suited to invading other people's disciplines, being not only extremely clever but also generally much less fussy than most about the problems they choose to study. Physicists tend to see themselves as the lords of the academic jungle, loftily regarding their own methods as above the ken of anybody else and jealously guarding their own terrain. But their alter egos are closer to scavengers, happy to borrow ideas and technologies from anywhere if they seem like they might be useful, and delighted to stomp all over someone else's problem.

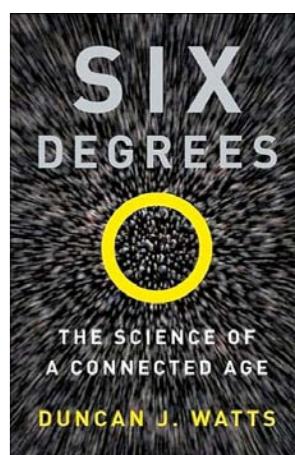


Physicists and interdisciplinarity



DUNCAN J. WATTS

As irritating as this attitude can be to everybody else, the arrival of the physicists into a previously non-physics area of research often presages a period of great discovery and excitement. Mathematicians do the same thing occasionally, but no one descends with such fury and in so great a number as a pack of hungry physicists, adrenalized by the scent of a new problem.

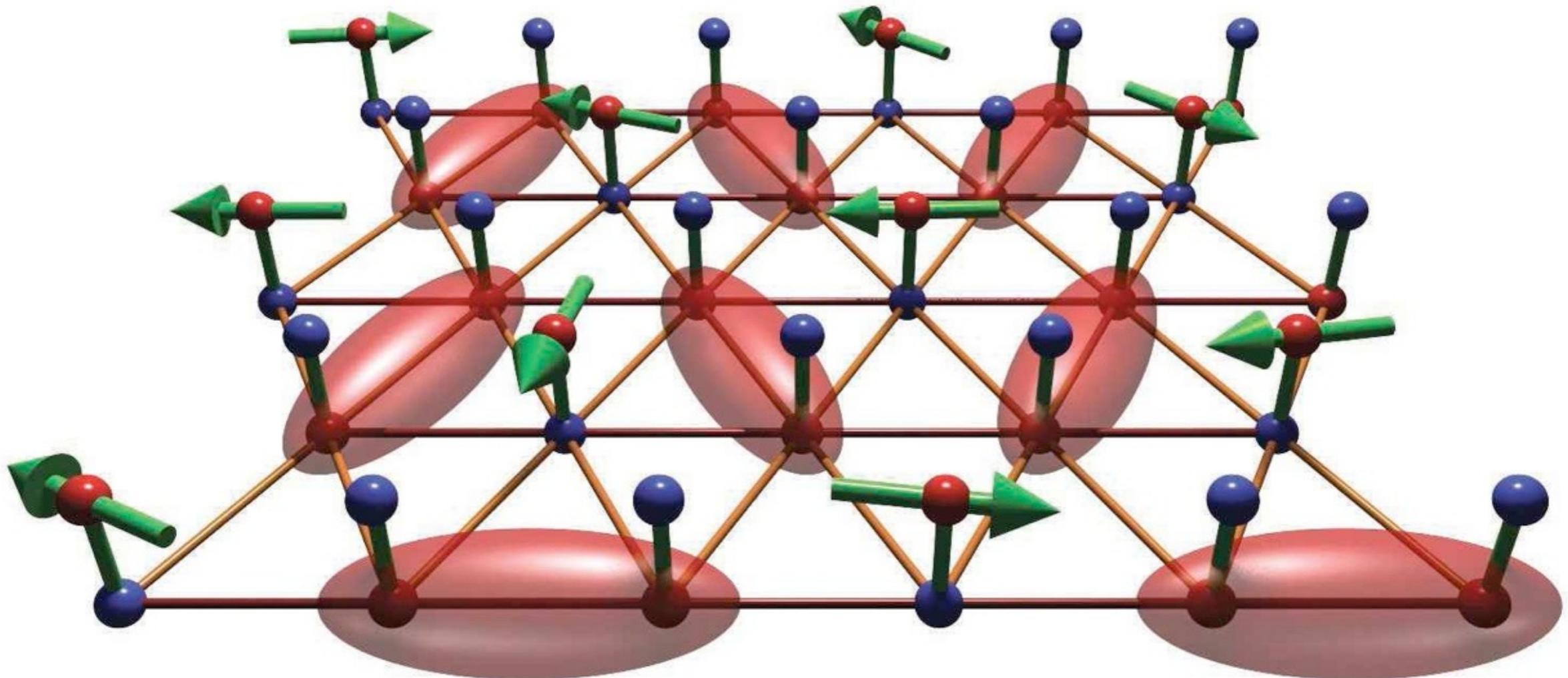


The interactions-based approach

Physicists study collective phenomena
emerging from the interactions of
individuals as elementary units in
complex socio-technological systems

The interactions-based approach

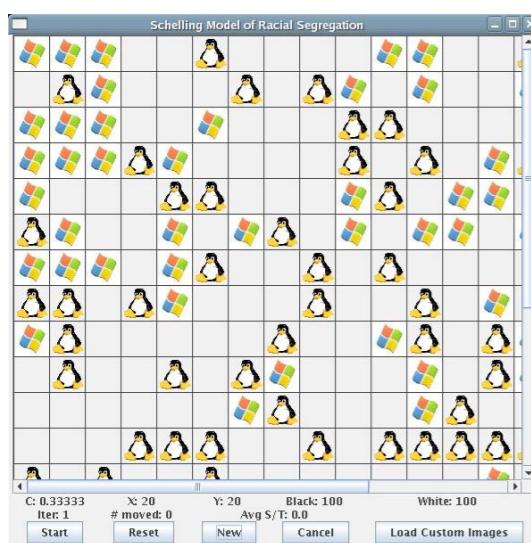
Strategic interactions / local optimization



Computational Social Science



Aimed to favor and take advantage
of massive ICT data



A [computer] model-based science
yielding predictive and explanatory
models

Computational Social Science

Eur. Phys. J. Special Topics **214**, 325–346 (2012)

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DOI: [10.1140/epjst/e2012-01697-8](https://doi.org/10.1140/epjst/e2012-01697-8)

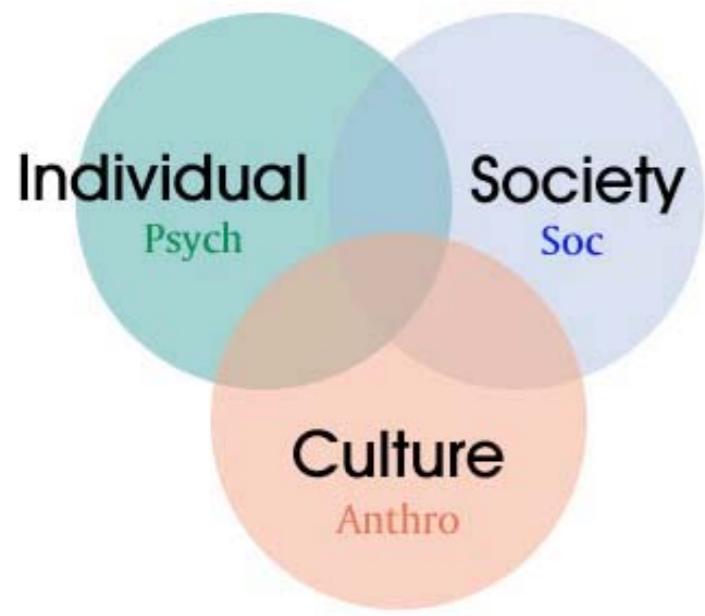
**THE EUROPEAN
PHYSICAL JOURNAL
SPECIAL TOPICS**

Regular Article

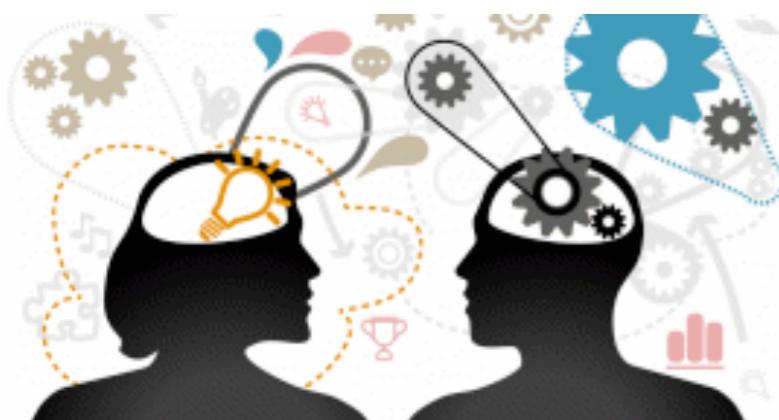
Manifesto of computational social science

R. Conte^{1,a}, N. Gilbert², G. Bonelli¹, C. Cioffi-Revilla³, G. Deffuant⁴, J. Kertesz⁵,
V. Loreto⁶, S. Moat⁷, J.-P. Nadal⁸, A. Sanchez⁹, A. Nowak¹⁰, A. Flache¹¹,
M. San Miguel¹², and D. Helbing¹³

Behavioral Science



Systematic analysis and investigation of human behavior through controlled and naturalistic observation, and disciplined scientific experimentation



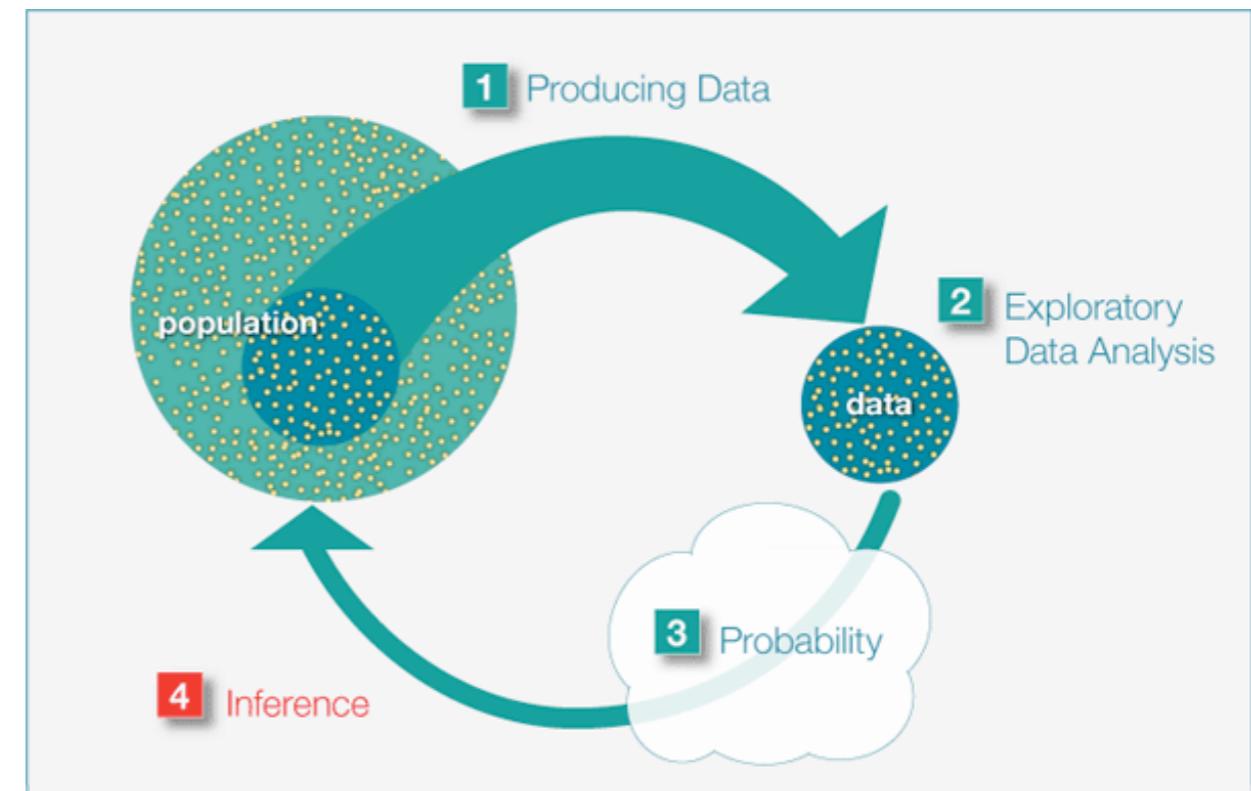
Effects of psychological, social, cognitive, and emotional factors on economic decisions; bounds of rationality of economic agents...

...and back!

Where disciplines meet

Challenges for new experimental work in integration with the modeling process:

- Test inferences from data
- Test simulation predictions
- Small vs large-scale
- Emergent behavior



So we look for

SMALL
DATA

So we look for

**SMALL
DATA**

So we look for

SMALL

CONTROLLED

DATA

Data Science vs Behavioral Science

Deloitte Review

ISSUE 16 | 2015



THE LAST-MILE PROBLEM

**How data science and behavioral
science can work together**

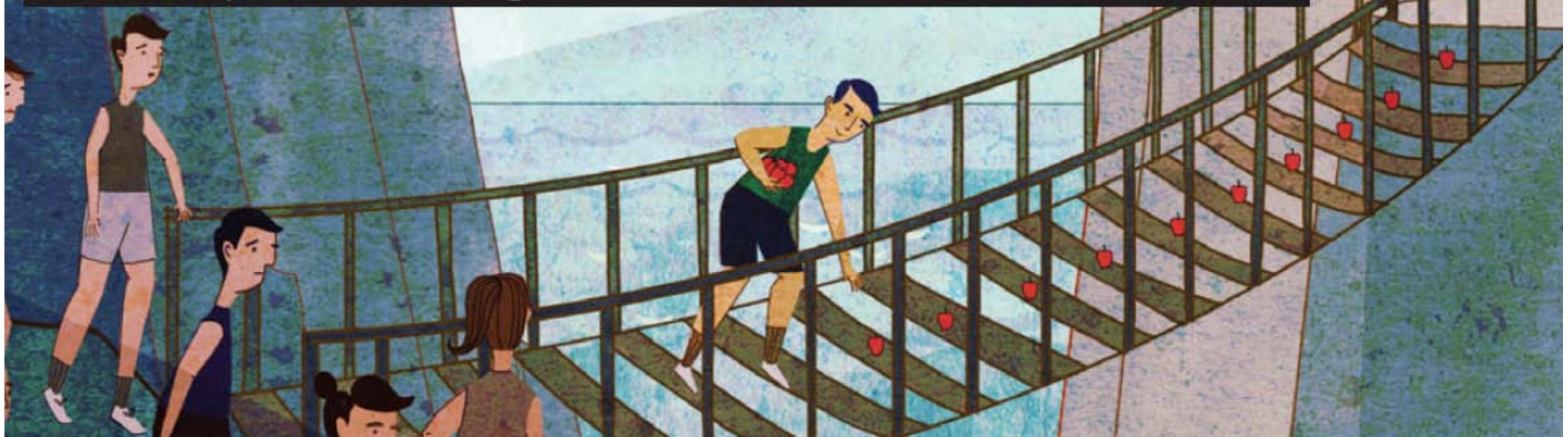
BY JAMES GUSCZA

Data Science vs Behavioral Science

Deloitte Review

ISSUE 16 | 2015

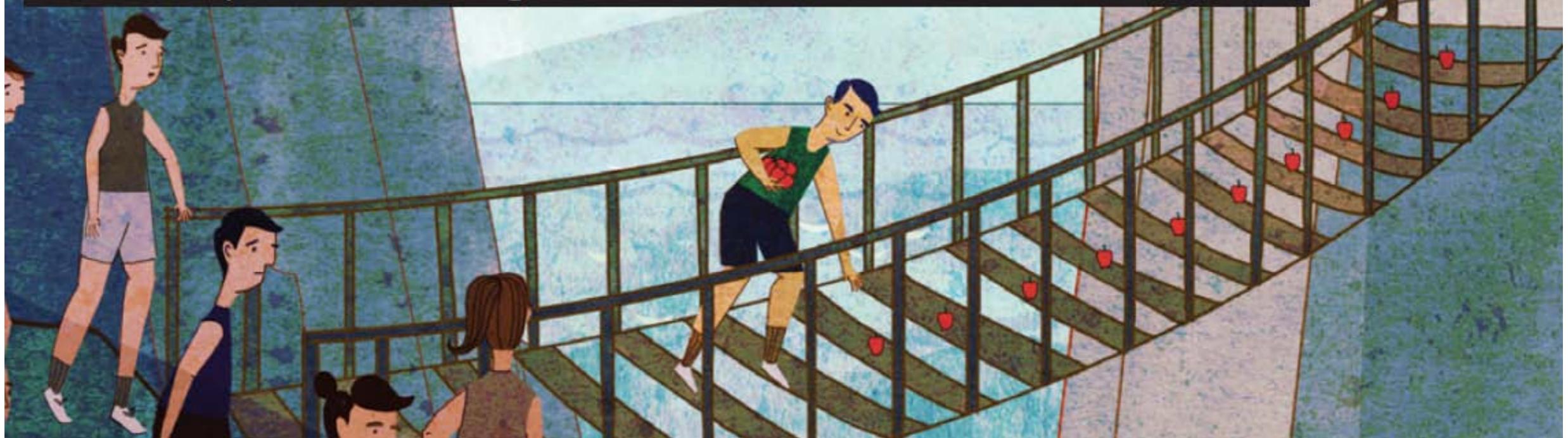
When the ultimate goal is behavior change, predictive analytics and the science of behavioral nudges can serve as two parts of a greater, more effective whole.



Data Science vs Behavioral Science

Once one starts thinking along these lines, other promising applications come to mind in a variety of domains, including public sector services, behavioral health, insurance, risk management, and fraud detection.

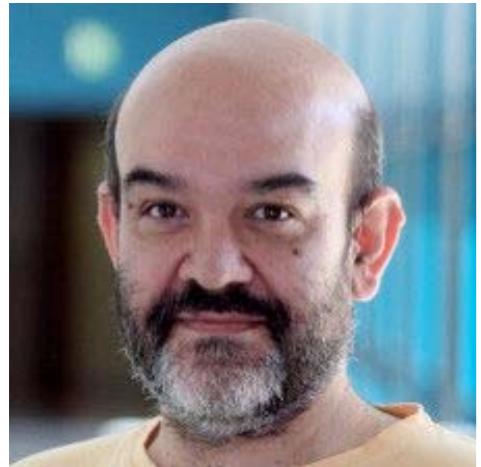
When the ultimate goal is behavior change, predictive analytics and the science of behavioral nudges can serve as two parts of a greater, more effective whole.



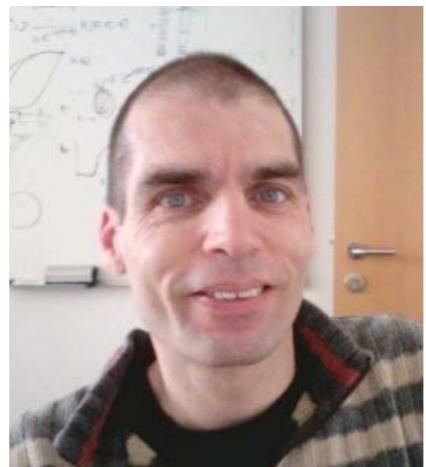
By way of illustration: Case studies

- Networks, cooperation and reputation
- Cooperation in hierarchical systems
- Behavioral phenotype classification
- Climate change mitigation

Work with



José A. Cuesta



Carlos Gracia-Lázaro



Yamir Moreno



Alfredo Ferrer



Lincoln Park Zoo



Katherine A. Cronin Daniel J. Acheson Penélope Hernández



Cronin *et al*, Sci. Rep. 5, 18 634 (2015)

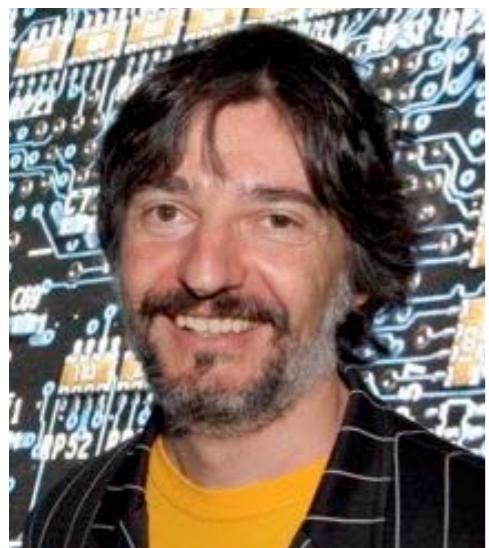


LINEEX

Work with



Mario Gutiérrez-Roig Julia Poncela-Casasnovas



Josep Perelló

Jordi Duch

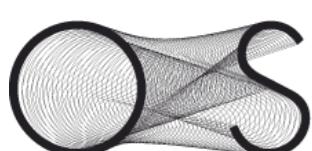
Nereida Bueno

Alberto Antonioni

Marco Tomassini

Poncela-Casasnovas *et al.*, submitted (2016)

Gutiérrez-Roig *et al.*, in preparation (2016)



Antonioni *et al.*, submitted (2016)

Case study 1. Networks

Nowak & May, Nature 359, 826 (1992)



Prisoner's dilemma

A game theoretical paradigm of social dilemma

	C	D
C	1	S
D	T	0



- 2 players
- 2 actions: **C**ooperate or **D**efect

$T > 1$: temptation to defect
 $S < 0$: risk in cooperation

Cooperation on networks: setup

1229 players (625, lattice; 604, heterogeneous)

