Design and Implementation of Online Behavioral Experiments

nodeGame.org

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The Puzzle of Cooperation

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Live Experiment in Class

https://nodegamedemo.herokuapp.com/

Check Point

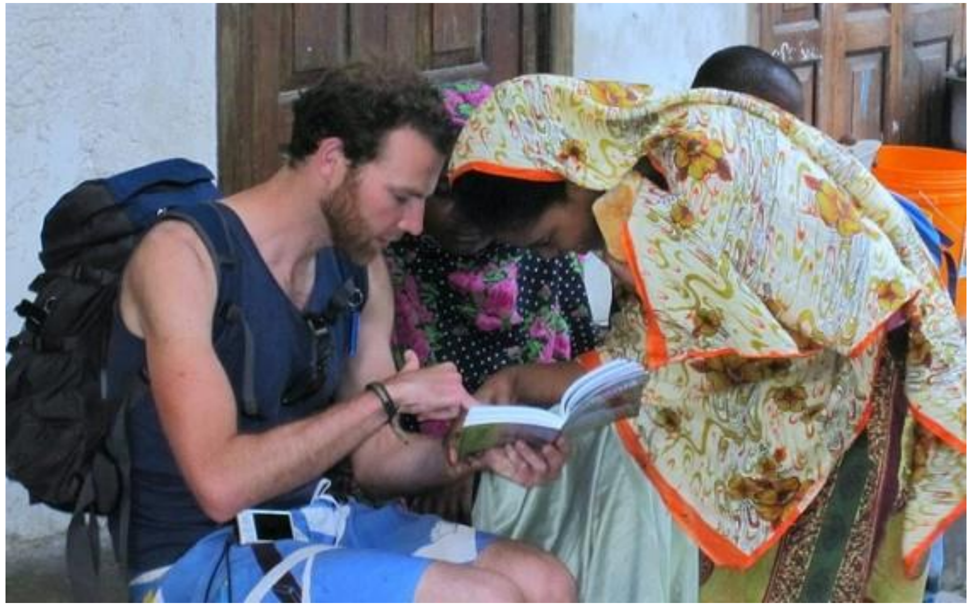
1. What game did you play ?
2. How would you describe the dynamics of the game ?
3. What strategy did you follow ?

Check Point

1. What game did you play ?
2. How would you describe the dynamics of the game ?
3. What strategy did you follow ?

If you were to develop a model to understand and explain the *macro dynamics* of the game based on *micro behavior* of the participants, which **assumptions** and **mechanisms** would you include?