Last year high school students

44% male, 56% female

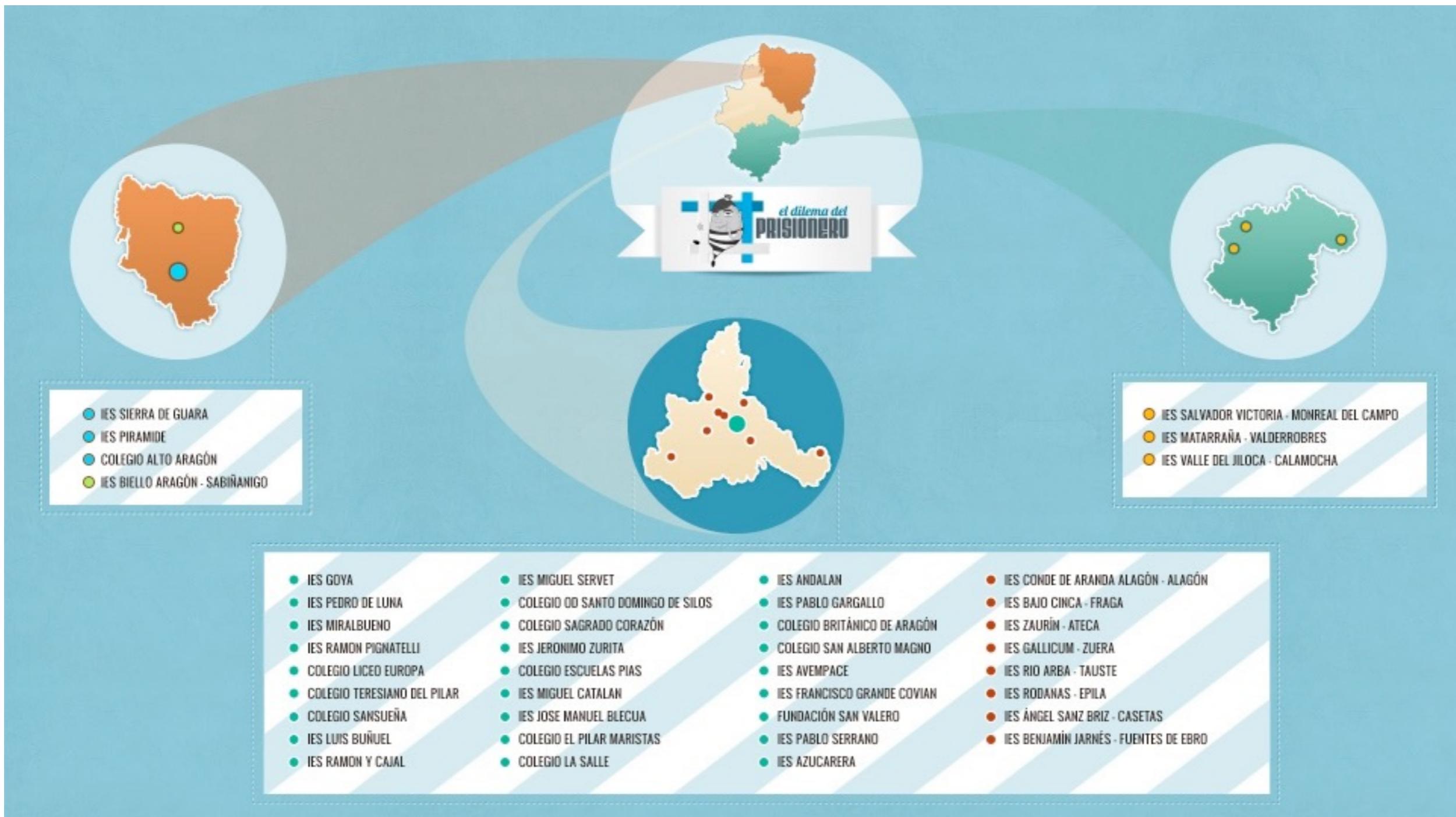
42 high schools in Aragón

From 10 AM till noon

10 000 €, on December 20, 2011; **largest** size ever

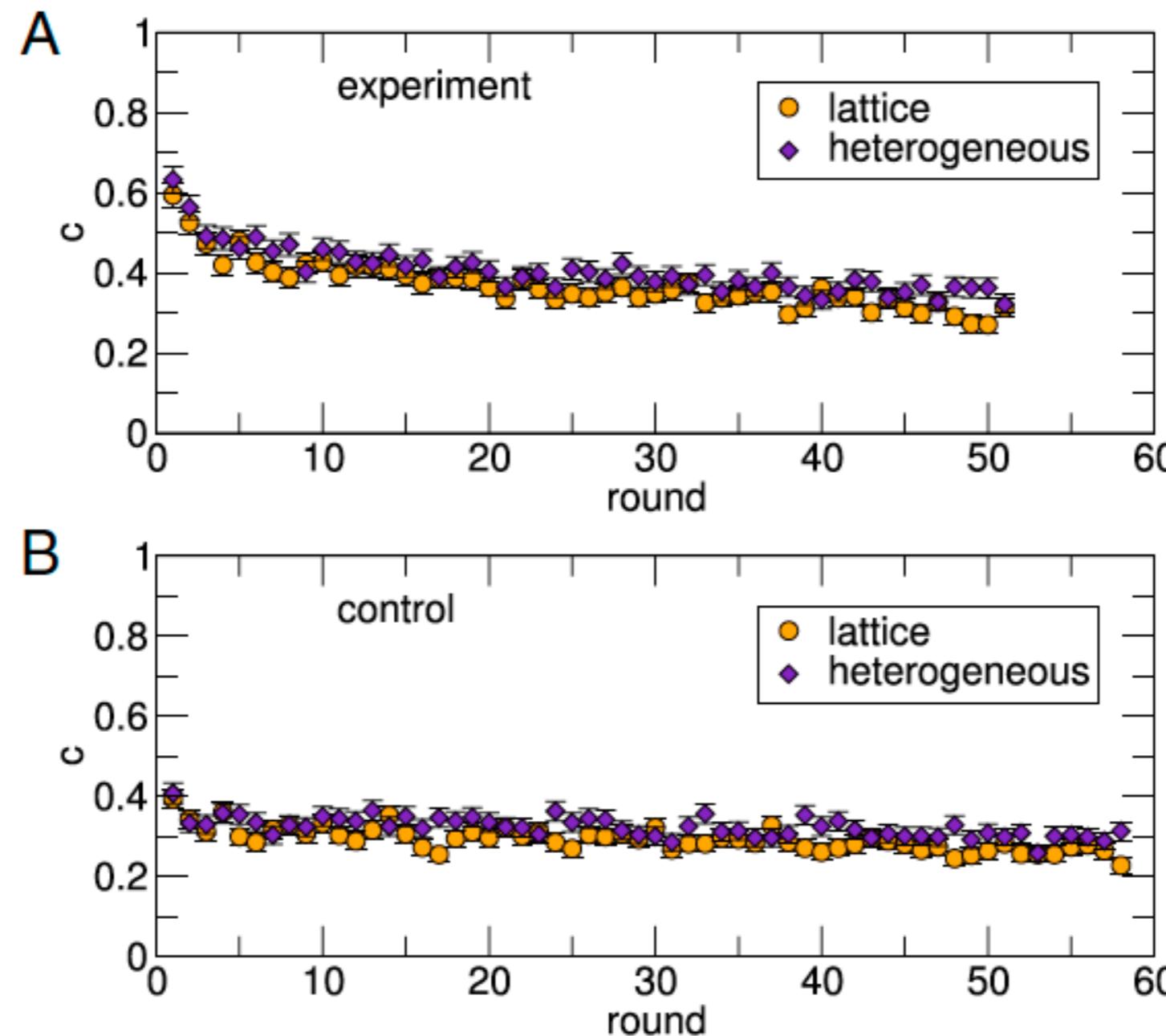


Cooperation on networks: setup

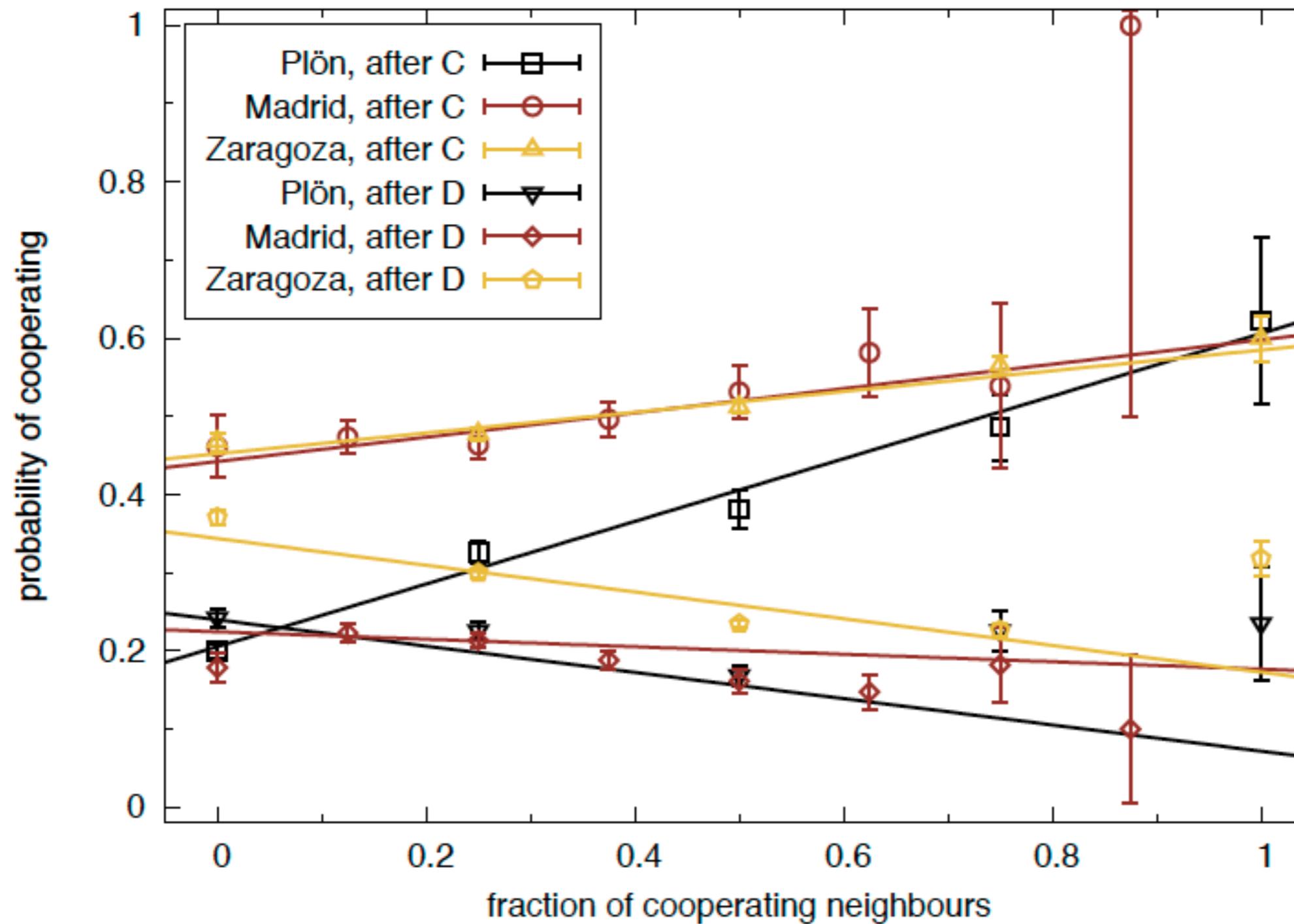


C. Gracia-Lázaro, A. Ferrer, G. Ruiz, A. Tarancón, J. A. Cuesta, A. S., Y. Moreno,
Proc. Natl. Acad. Sci USA **109**, 12922-12926 (2012)

Cooperation on networks: facts

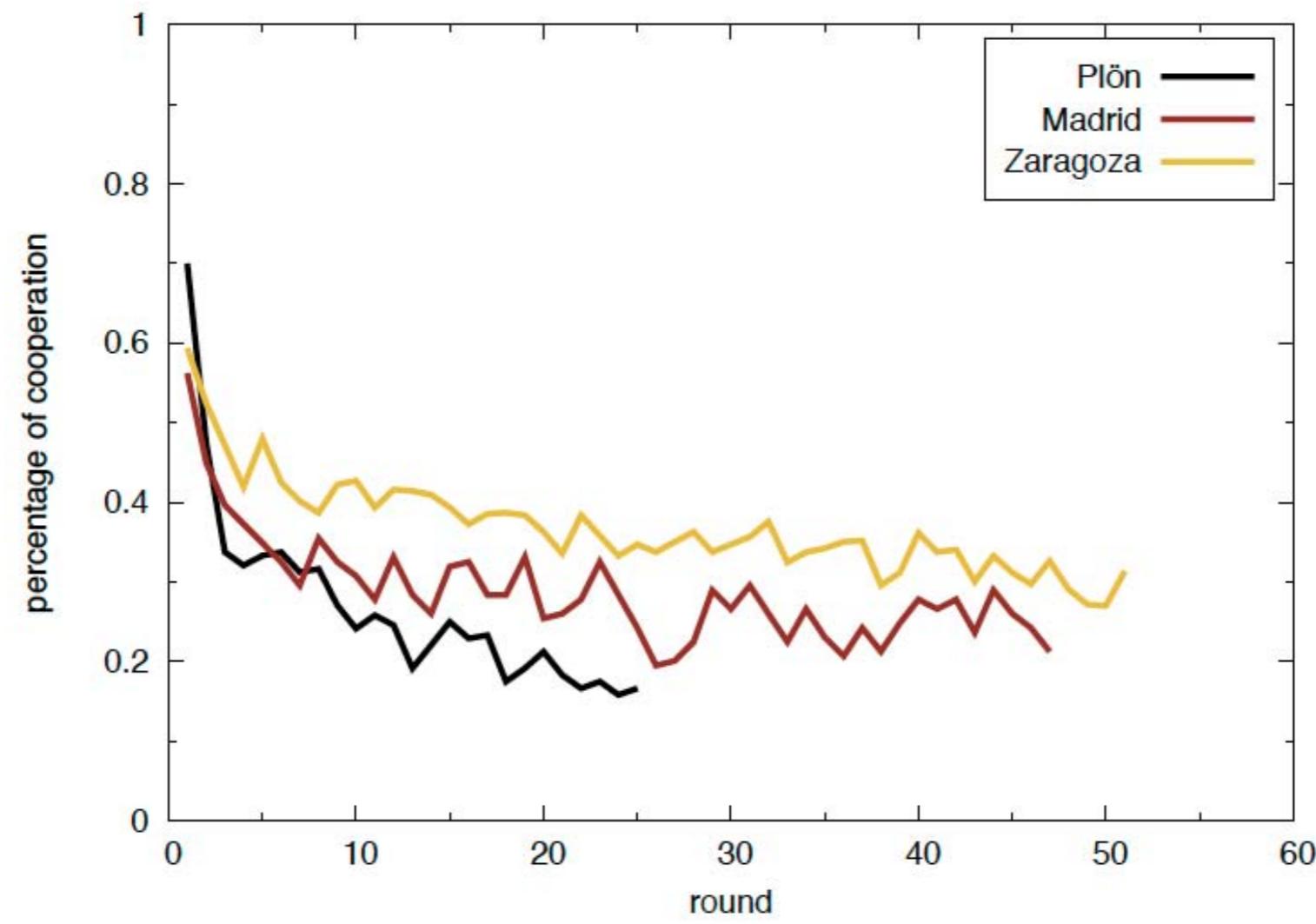


Cooperation on networks: mechanism



No network reciprocity

Static networks do **not** support cooperation in a Prisoner's Dilemma



Kirchkamp & Nagel. Games Econ. Behav. 58, 269–292 (2007)

Traulsen *et al.* Proc. Natl. Acad. Sci. USA 107, 2962 (2010)

Grujić *et al.* PLOS ONE 5, e13749 (2010)

Gracia-Lázaro *et al.* Proc. Natl. Acad. Sci. USA 109, 12922 (2012)

Grujić *et al.* Sci. Rep. 4, 4615 (2014)

Dynamic networks

Dynamic networks support cooperation in a Prisoner's Dilemma



Rand *et al.* Proc. Natl. Acad. Sci. USA **108**, 19193 (2011)

Wang *et al.* Proc. Natl. Acad. Sci. USA **109**, 14363 (2012)

Dynamic networks

Wang *et al.* Proc. Natl. Acad. Sci. USA **109**, 14363 (2012)

Link Rewiring: Phase 1

You are now in the "Propose/Delete link(s)" phase of "Link Rewiring". You can delete links unilaterally; however, proposals for new links must be agreed to by the other players in Phase 2.

The payoff table for interacting with one neighbor is shown below. In each cell, the first number represents your payoff, and the second number represents the payoff to your neighbor.

		Your Neighbor's Strategy	
		A	B
Your Strategy	A	4, 4	-1, 7
	B	7, -1	1, 1

Your total points accrued so far is 219. You earned 71 points last round.

This phase goes for 45 seconds. There are 22 seconds remaining in this phase.

YOU: Player 23 [AAAAAA]

The letters in square brackets represent the history of strategy choices for each player up to 5 rounds (the strategies for more recent rounds are on the right). A rewiring can be either a "Propose" or a "Delete". You can make at most 3 rewirings in this phase (i.e. you can check at most 3 checkboxes below).

**These are the players that are LINKED to you in the network.
Please check the ones that you want to DELETE A LINK to.**

- Player 14 [AAAAAA]
- Player 15 [AAAAAA]
- Player 16 [AAAAAA]
- Player 24 [BBBBBB]
- Player 6 [AAAAAA]
- Player 8 [BBBBBB]
- Player 18 [AAAAAA]
- Player 19 [AAAAB]
- Player 20 [ABAAA]
- Player 10 [AAAAAA]
- Player 21 [AAAAAA]
- Player 22 [AAAAAA]
- Player 1 [AAAAAA]
- Player 3 [AAAAAA]
- Player 4 [AAAAAA]
- Player 5 [AAAAAA]
- Player 12 [AAAAAA]
- Player 13 [AAAAAA]
- Player 17 [AAAAAA]
- Player 2 [AAAAAA]
- Player 7 [AAAAAA]
- Player 9 [AAAAAA]
- Player 11 [AAAAAA]

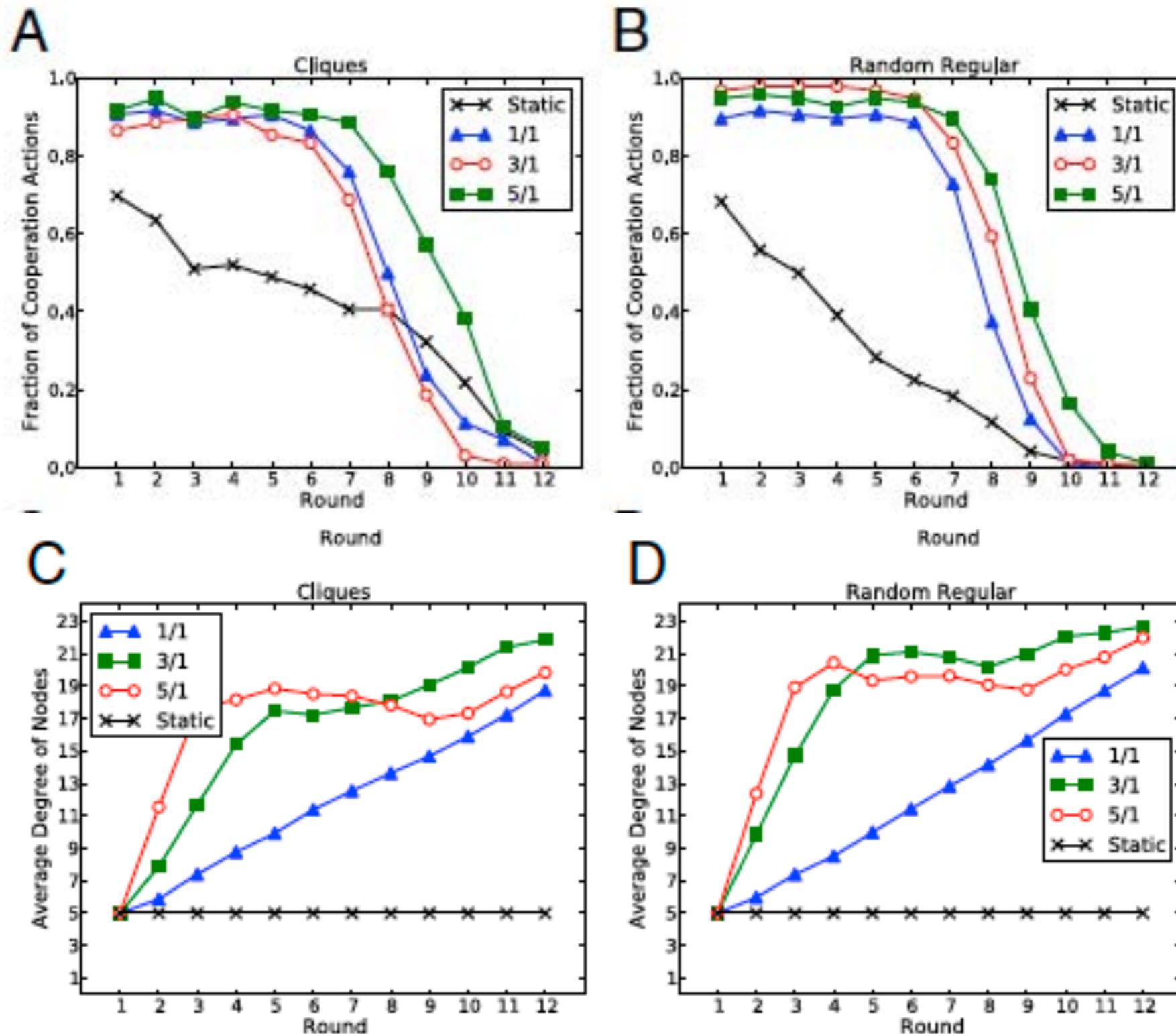
**These are the players that are NOT LINKED to you in the network.
Please check the ones that you want to PROPOSE A LINK to.**

- Player 24 [BBBBBB]
- Player 6 [AAAAAA]
- Player 8 [BBBBBB]
- Player 10 [AAAAAA]

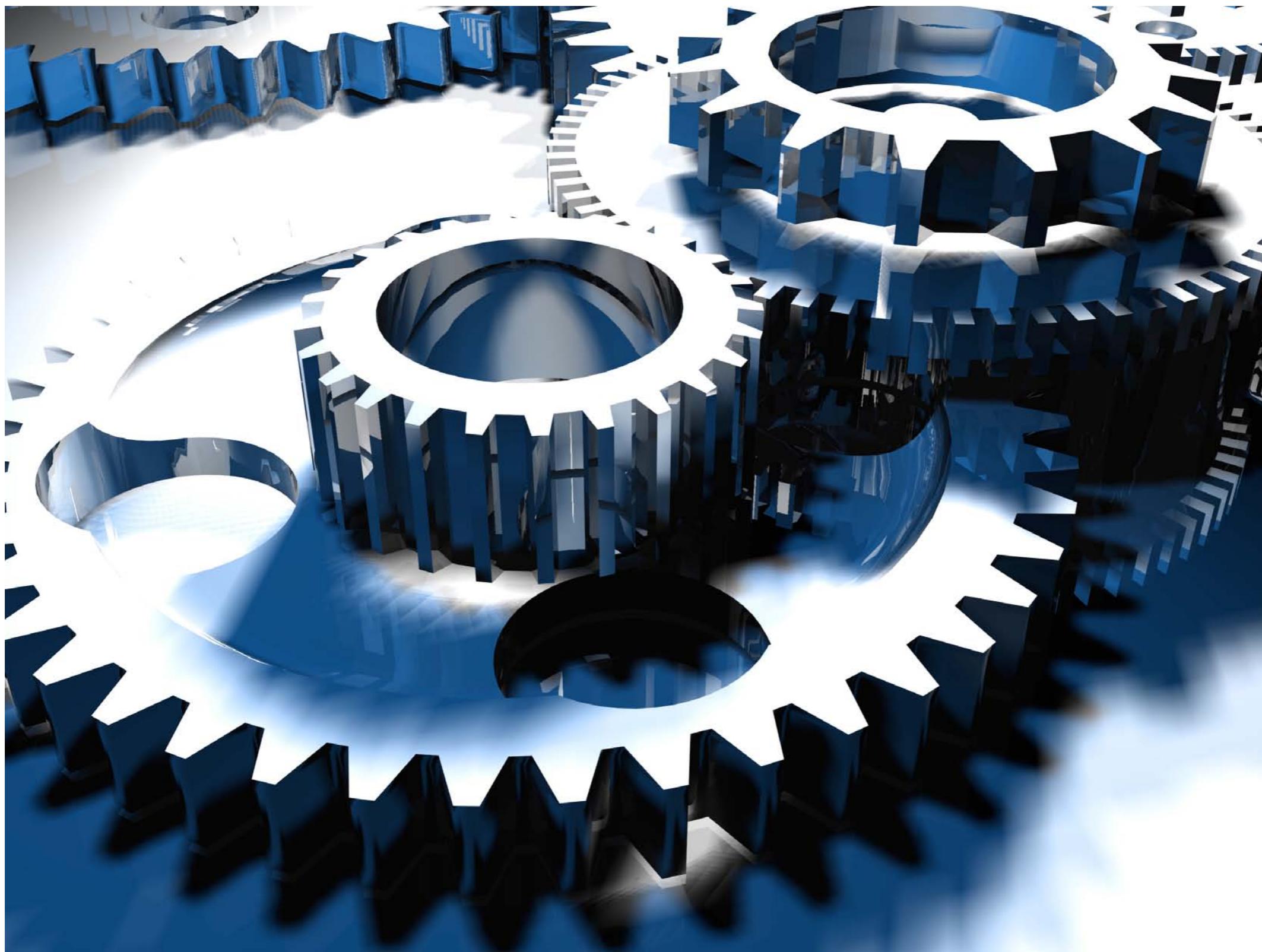
Submit

Emergence of cooperation

Wang *et al.* Proc. Natl. Acad. Sci. USA **109**, 14363 (2012)



What is the mechanism?



Experiment on information

Stage 1: Play Prisoner's Dilemma with current neighbors

Ronda 2

Primera fase

00:00:15

Matriz de pagos

ELECCIÓN DE UN VECINO

		ELECCIÓN DE UN VECINO	
		A	B
SU ELECCIÓN	A	7	0
	B	10	0

Ganancia en la última ronda 20.0

Éstos son tus vecinos en la red

jugador30 [B] jugador31 [A] jugador33 [A] jugador34 [B]

Estrategia A **Estrategia B**

Experiment on information

Stage 2: Modify network

Ronda 2

Ganancia en la última ronda 14.0

¿Qué enlaces quieres romper?

jugador30 [B] jugador31 [A] jugador33 [A] jugador34 [B]

Aceptar

Segunda fase

¿Qué enlaces quieres proponer?

jugador26 [B] jugador27 [A] jugador28 [A] jugador29 [B]
jugador35 [B] jugador36 [A] jugador37 [B] jugador38 [B]
jugador39 [B] jugador40 [A]

00:00:32

Ronda 2

Ganancia en la última ronda 7.0

¿Qué enlaces quieres aceptar?

jugador32 [A]

Aceptar

Tercera fase

00:00:24



Experiment on information



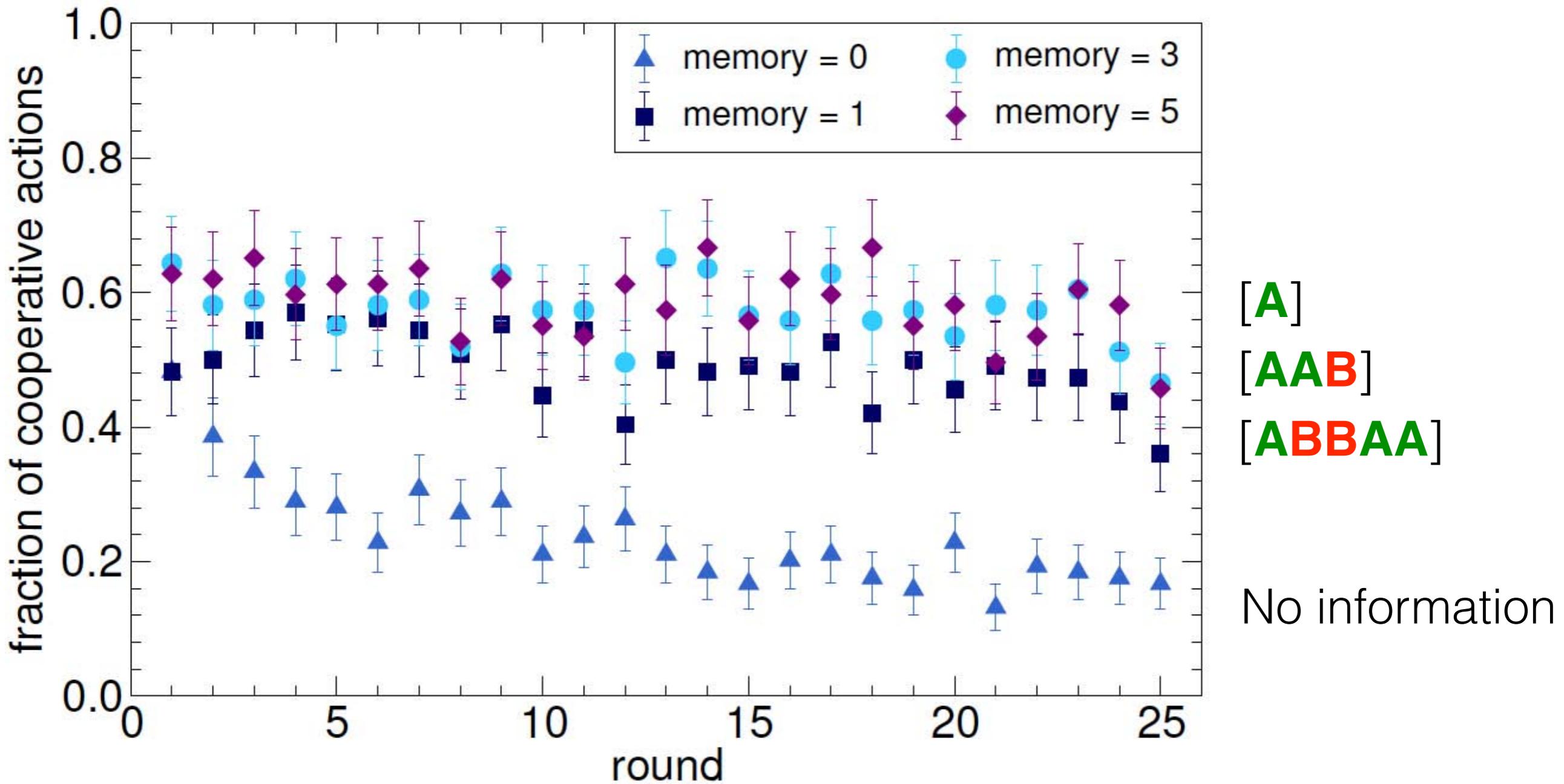
No information

[**A**]

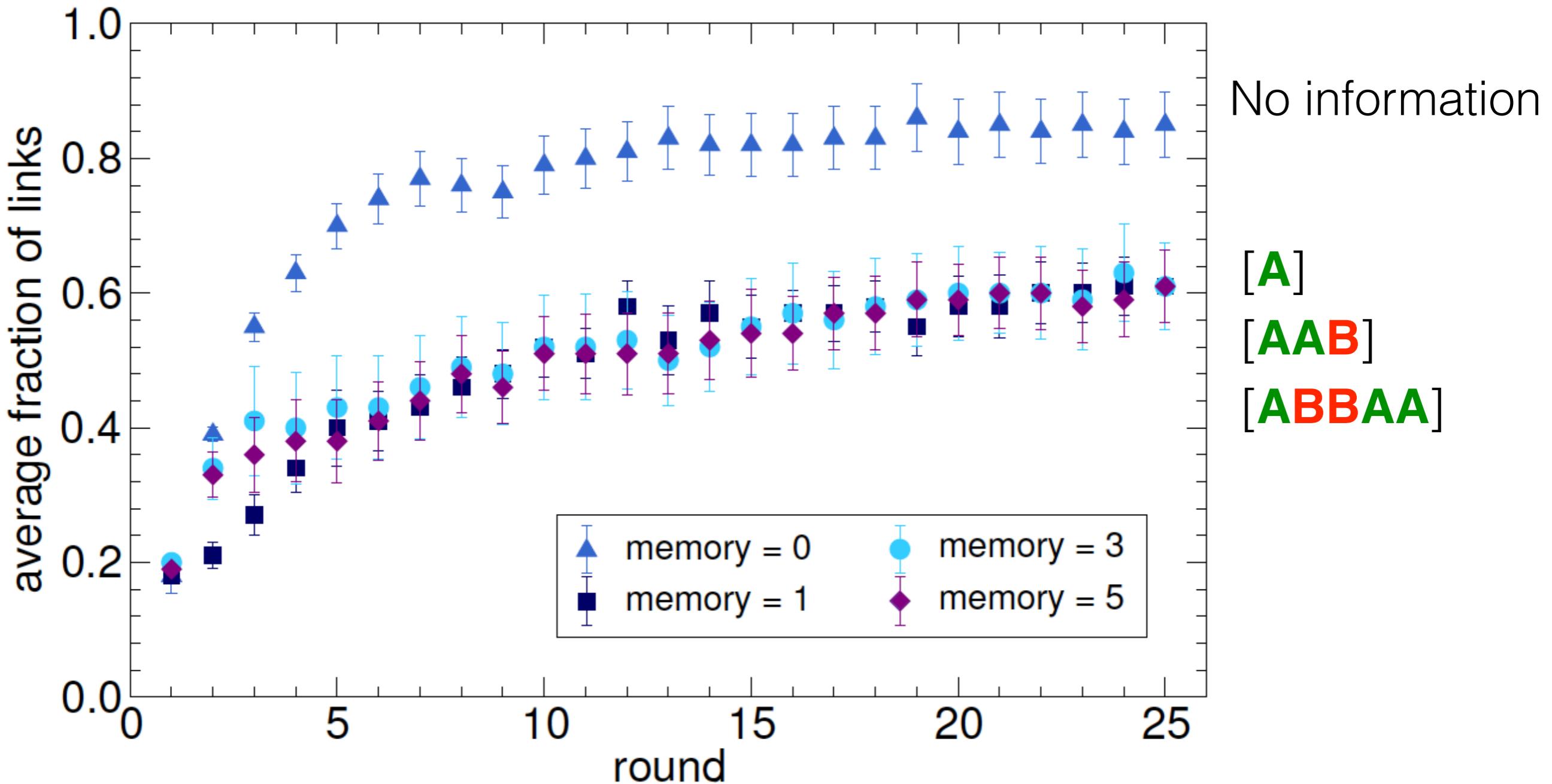
[**AAB**]

[**ABBA**A]

Results: Cooperation

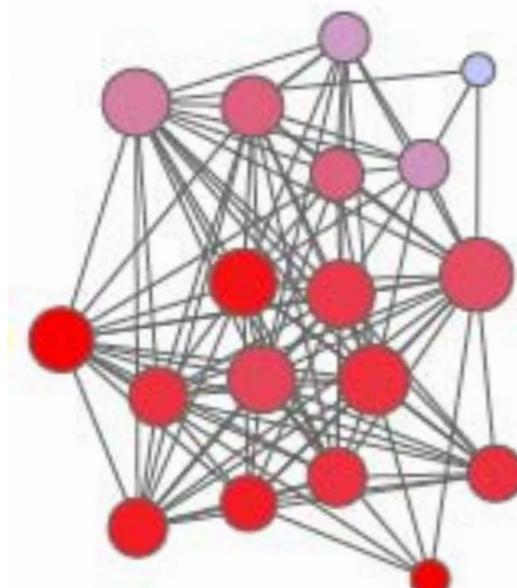


Results: Network

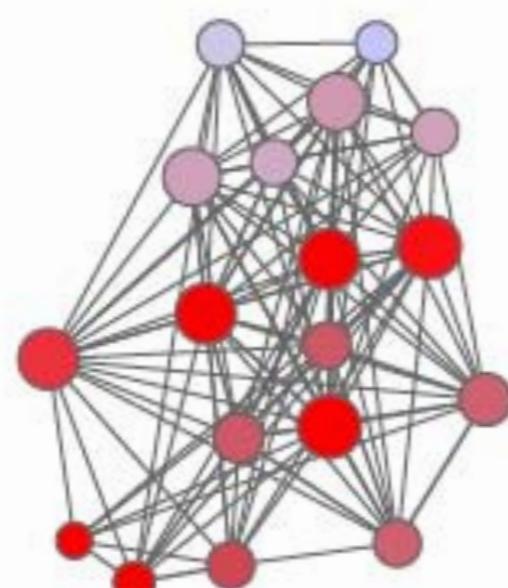


Results: Network

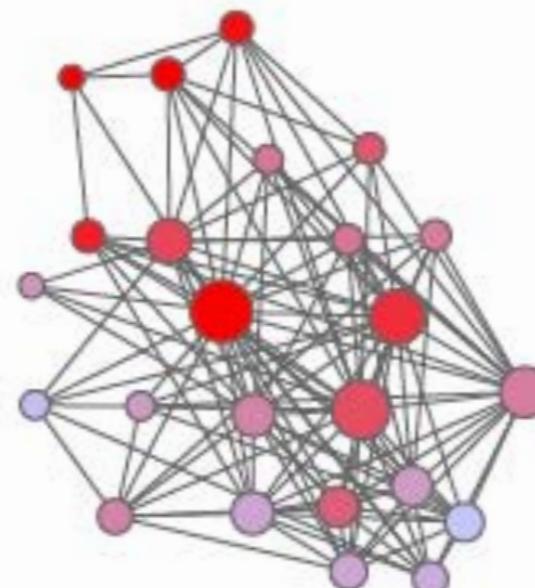
[**ABBA**A]



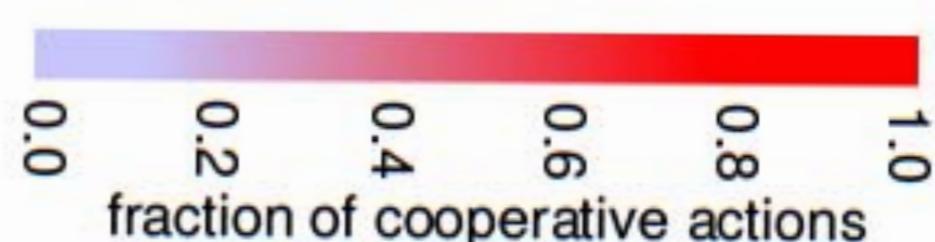
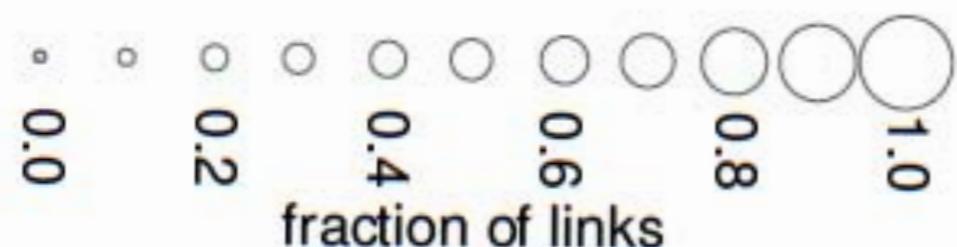
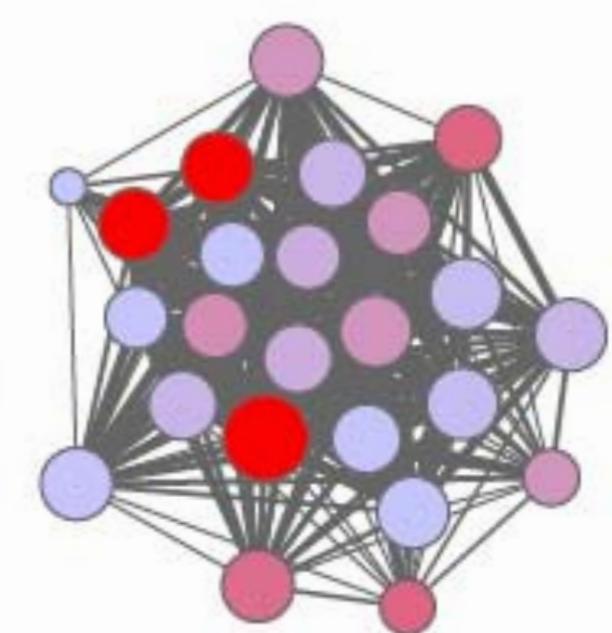
[**AAB**]



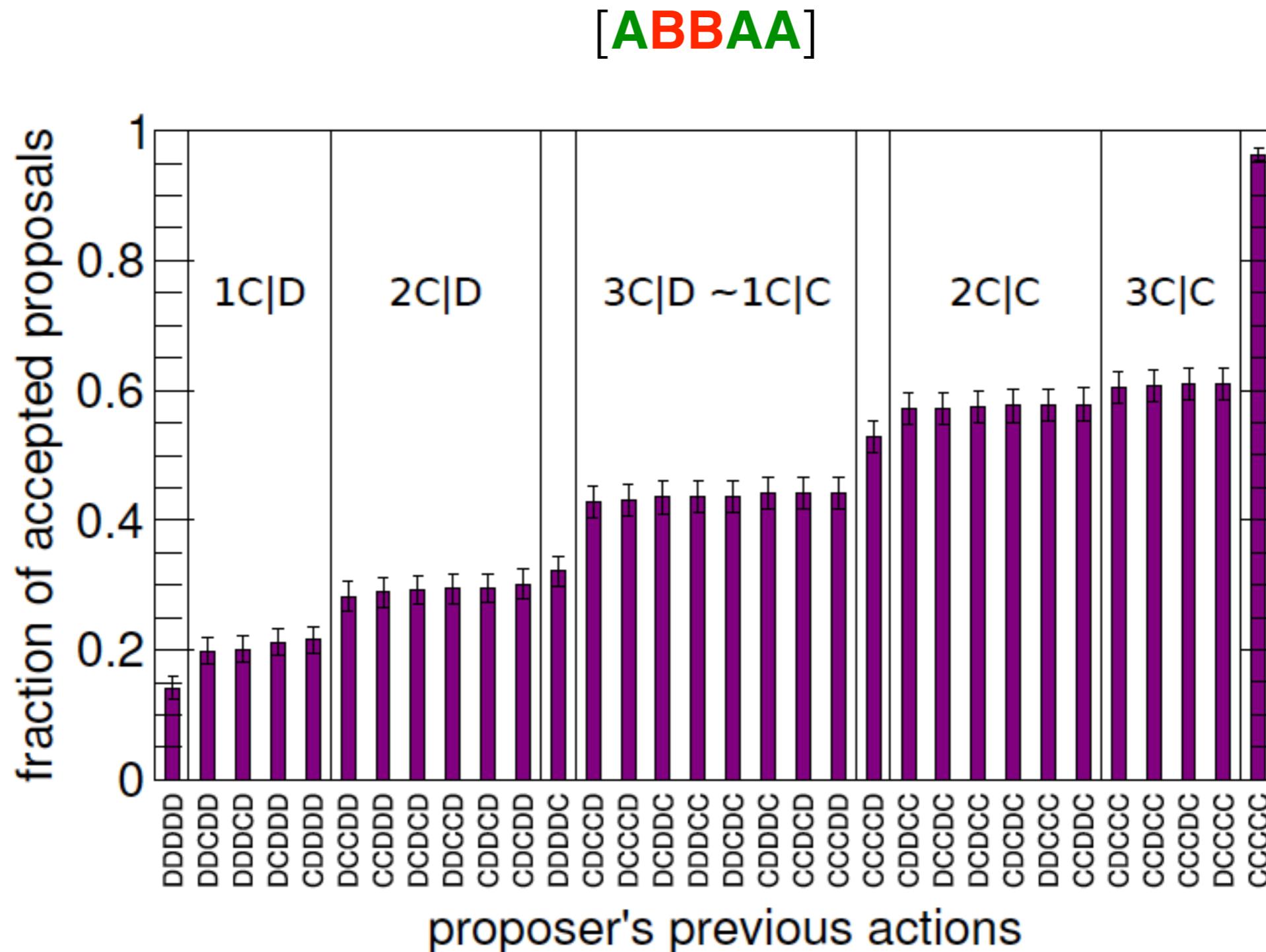
[**A**]



No information

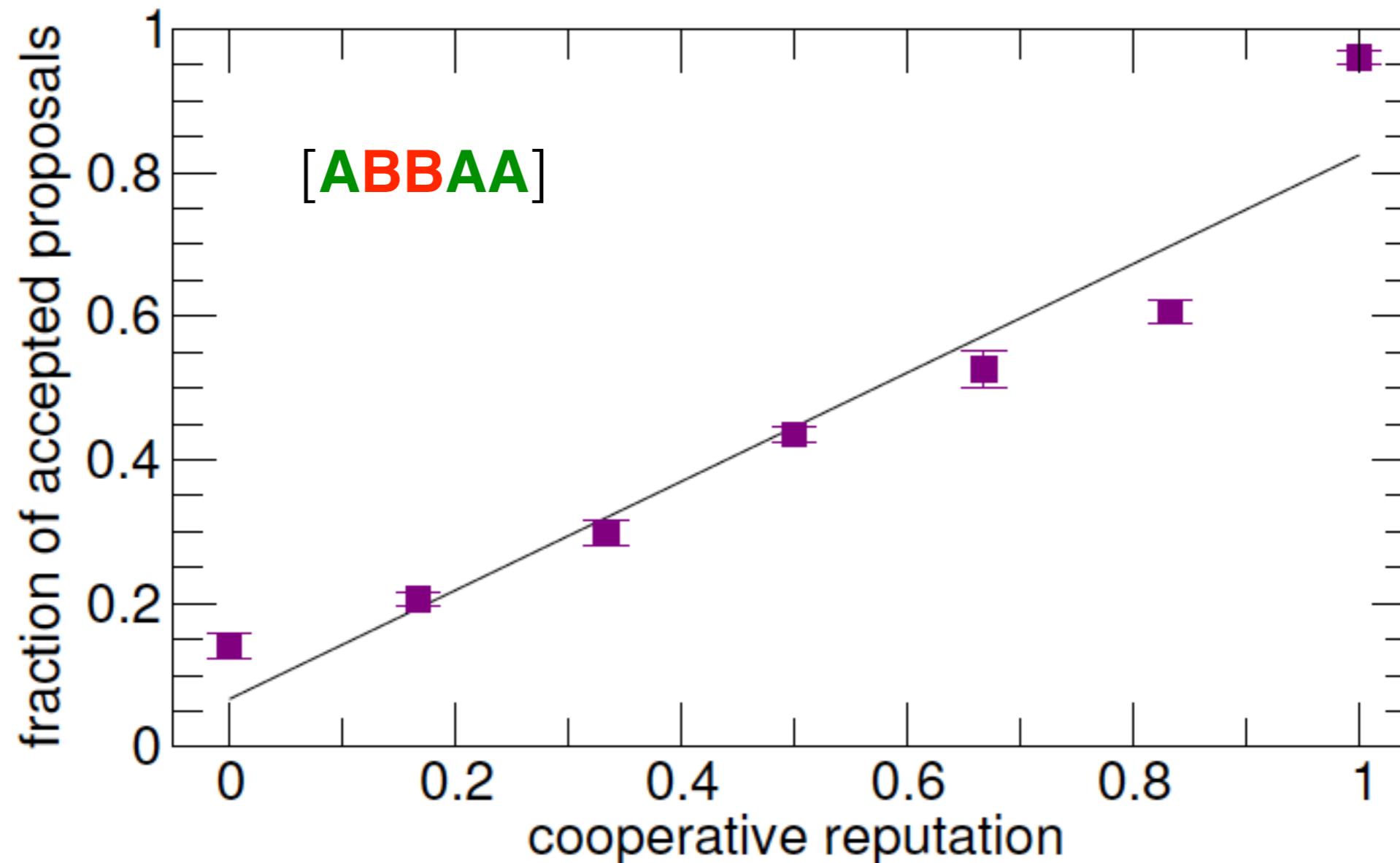


Results: Reputation



Results: Reputation

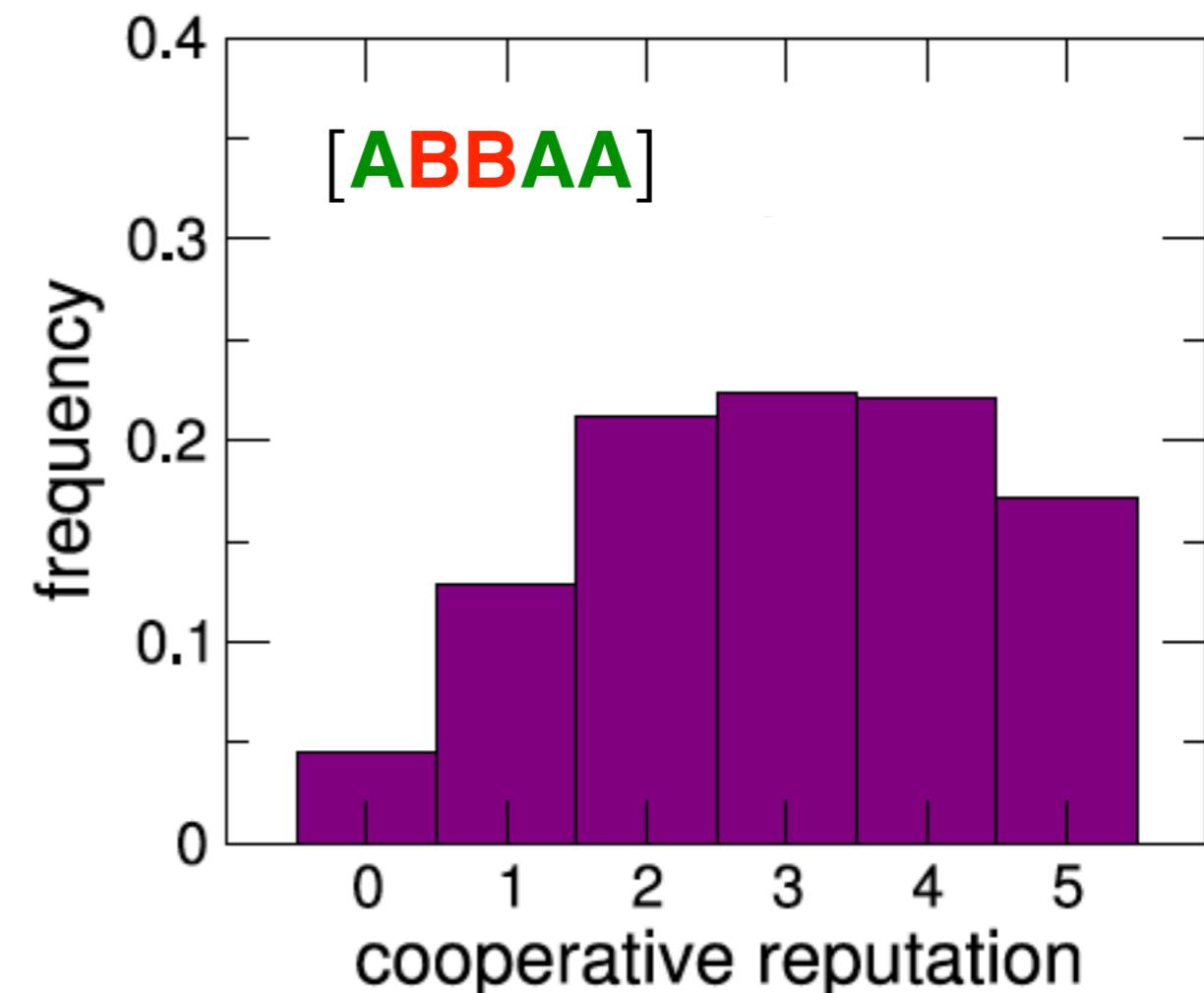
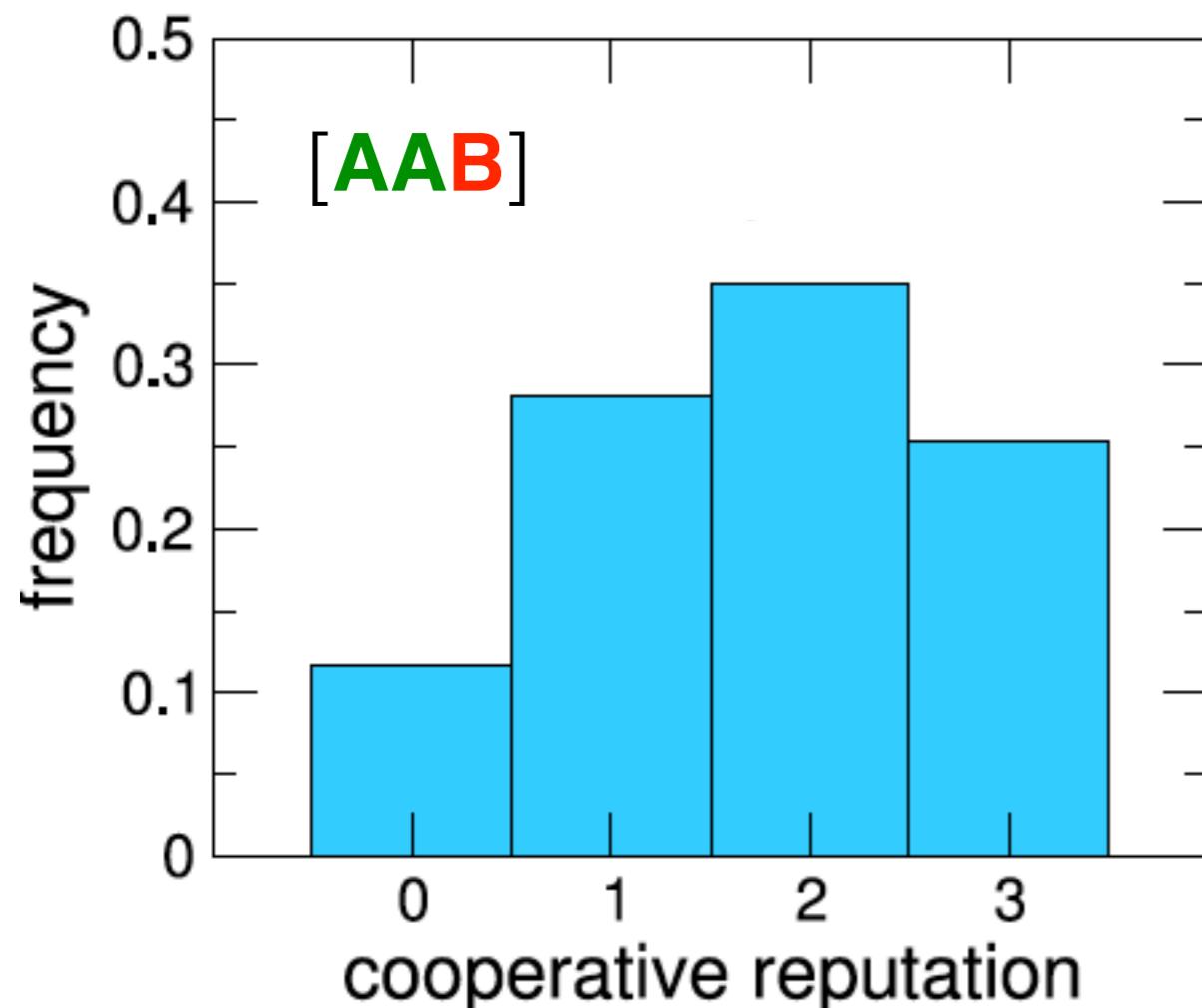
$$r = wC_{\text{last}} + (1 - w)\bar{C}$$



[AAB] $w = 0.280 \pm 0.024$

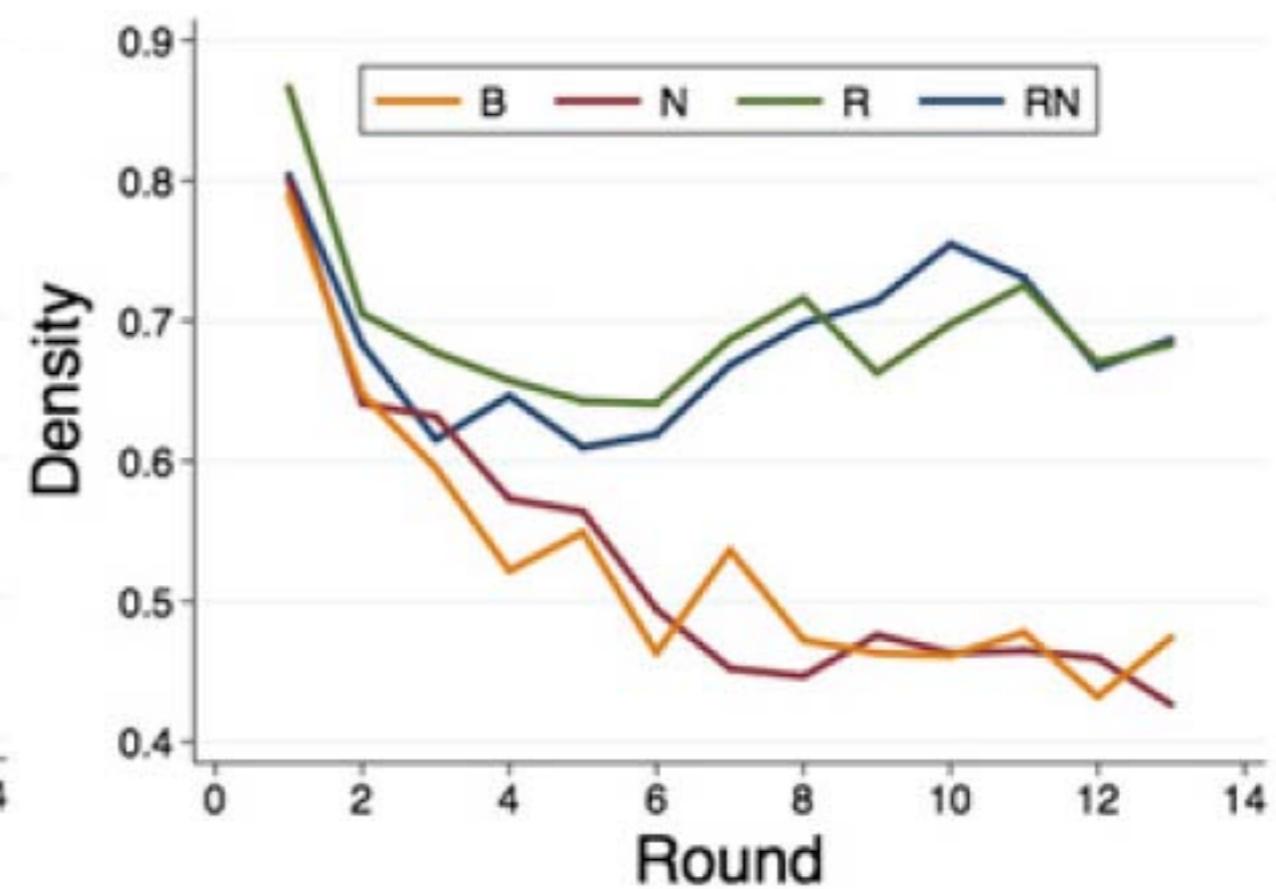
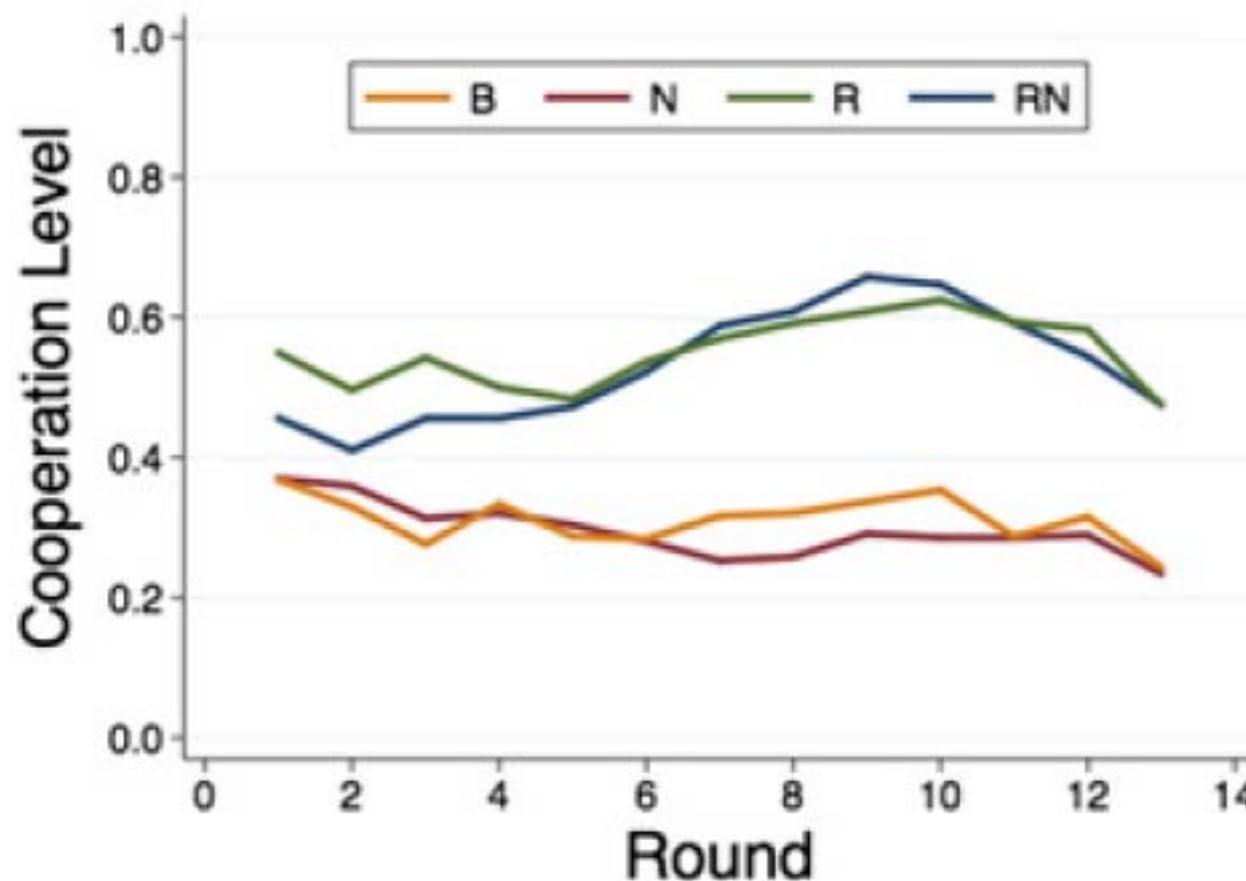
[ABBA] $w = 0.165 \pm 0.015$

Results: Reputation

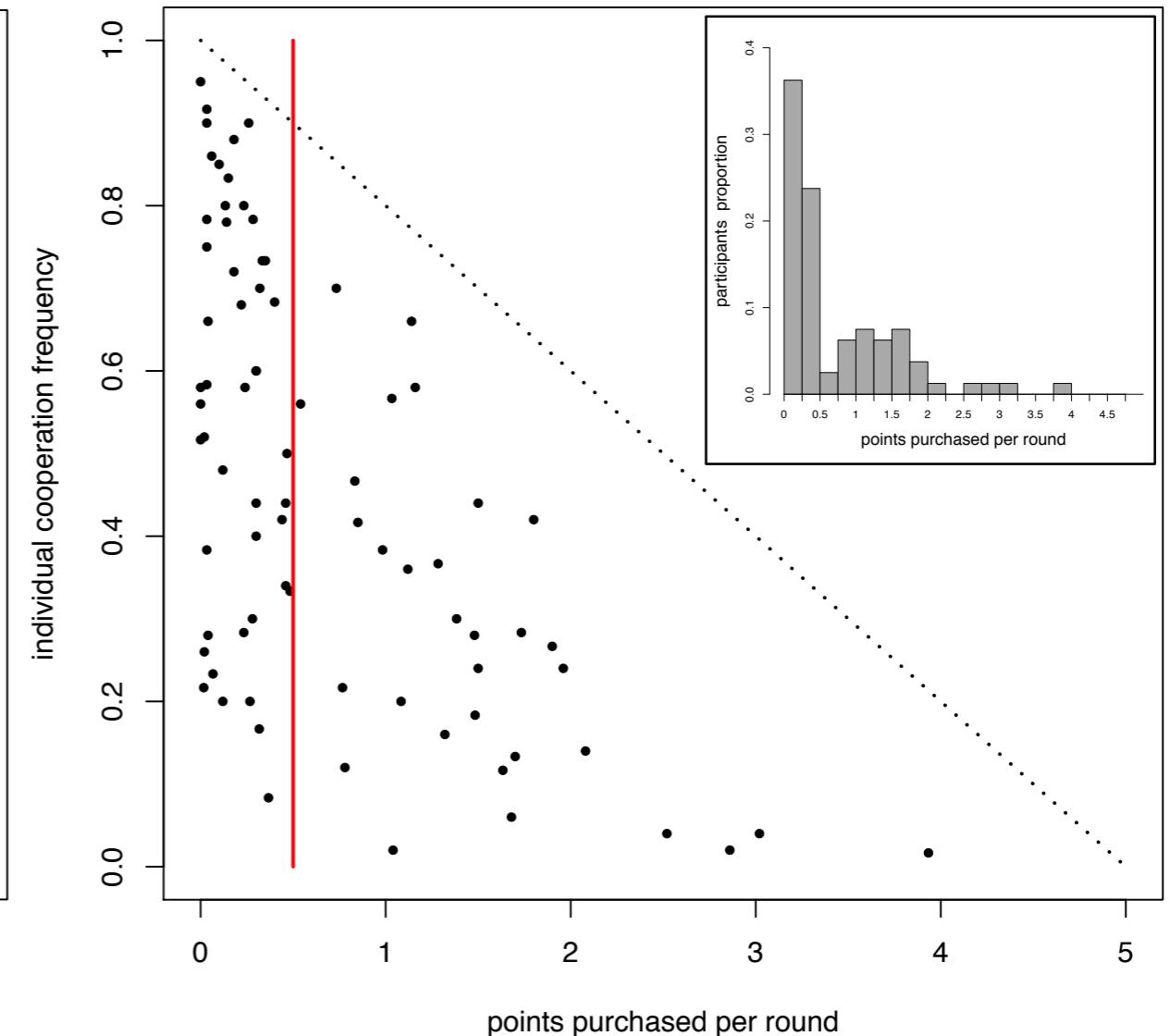
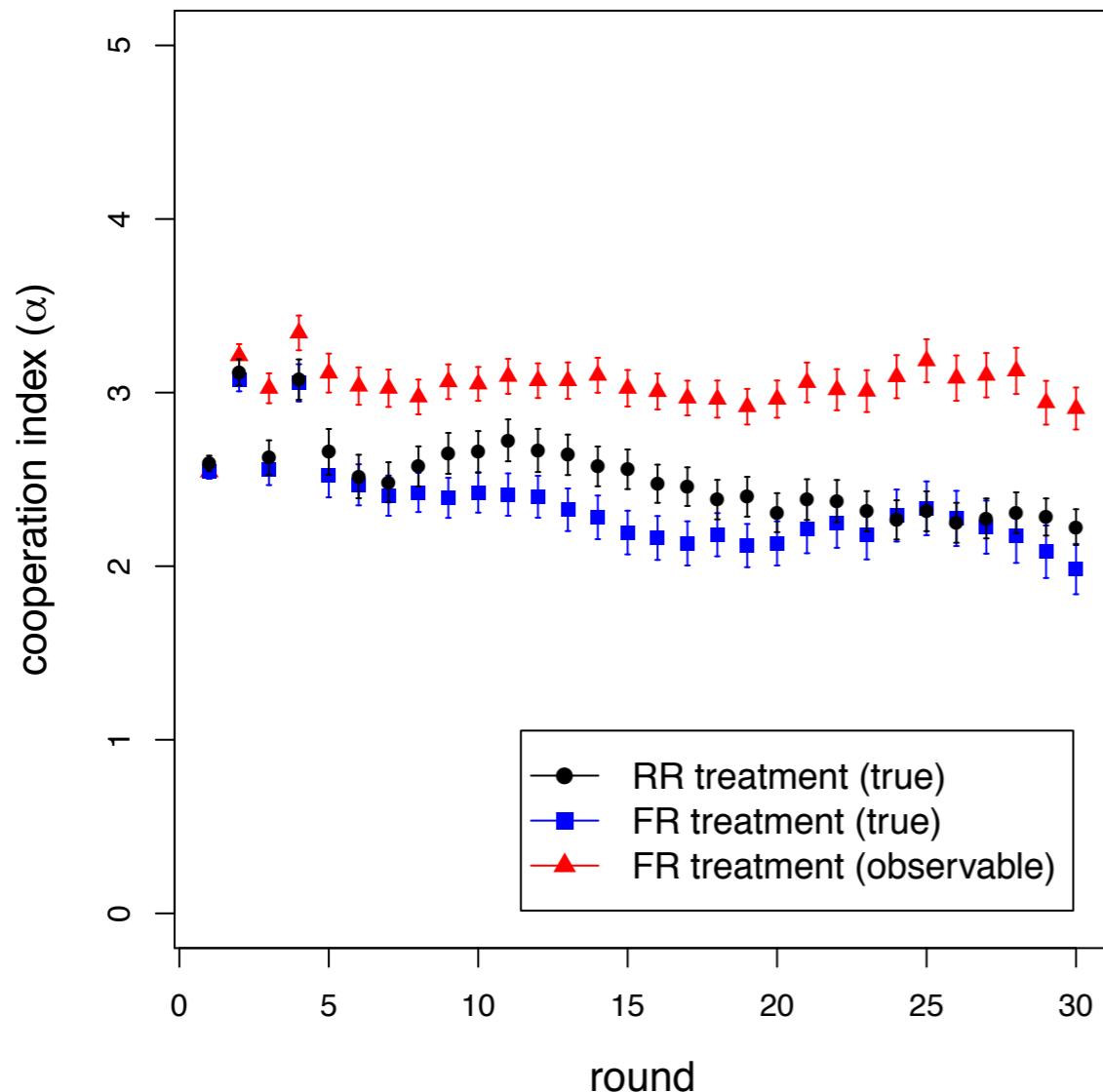


Independent confirmation

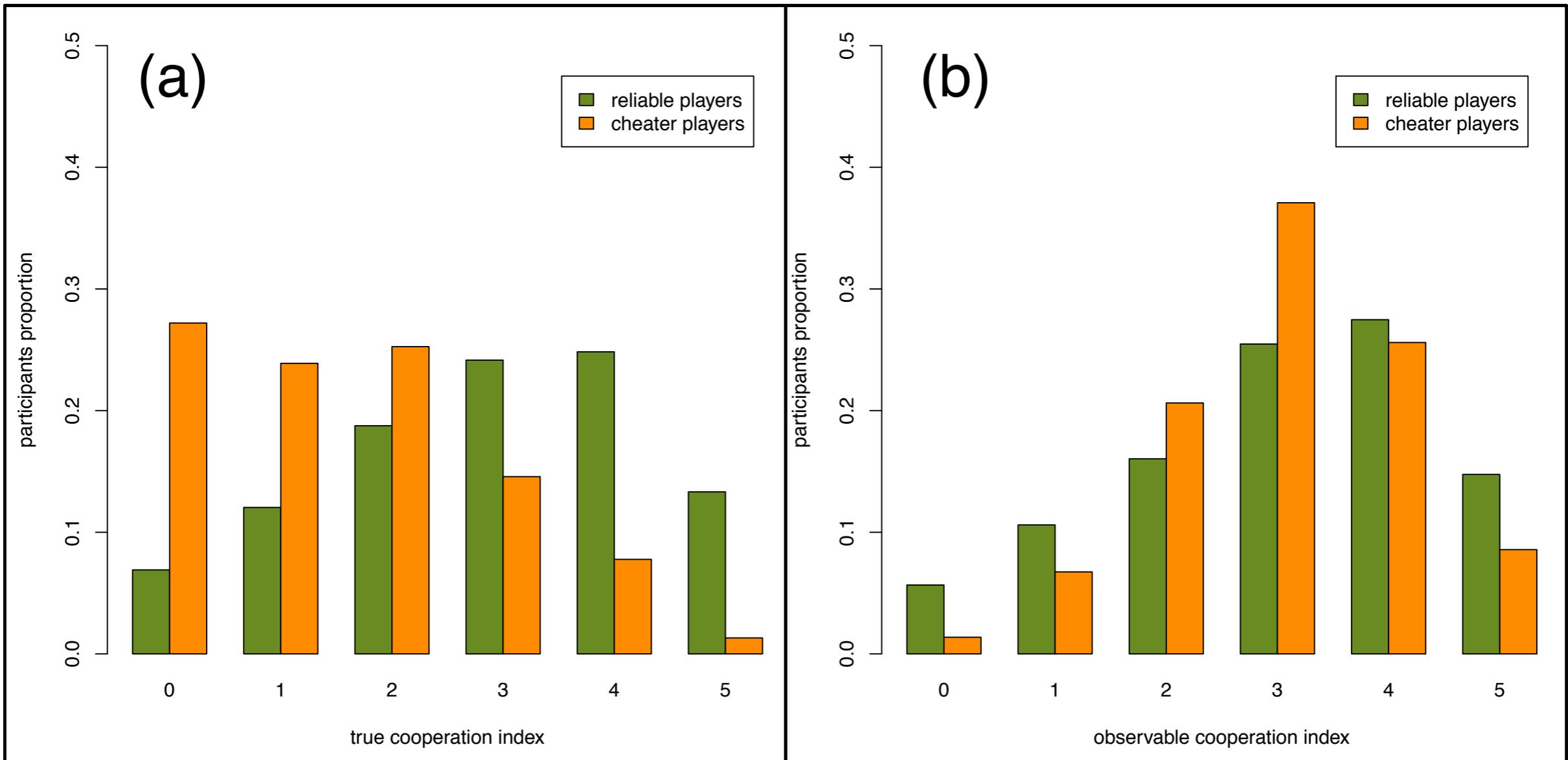
[**ABBA**A]



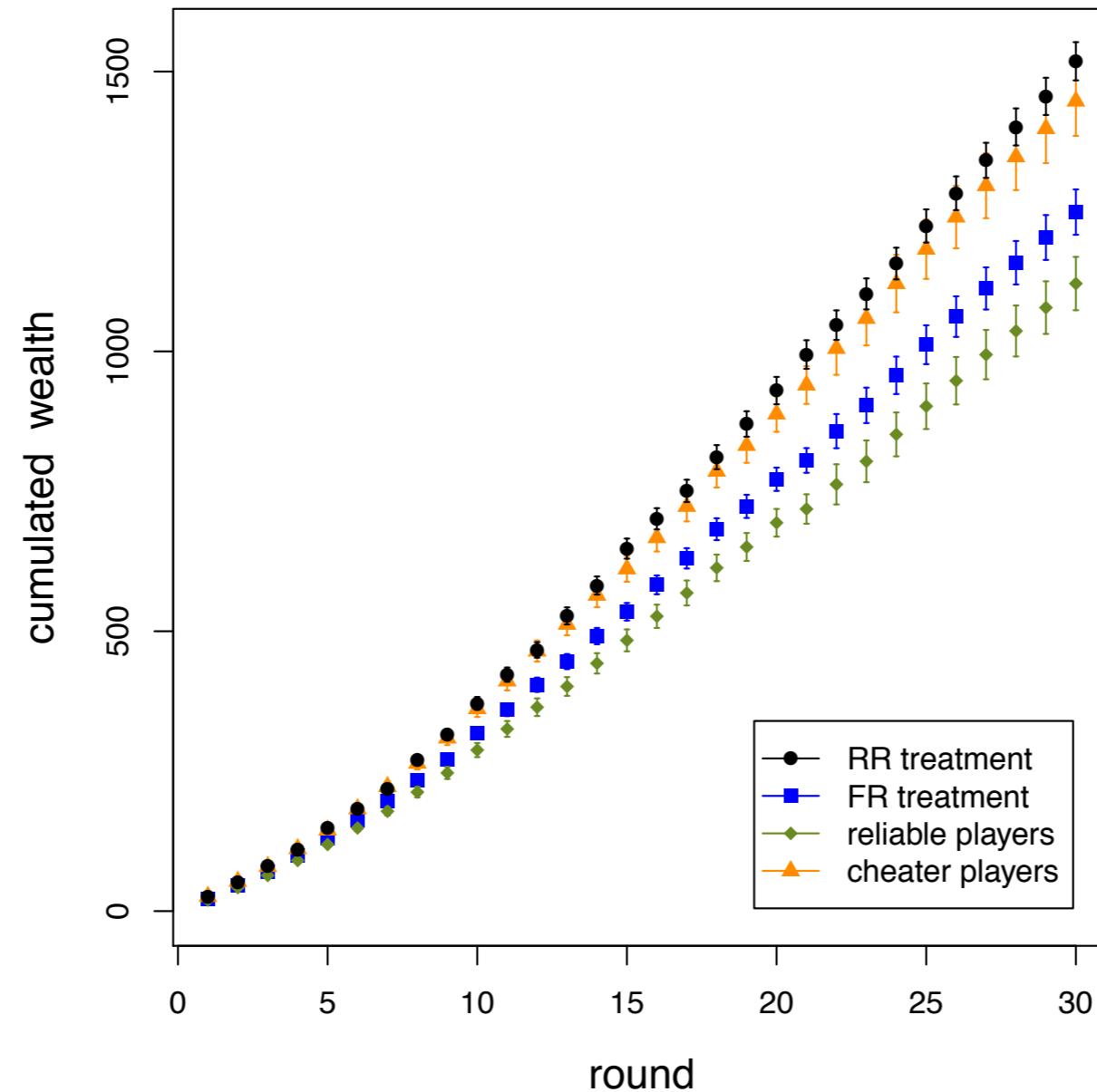
But, what if reputation can be faked?



Cheaters manage to disguise



Inequality increases



Gini coefficients: 0.27 (Finland) vs 0.37 (Tanzania)

Case study 2: Bridging experiments and reality



Non-non-human primate project

Cottontop tamarin (*Saguinus oedipus*)



Non-non-human primate project

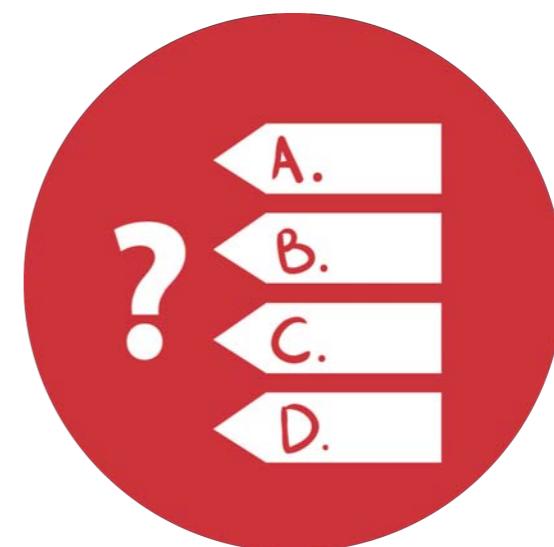
Chimpanzee (*Pan troglodytes*)



Experimentally induced hierarchy



$$\begin{array}{r} 84 \\ + 43 \\ \hline 127 \end{array}$$
A handwritten addition problem on lined paper. The problem is 84 + 43 = 127. The numbers are written in black ink, and the equals sign and answer are written below them.



Collaborative task

Contribute to a pot totalling 20 points or more



Receive 40 points for both of you

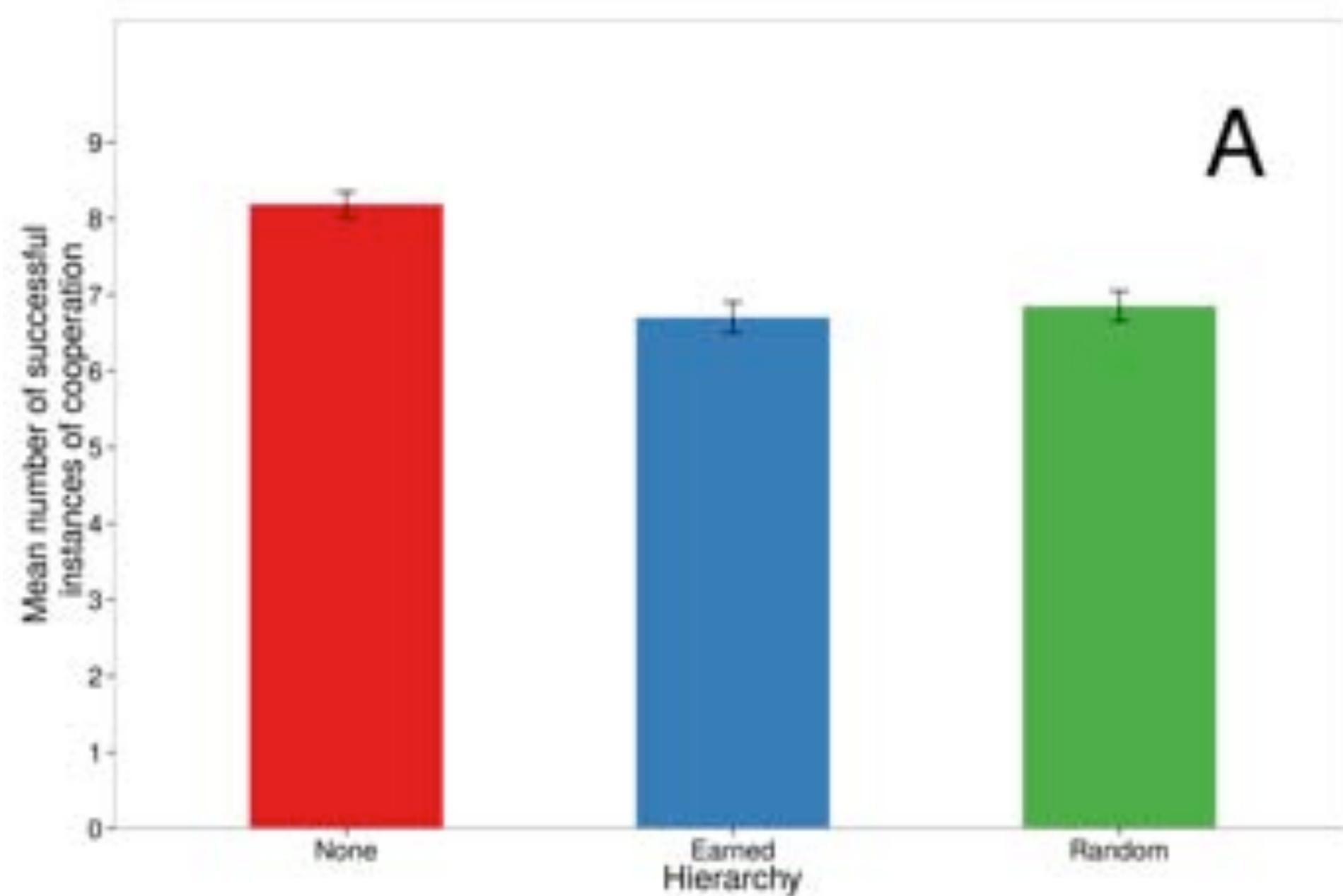
Splitting task

Higher ranked guy proposes a splitting (ultimatum-like)

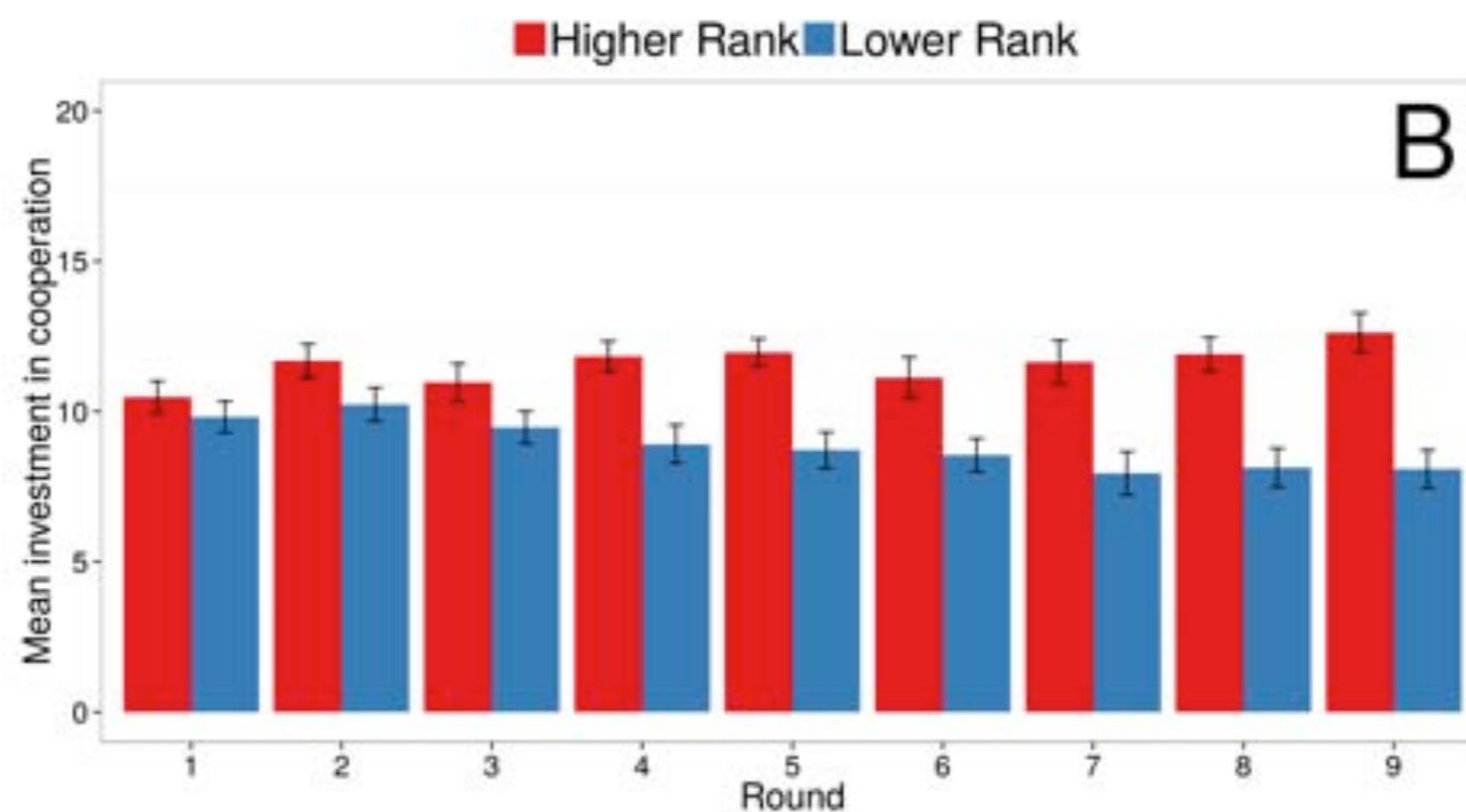
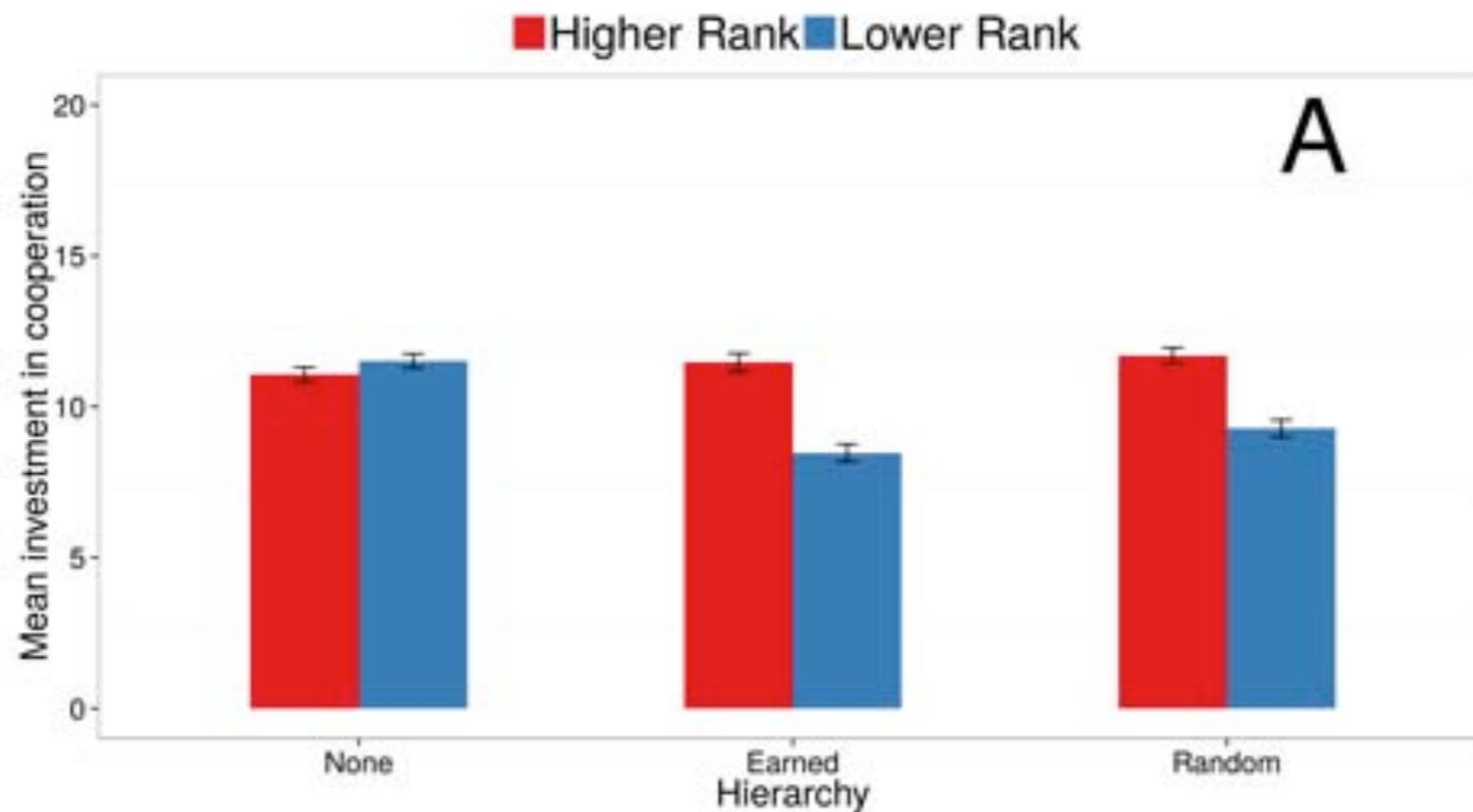


Lower-ranked guy accepts or “fights”

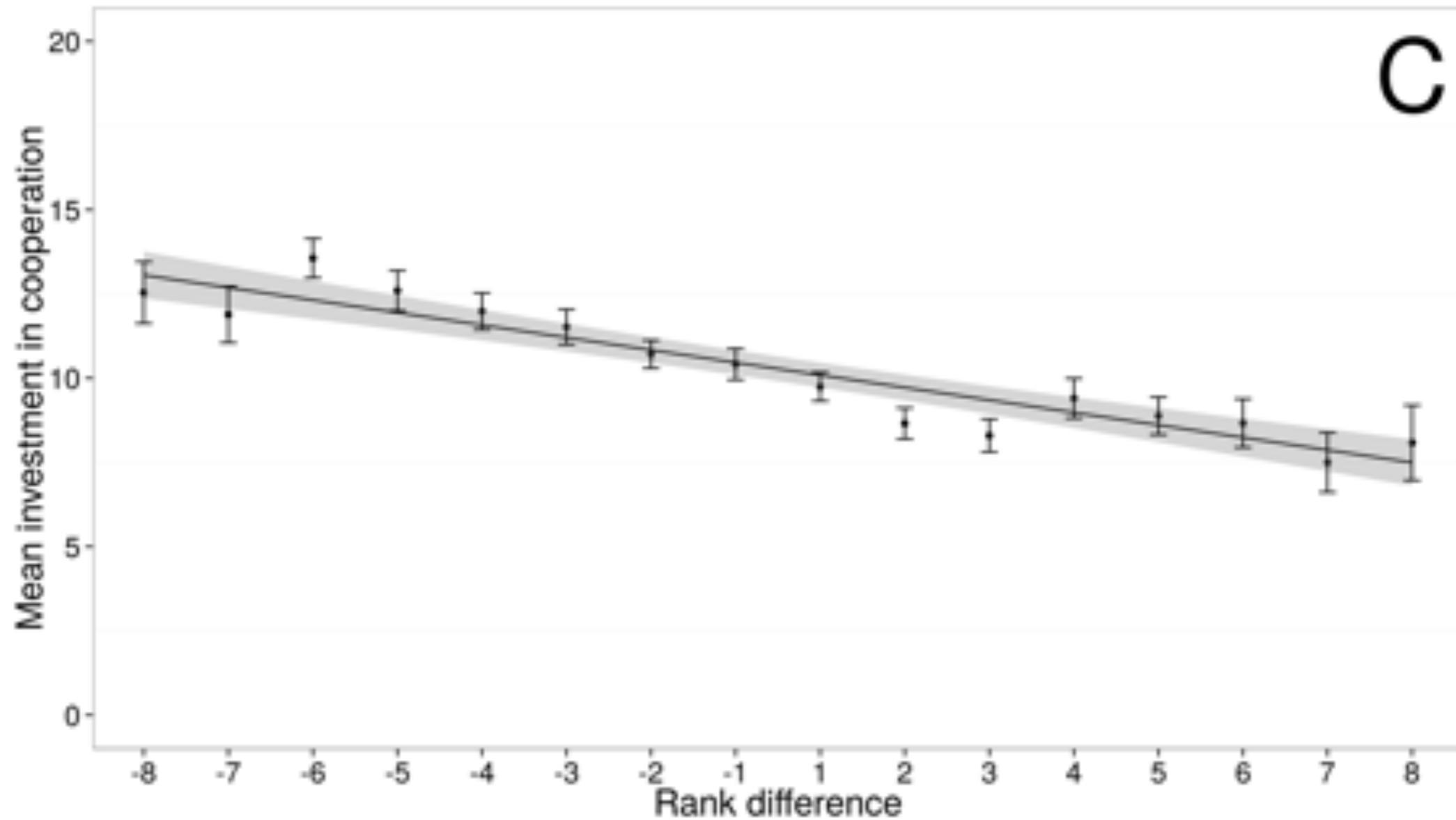
Hierarchy decreases cooperation



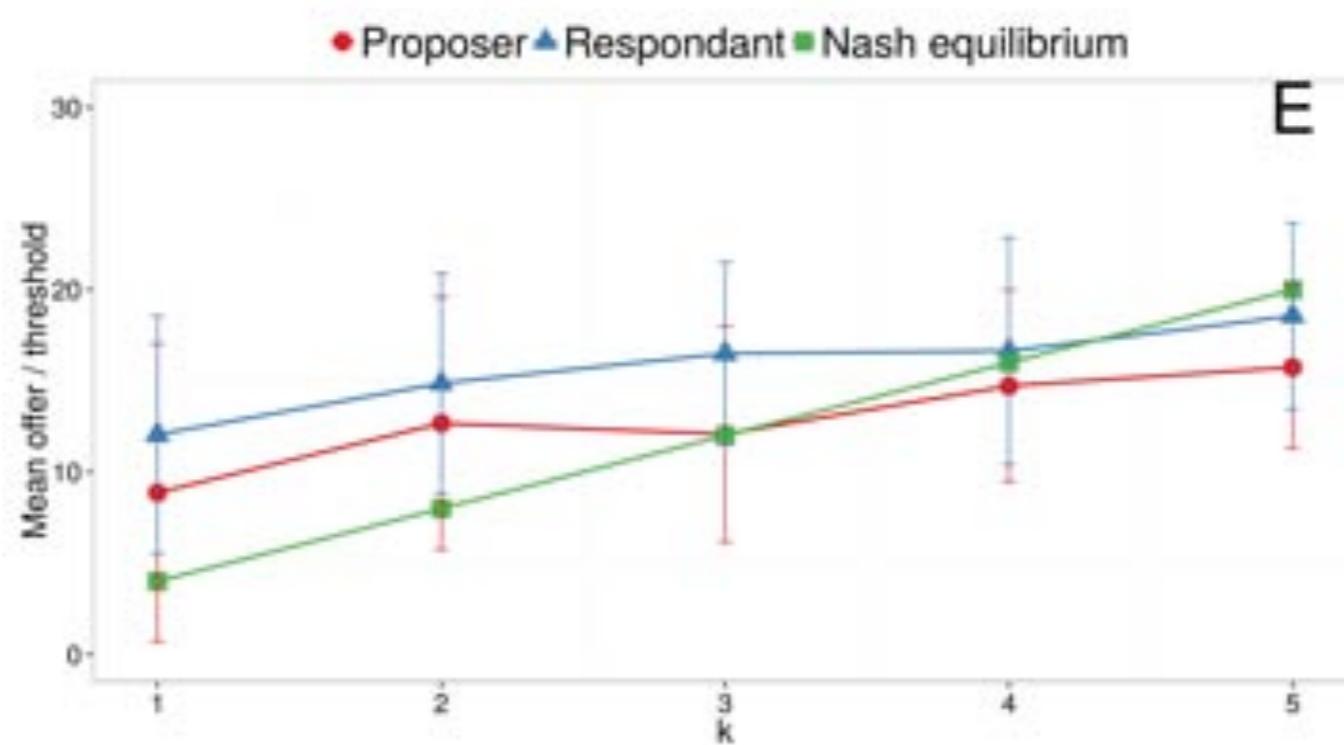
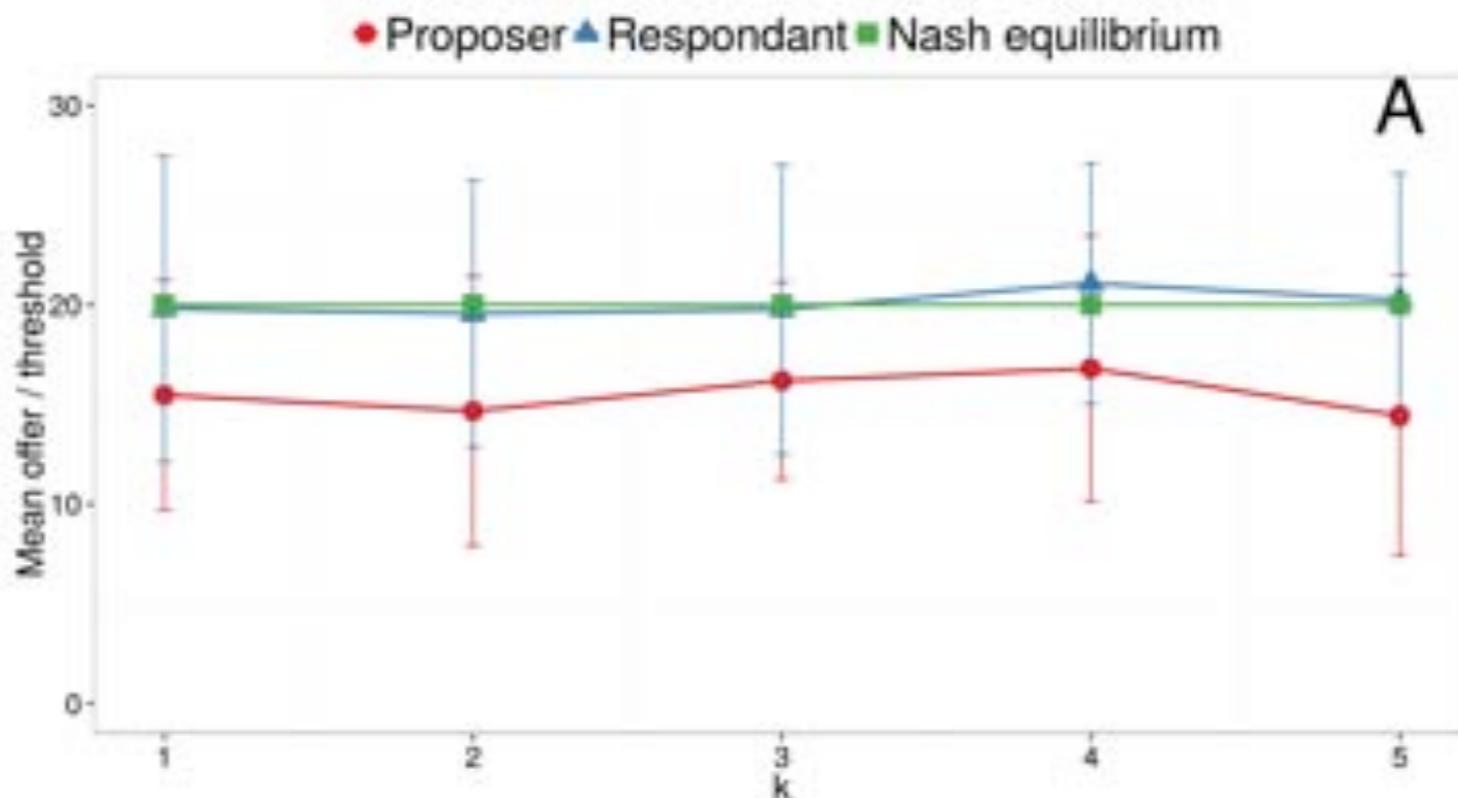
Role of the lower ranked subject



Rank difference predicts contributions



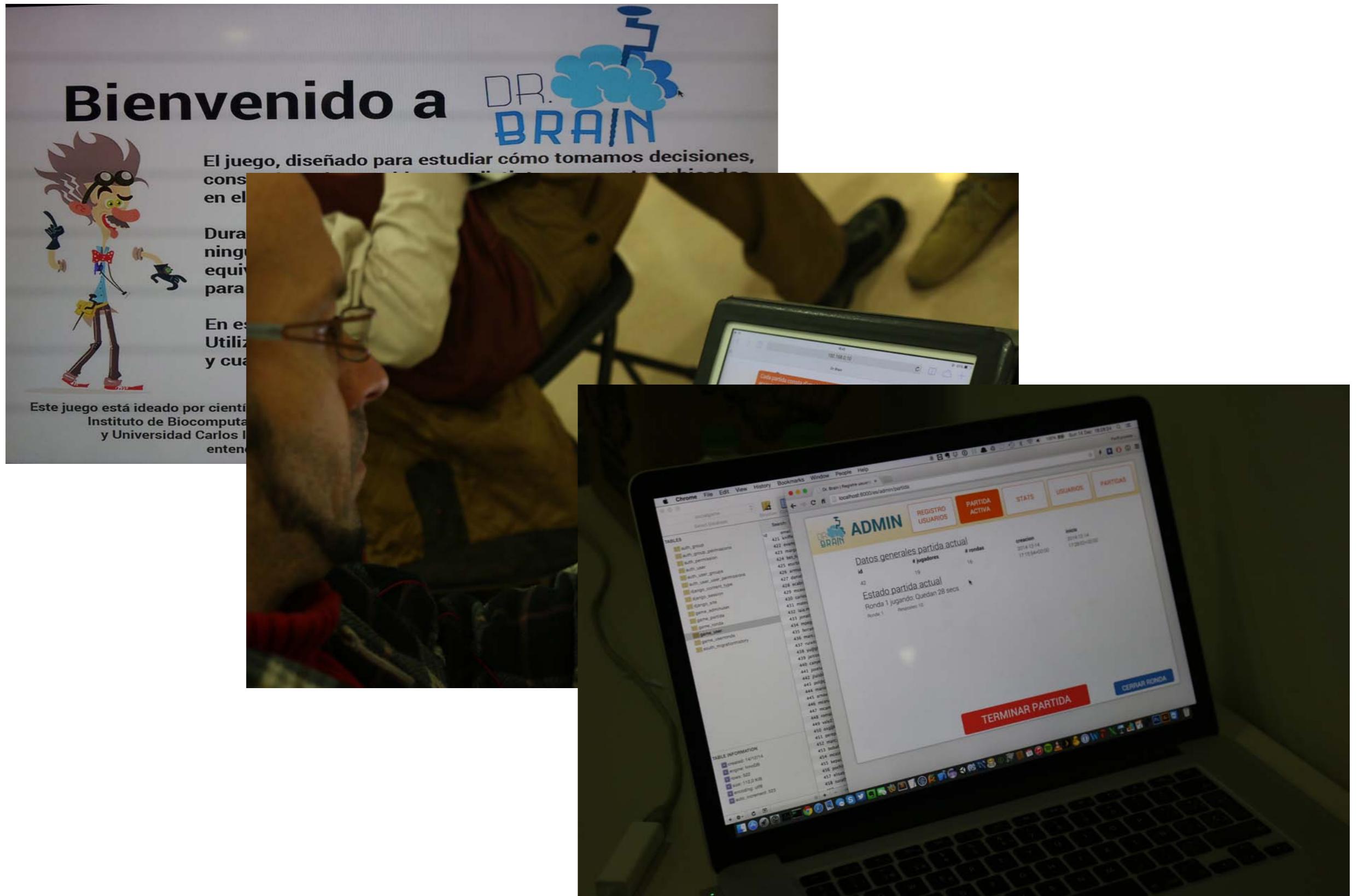
Offers and expectations



Case study 3: Behavioral “phenotypes”



Case study 3: Behavioral “phenotypes”



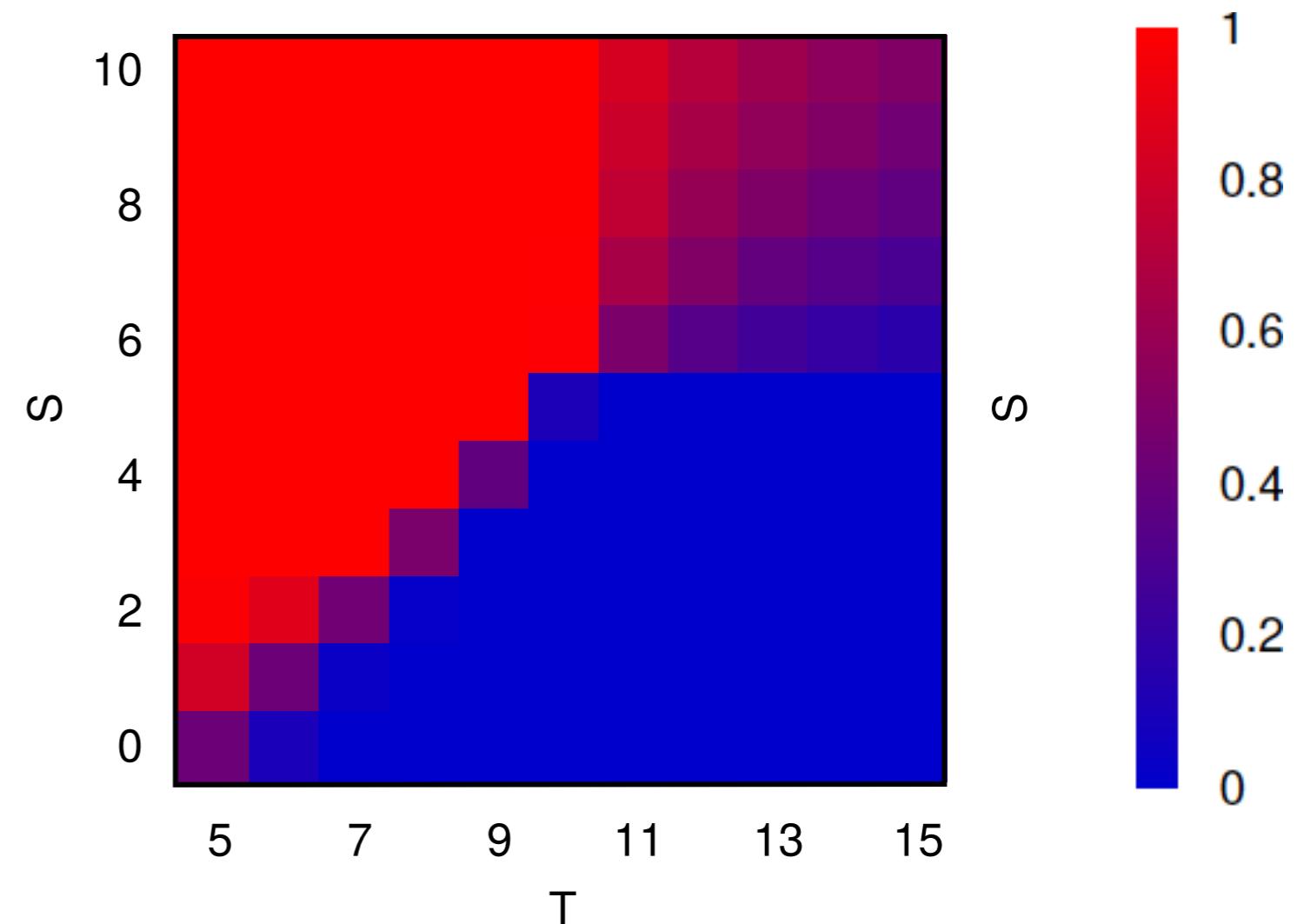
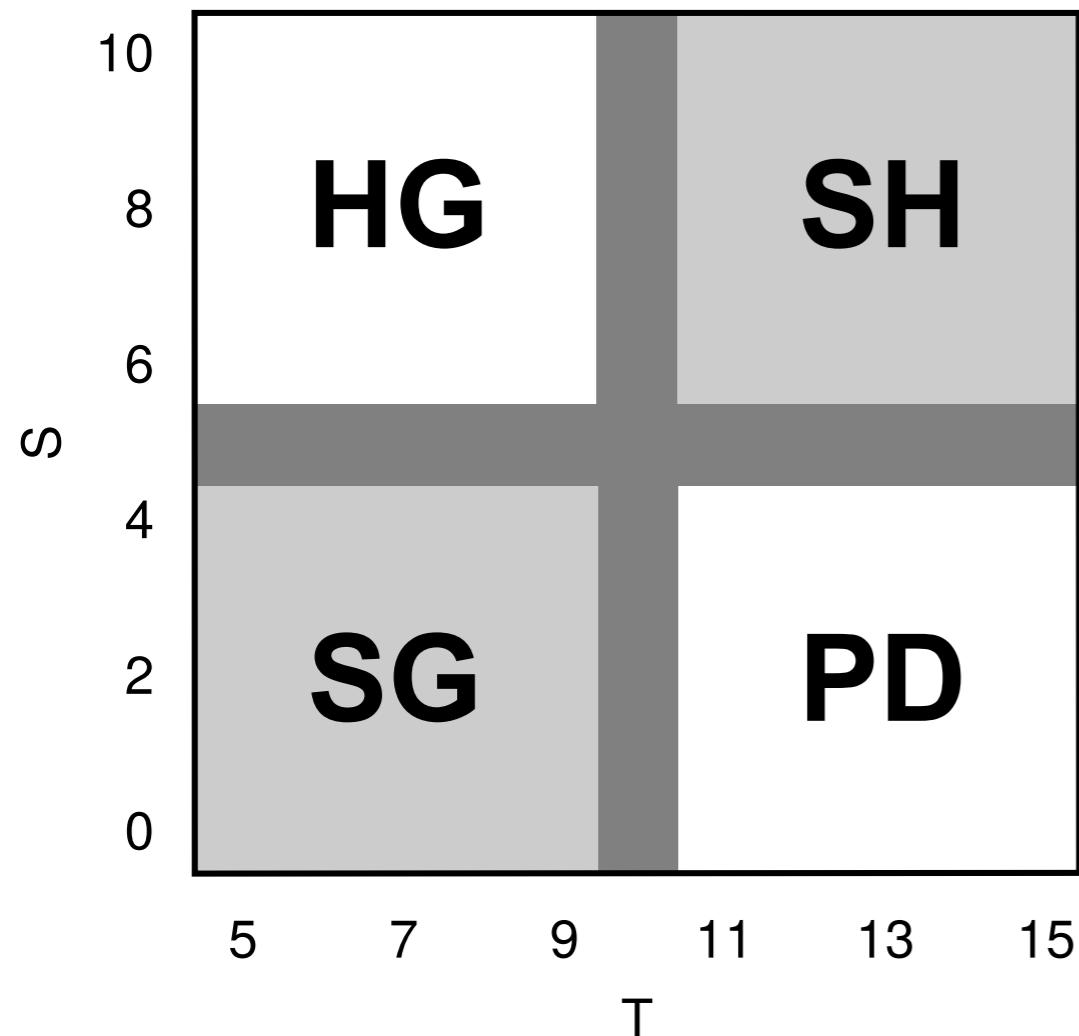
Case study 3: Behavioral “phenotypes”



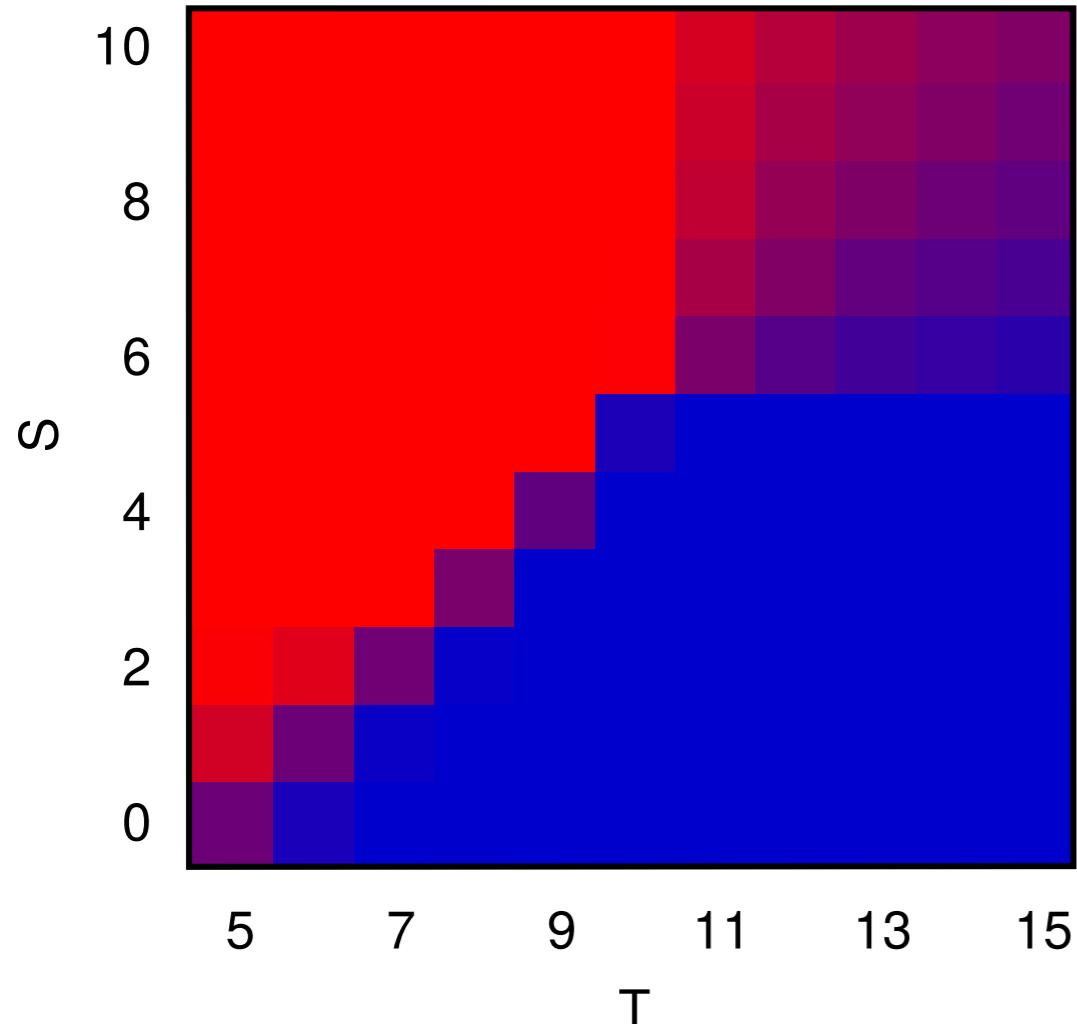
Social dilemmas

	C	D
C	1	S
D	T	0

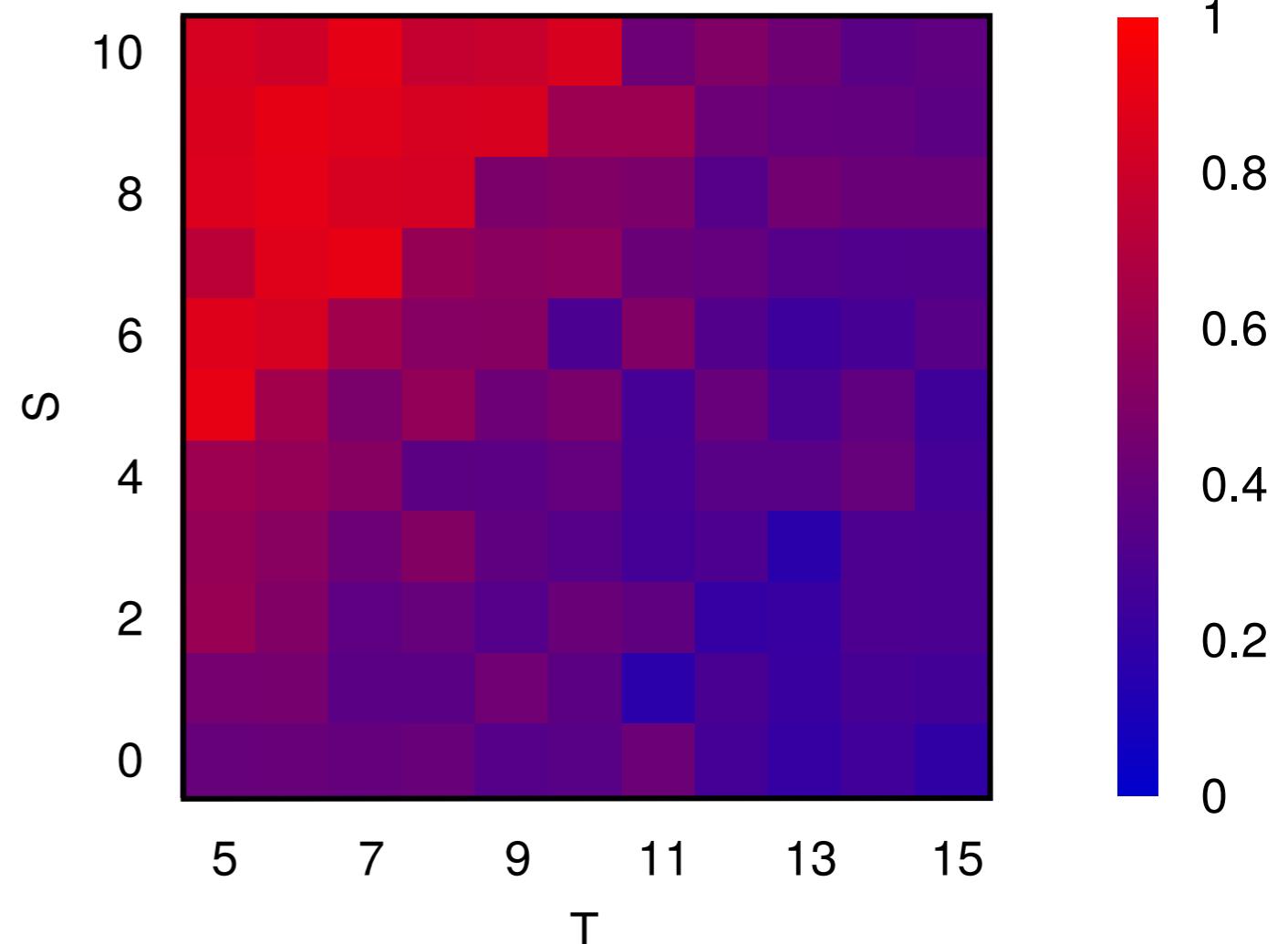
Behavior across different situations



Aggregate results

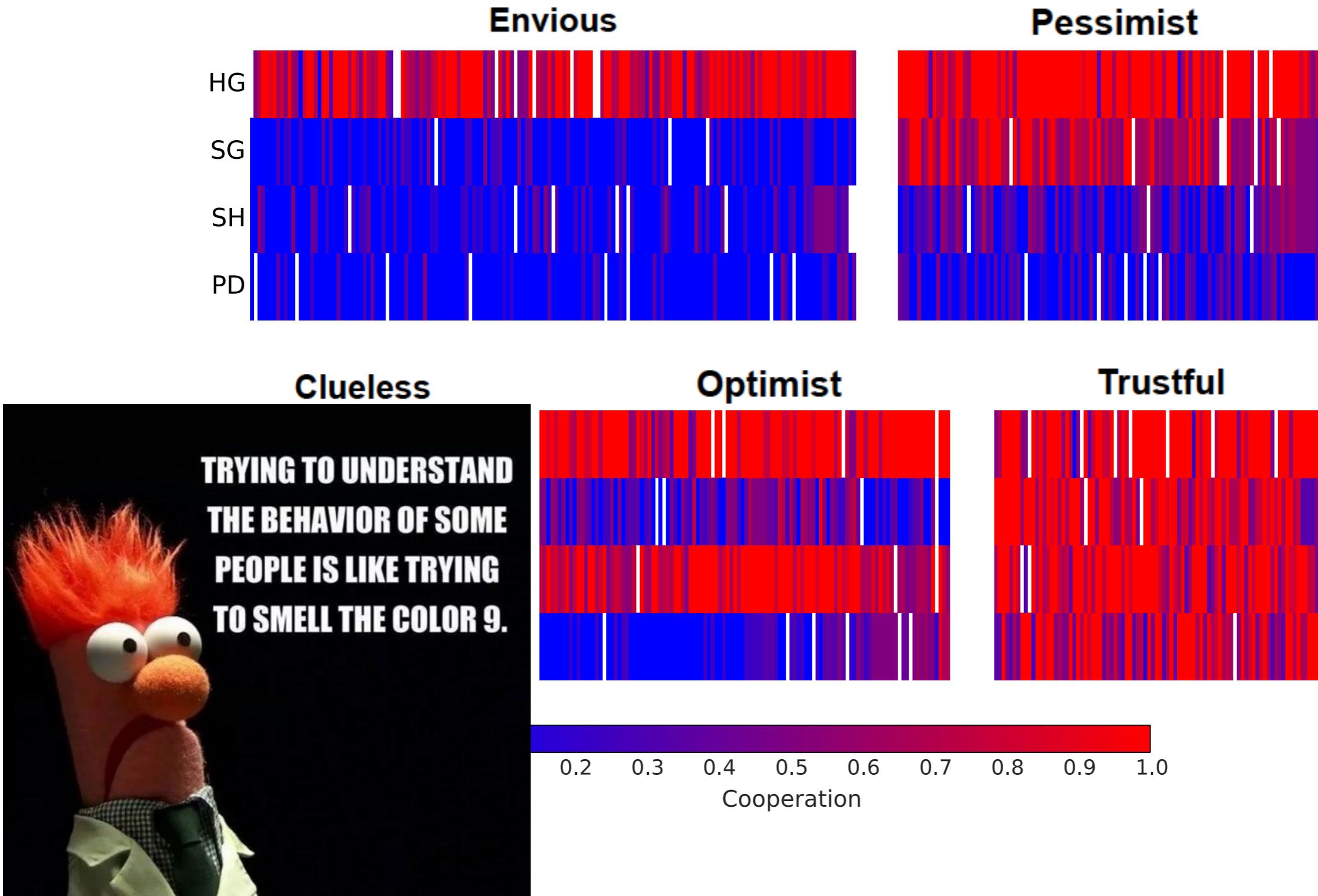


Predicted

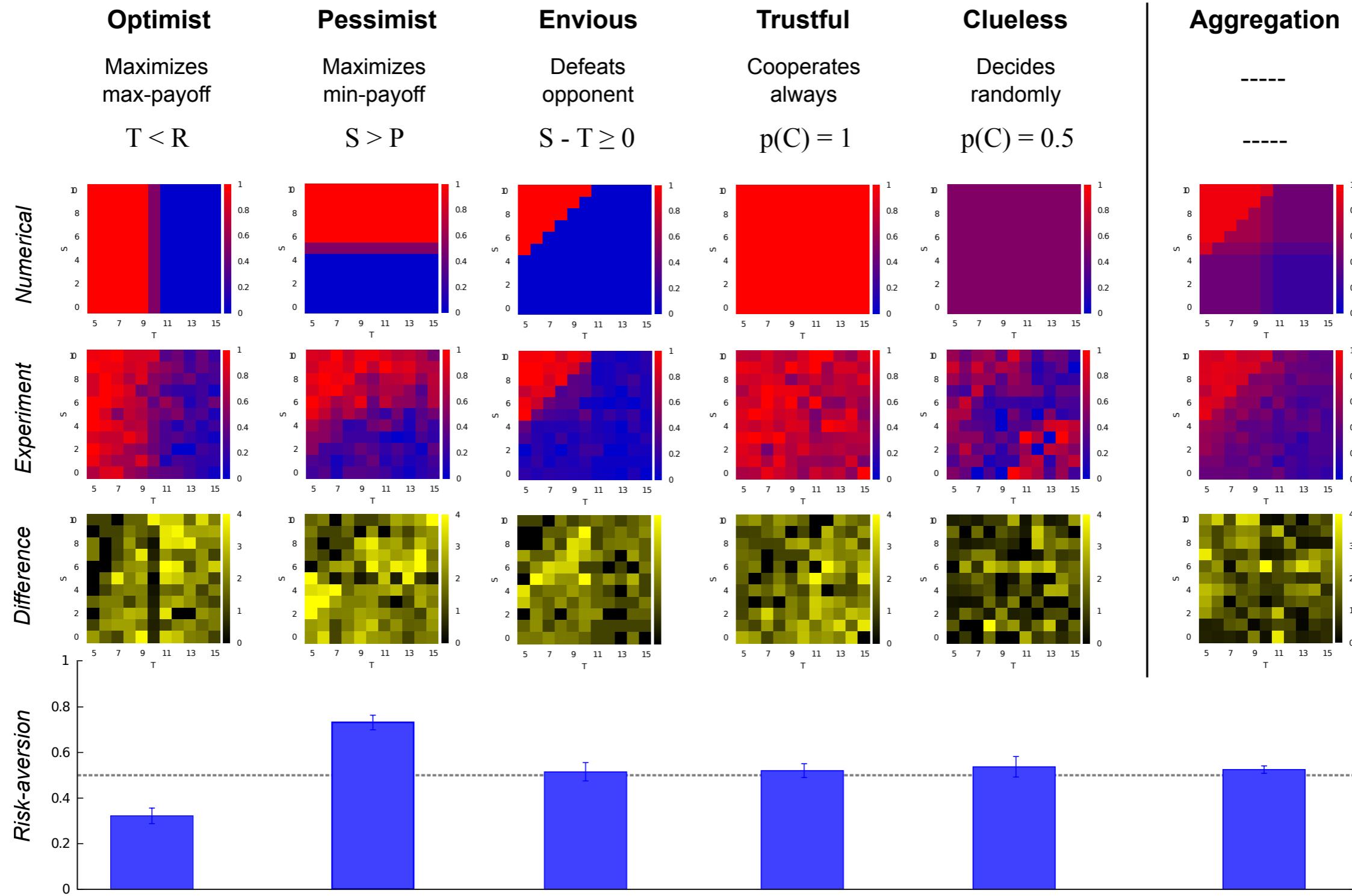


Observed

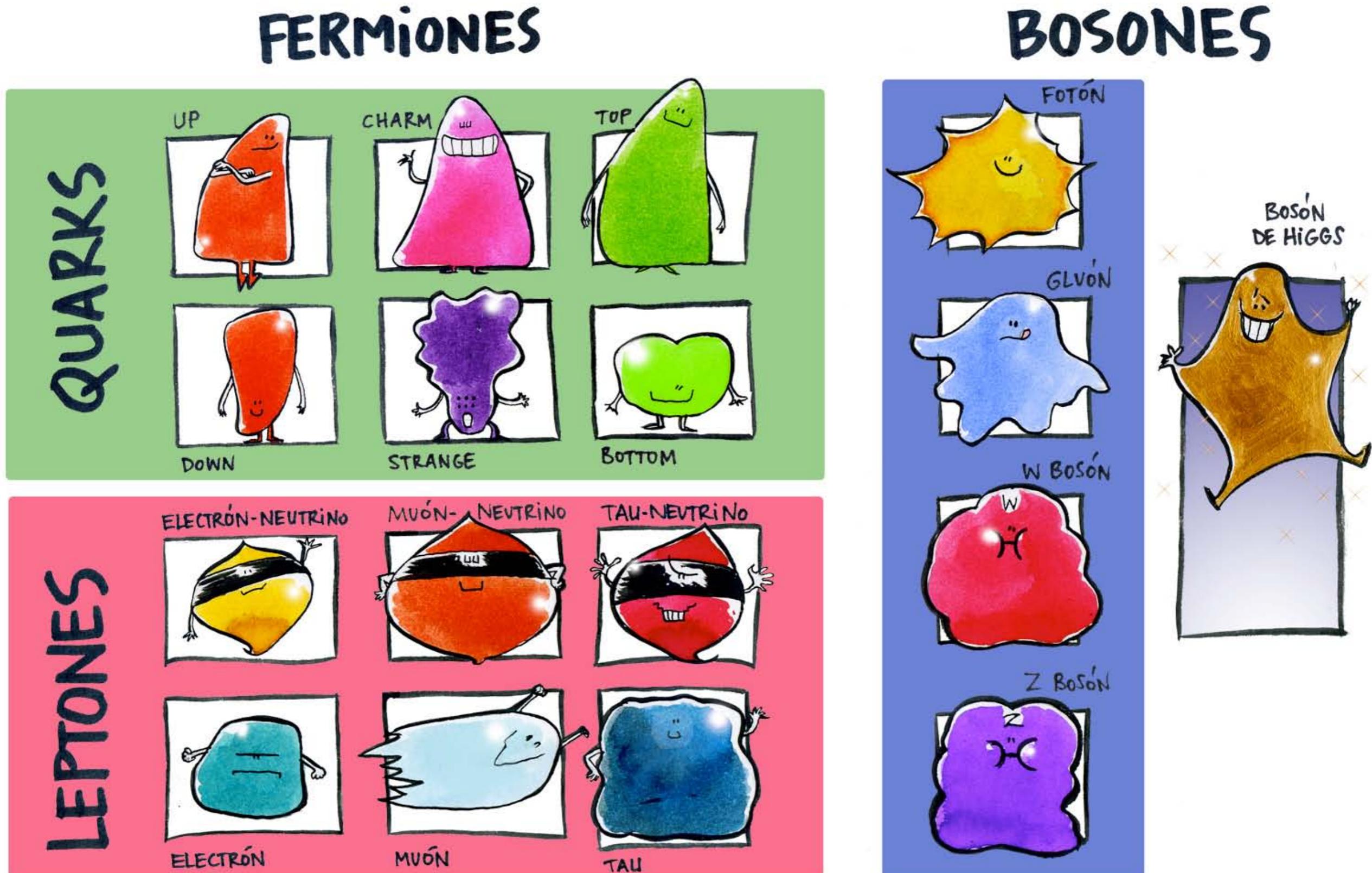
Agnostic individual classification



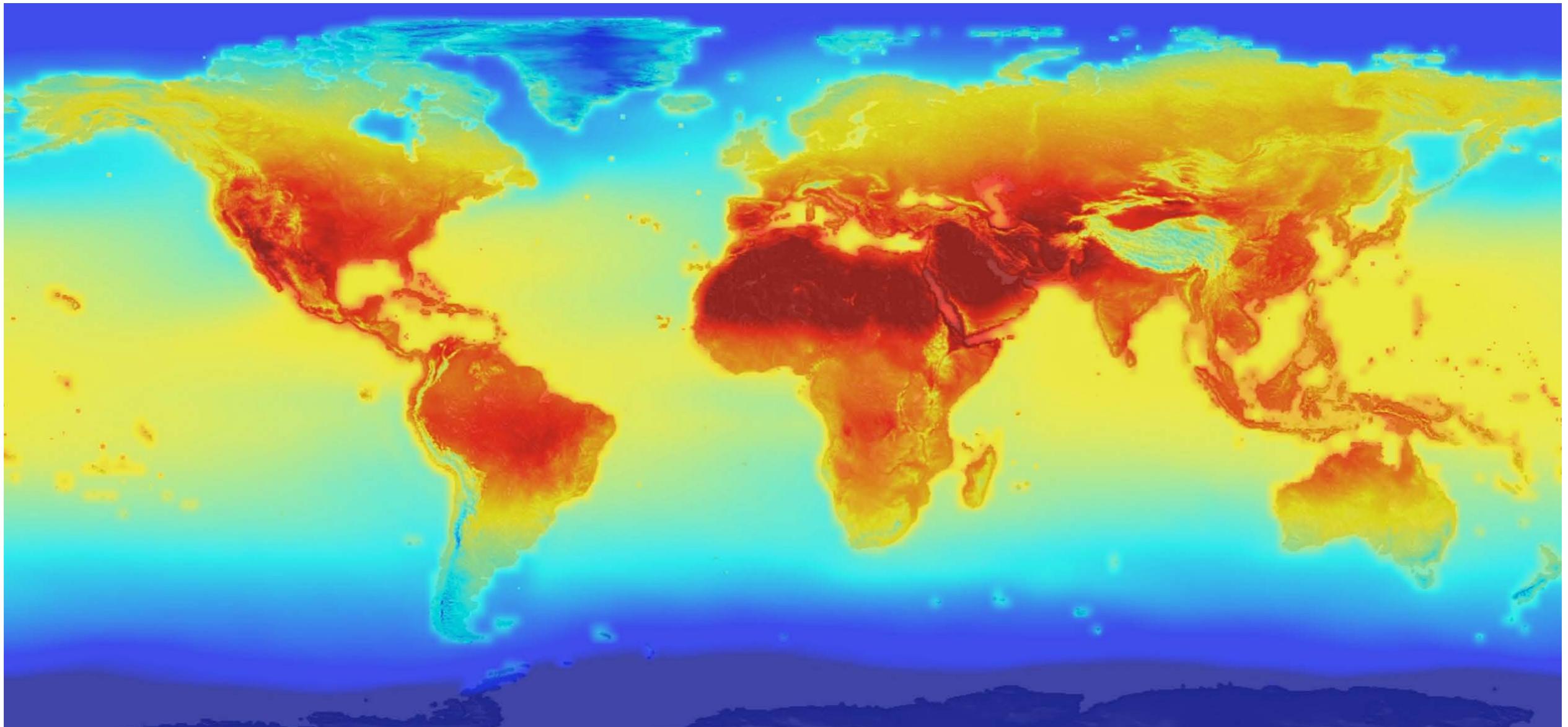
Phenotypes



Too many phenotypes?



Case study 4: Climate change mitigation



Climate change game

Bienvenido a **El juego del clima**



TUTORIAL: CÓMO SE JUEGA?

En estas pantallas te enseñaremos cómo jugar al juego del clima que nos propone Dr. Brain, un juego diseñado para estudiar cómo tomamos decisiones.

Utiliza las **flechas laterales** para desplazarte por el tutorial, y cuando acabes podrás empezar la partida.

Este juego está ideado por científicos de la Universitat de Barcelona (UB), Universitat Rovira i Virgili (URV), Instituto de Biocomputación y Sistemas Complejos (BIFI) - Universidad de Zaragoza (UZ) y Universidad Carlos III de Madrid (UC3M), es a la vez un experimento para estudiar y entender cómo los humanos tomamos las decisiones.

Climate change game

El objetivo del juego es **RECAUDAR 120 EUROS** en un fondo común para financiar acciones contra el cambio climático.

El juego se desarrollará a lo largo de **10 rondas**. En cada ronda cada jugador debe aportar al fondo común **entre 0 y 4 euros** del capital que le quede.

The screenshot shows a game interface with a pink header. On the left is a logo with the letters 'Dra' and 'in'. In the center, the word 'Tiempo' is displayed above a blue progress bar. To the right of the bar is the text 'El juego del clima' and a user icon labeled 'bb'. Below this, the text 'Ronda 1 de 10' is centered. To the right of the text is a stack of gold coins. The text 'Te quedan: 30' is followed by the same stack of gold coins emoji. Below this, the question '¿Cuánto quieres contribuir?' is asked. At the bottom, there are five numbered buttons from 0 to 4, each accompanied by an illustration of a flask containing liquid and a coin.

Ronda 1 de 10

Te quedan: 30

¿Cuánto quieres contribuir?

0 1 2 3 4

Usa estos botones para hacer tu selección

Climate change game

Al final de cada ronda y una vez los 6 jugadores hayan decidido podrás consultar :

- 1) La cantidad de dinero que hay en el fondo común.
- 2) Cuánto ha puesto cada jugador en la ronda anterior.
- 3) El capital actual y el capital inicial de cada jugador.

Resultados ronda 1

	Capital inicial	Contribución ronda	Capital actual
Jugador 1	20€	1€	19€
Jugador 2	40€	2€*	38€
Jugador 3	60€	3€	57€
Jugador 4	30€	0€	30€
Jugador 5	40€	4€	36€
Jugador 6	50€	3€	47€
TOTAL		13€	

Objetivo

120€

Fondo común

13€

NOTA: En las contribuciones marcadas con * el sistema ha decidido por el jugador

Climate change game

Si después de las 10 rondas **HAY 120 EUROS O MÁS** en el fondo común:



- 1) Recibirás **EL CAPITAL QUE HAYAS AHORRADO** en forma de un cheque regalo para la tienda online de ABACUS.
- 2) Destinaremos los 120 euros a una tareas de reforestación en el Parque de Collserola.

Si después de las 10 rondas **HAY MENOS DE 120 EUROS** en el fondo común:



- 1) Tienes un **10% de probabilidad** de recibir **EL CAPITAL QUE HAYAS AHORRADO** en forma de un cheque regalo para la tienda online de ABACUS.
- 2) No podremos destinar el dinero del fondo a la plantación de arboles.

Climate change game, heterogeneous version

Antes de empezar la partida, Dr. Brain hará un sorteo para asignaros un **número de jugador** y de **cuánto dinero disponéis inicialmente**. Este capital inicial estará entre **20 y 60 euros**.

Además, ¡también sabréis lo que tienen los demás!

Vas a ser el: **JUGADOR 2**

Empezaras con: **30€**

Y el resto de jugadores:

JUGADOR 1: **20€**

JUGADOR 3: **40€**

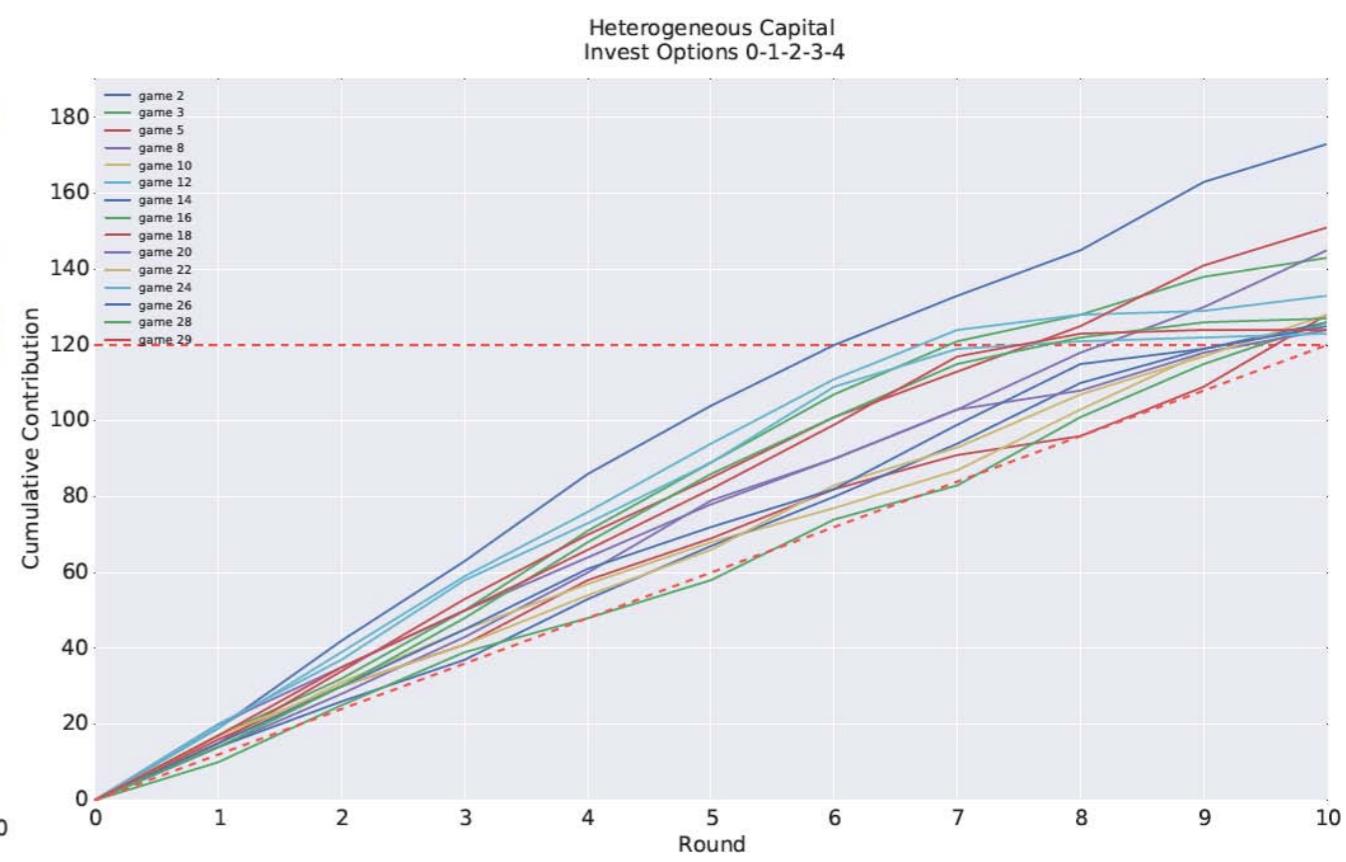
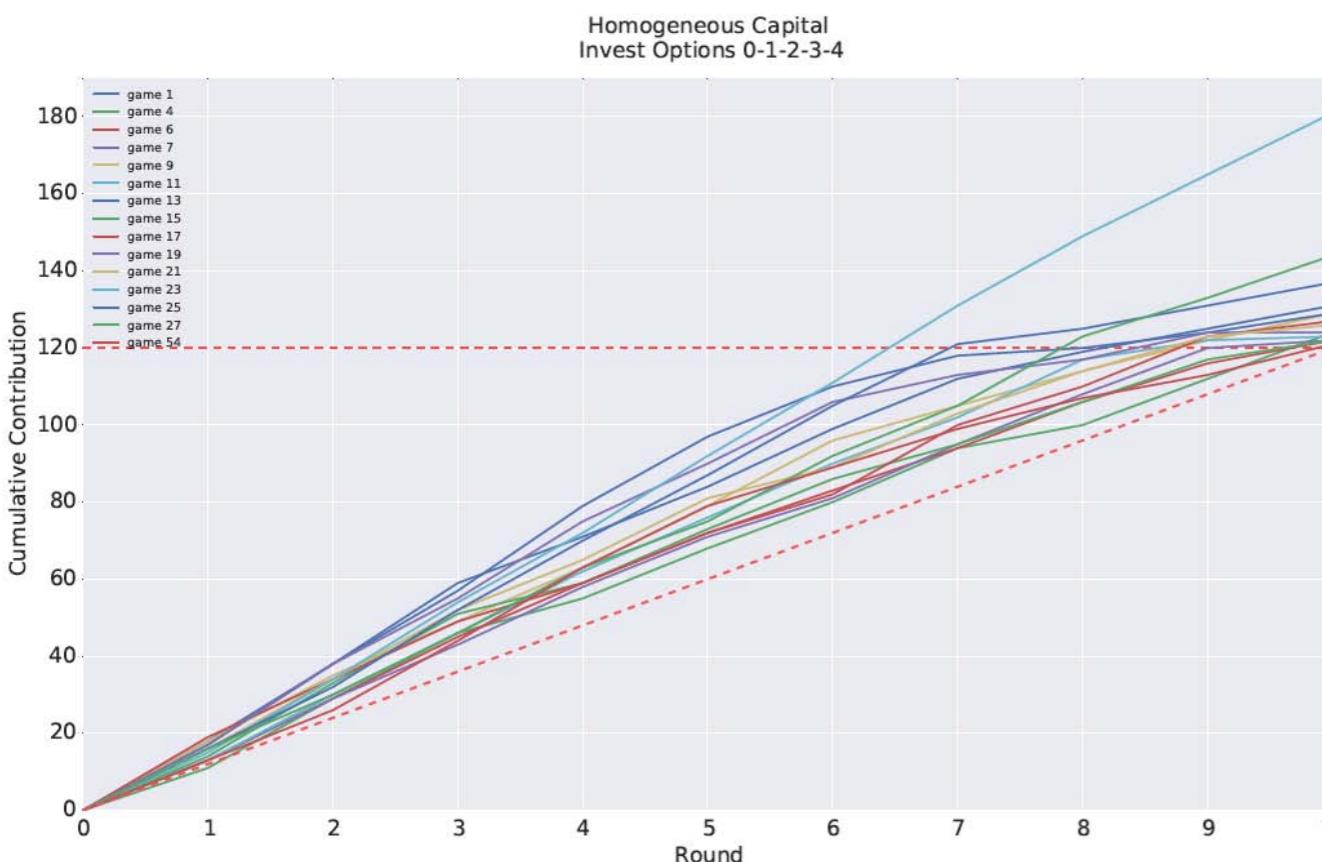
JUGADOR 4: **50€**

JUGADOR 5: **60€**

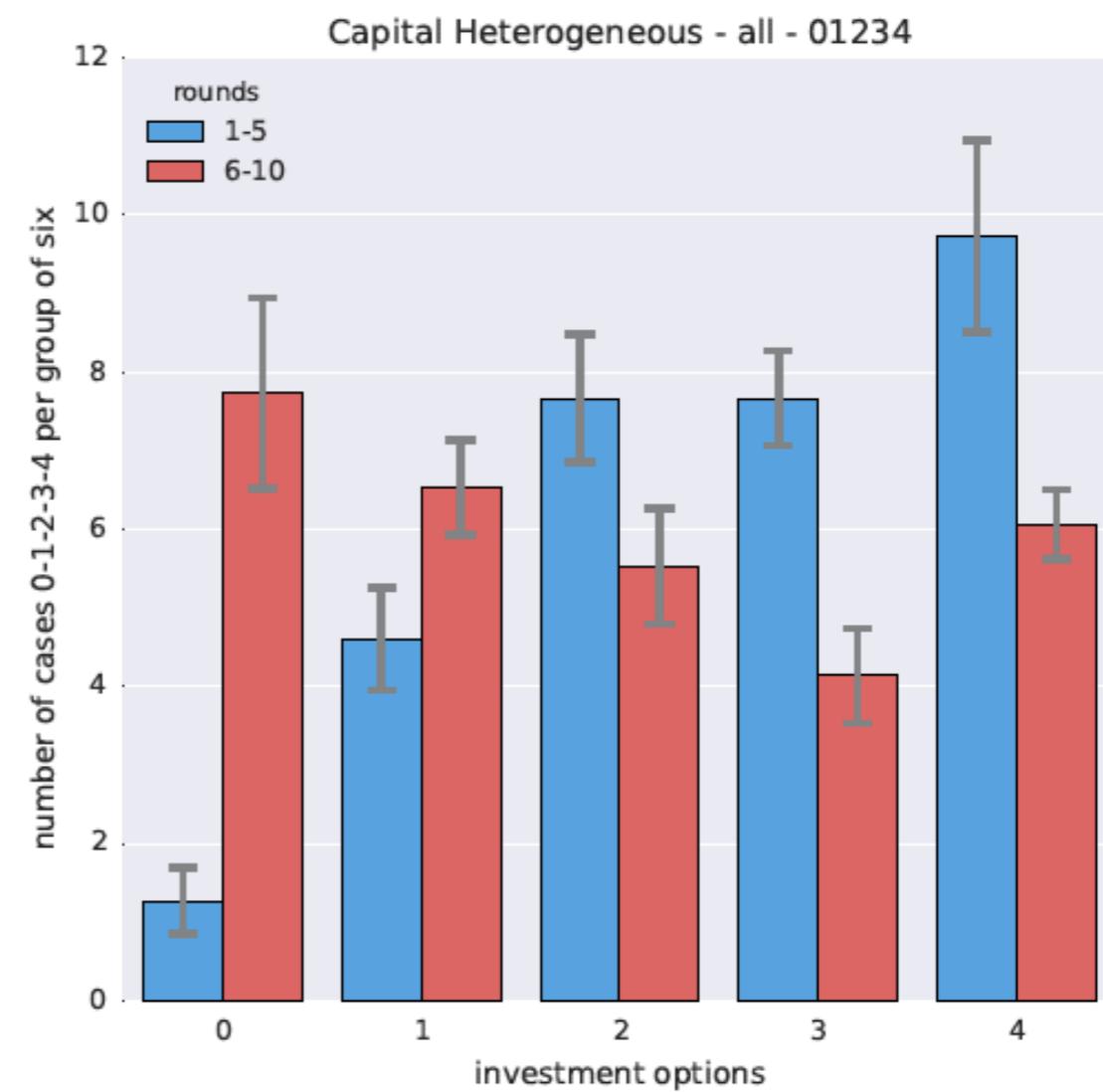
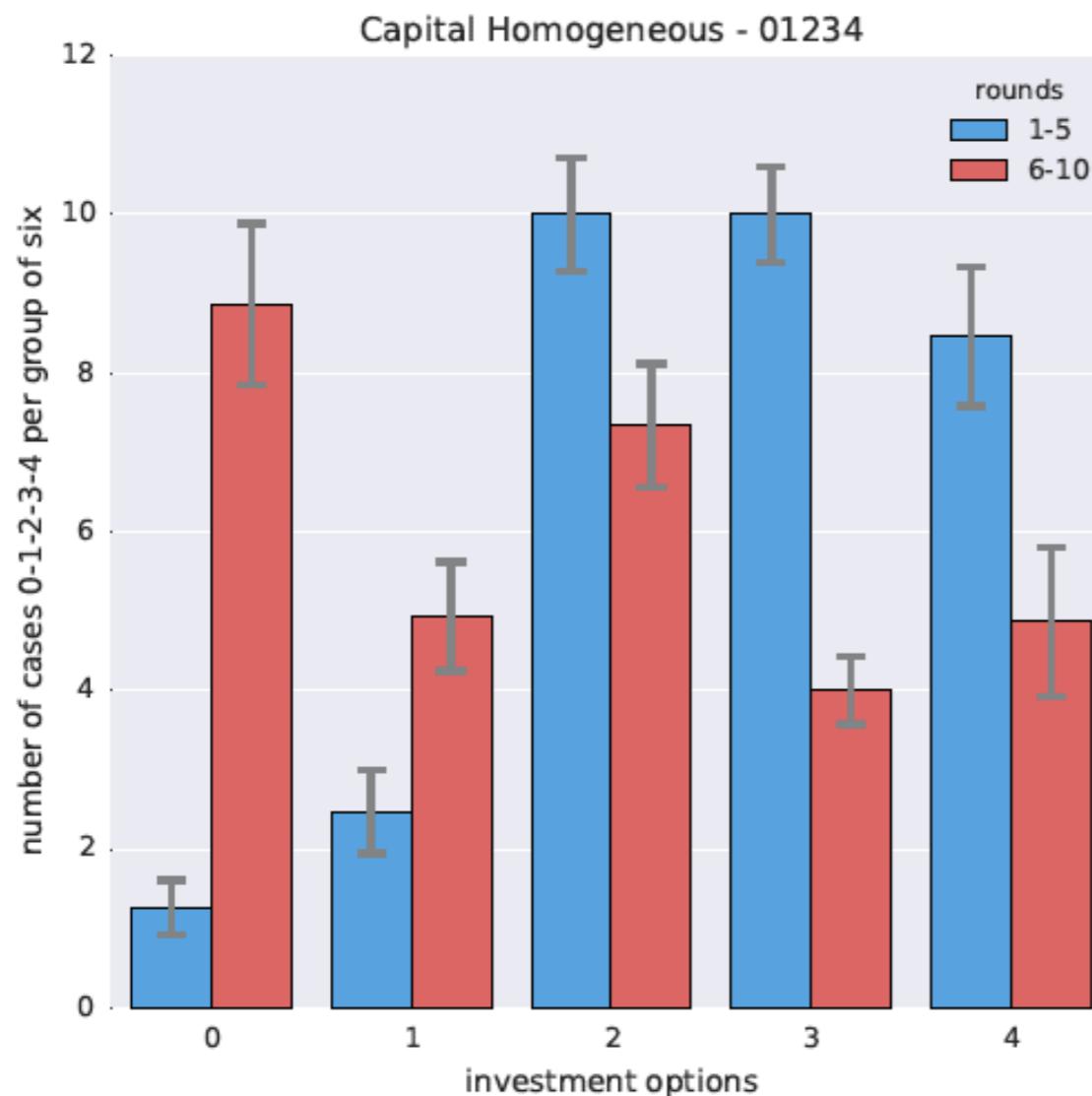
JUGADOR 6: **40€**



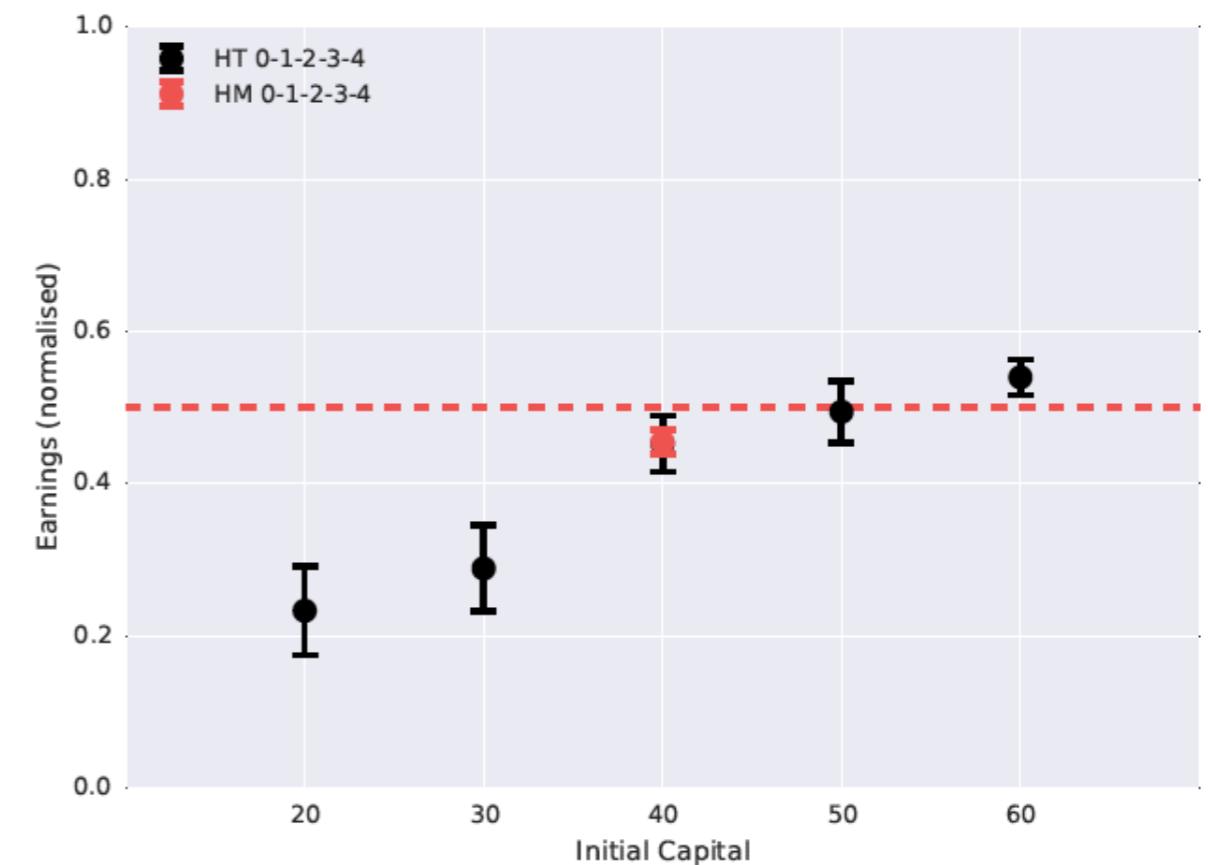
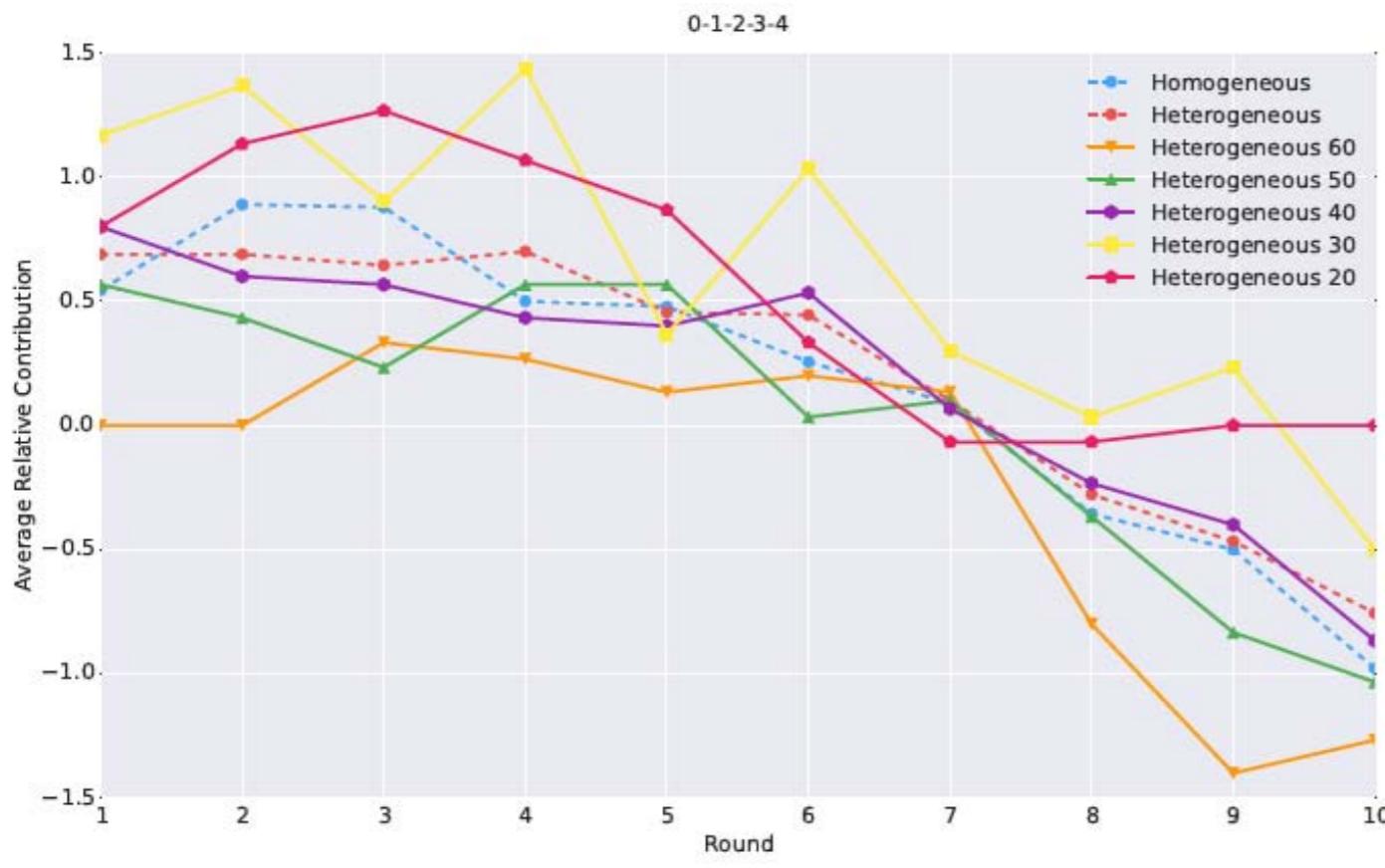
Is collective action successful?



How do players behave?



How do players behave?



Summary: case study 1



Seller Information

firstclassbooks

★★★★★ 88%

positive over the past 12 months. (114,120 total ratings)

Fiona0303

★★★★★ 96%

positive over the past 12 months. (806 total ratings)

The **mechanism** for cooperation in dynamic networks is **reputation**

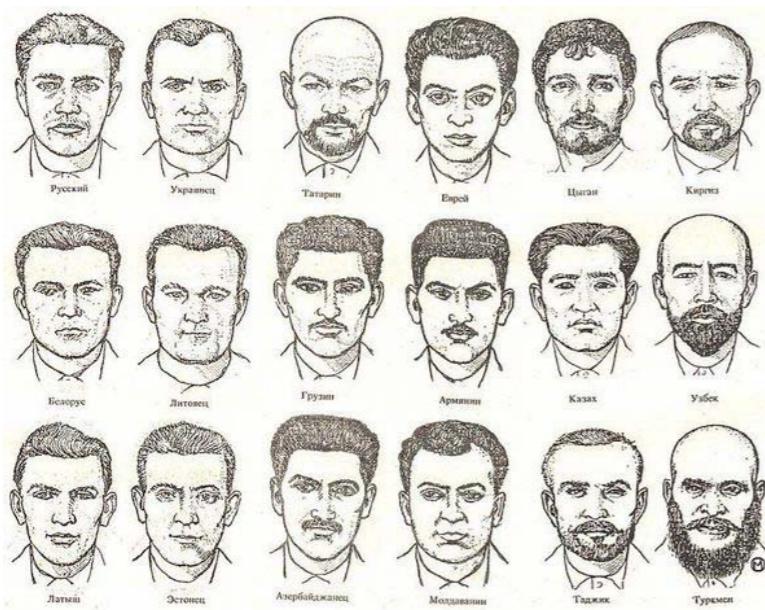
Reputation combines **last action** with **average action**

Faking reputation does not affect cooperation but **increases inequality**

Summary: case studies 2 & 3



Hierarchy is detrimental
for cooperation



People seem classifiable in
a few **recognizable phenotypes**

No (self-regarding) rationality

Summary: case study 4



Climate change is averted
by all groups (50% in 2008)



**People 3 times richer
contributed 1/3 less**

Outlook

Small vs large-scale: FET Open IBSEN (Sep 15 - Aug 18)

**Bridging the gap: from Individual Behaviour
to the Socio-tEchnical maN**

<http://www.ibsen-h2020.eu>

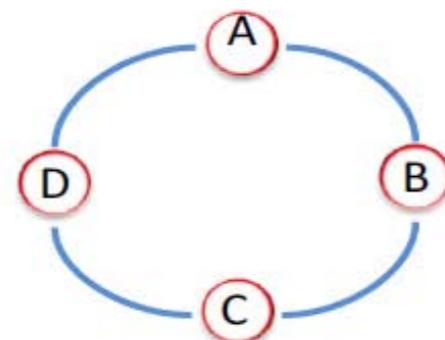
@IBSEN_H2020



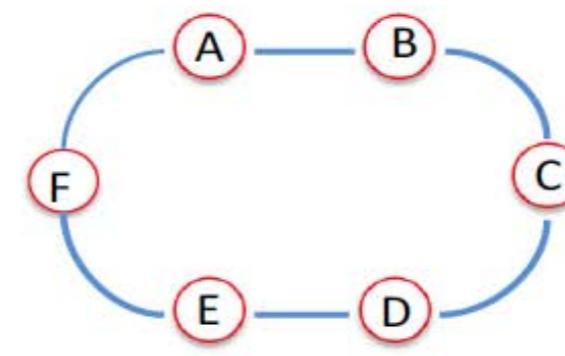
Outlook: example

Small vs large-scale: FET Open IBSEN (Sep 15 - Aug 18)

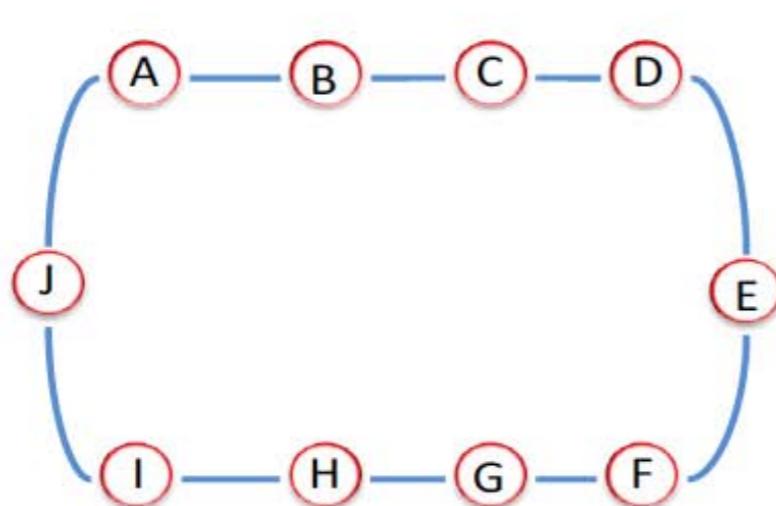
Trading in networks



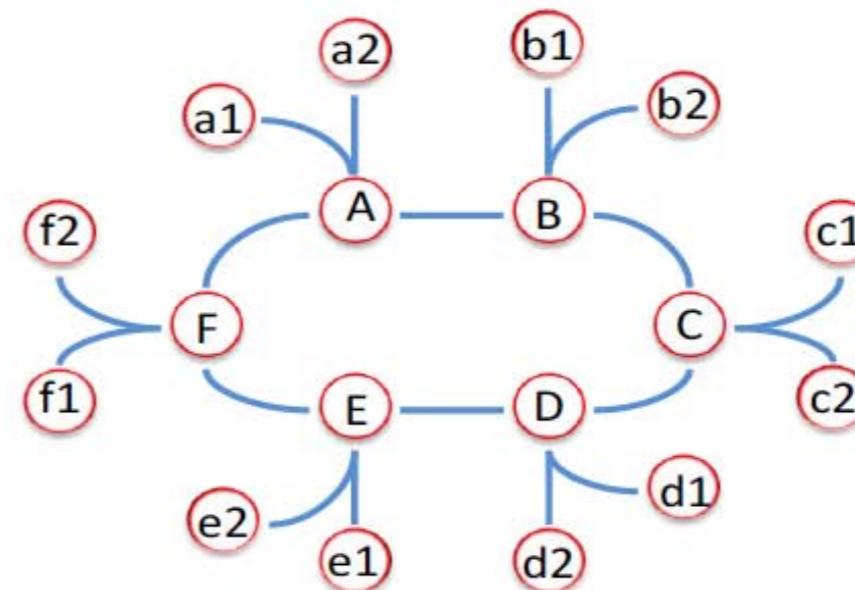
RING 4



RING 6



RING 10



RING with HUBS & SPOKES

Computational social science: interactions among people and complex socio-technological systems

@anxosan



Refs available from <http://www.anxosanchez.eu>