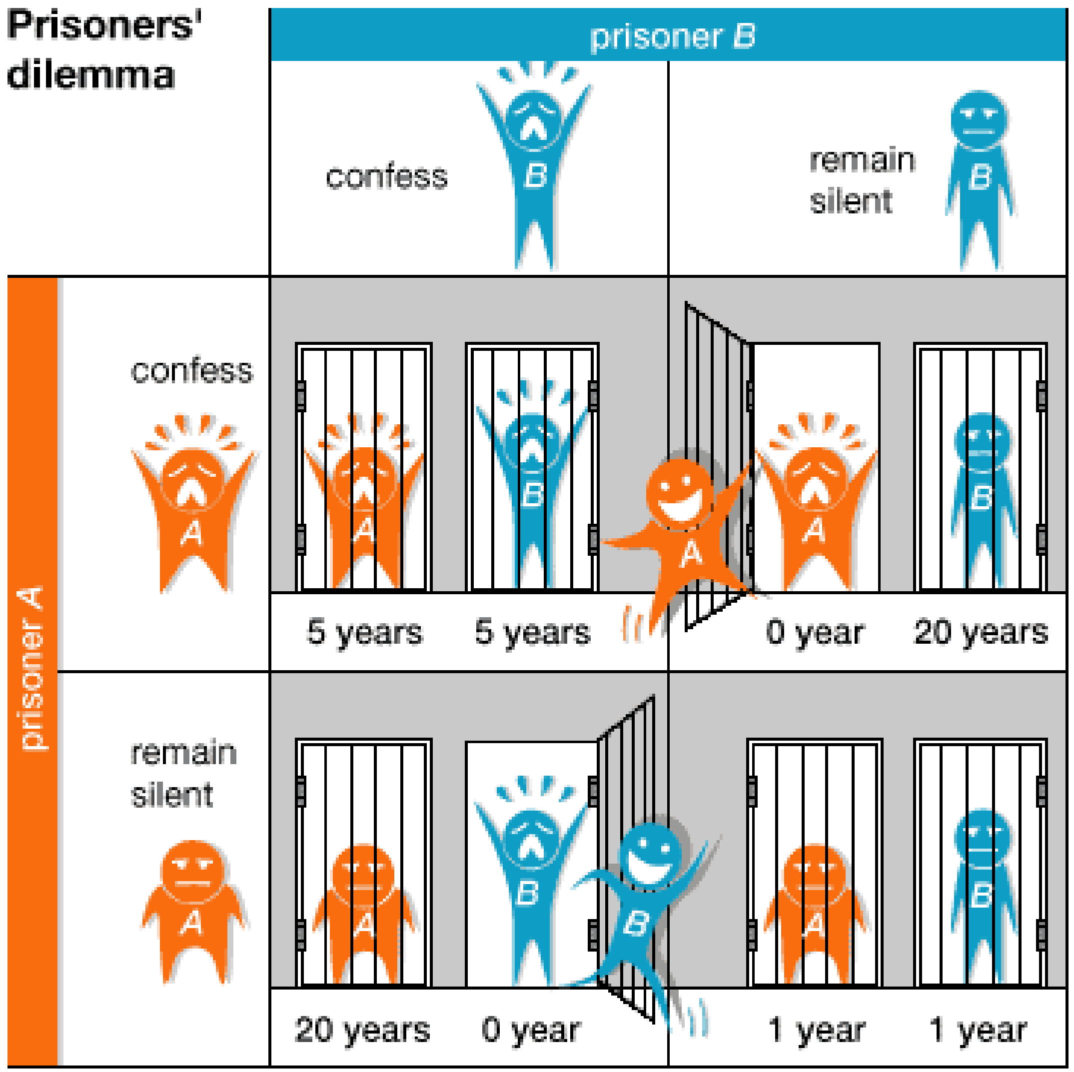
The Puzzle of Cooperation



Game Theory

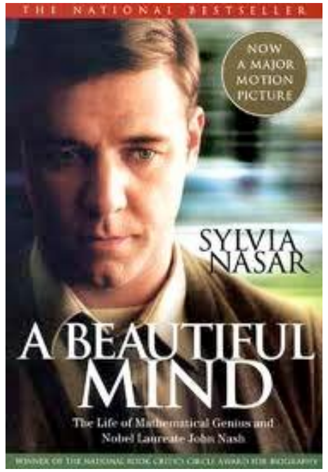
- Mathematical framework to model **strategic interactions** of individuals
- Formalizes the notion of finding a "best strategy" (**Nash equilibrium**) when facing a well-defined decision situation (**games**)
- Underlying assumption is that individuals optimize their ‘payoffs’ (or more precisely: ‘utility’) when faced with strategic decisions
- **Repeated interactions** are interesting for simulations (results can be completely different from one-shot games)

Human Cooperation: Prisoner Dilemma (PD)



Nash Equilibrium

- Is the strategy that players always play with no regrets: **best response**
- No player has an incentive to deviate from a Nash equilibrium
- In many circumstances, there is **more than one** Nash equilibrium



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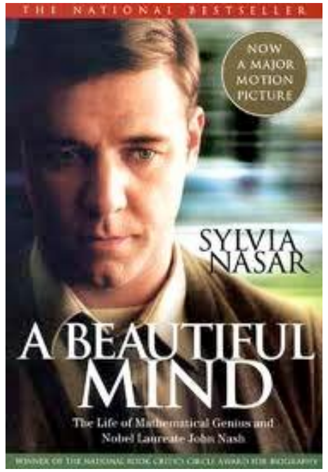
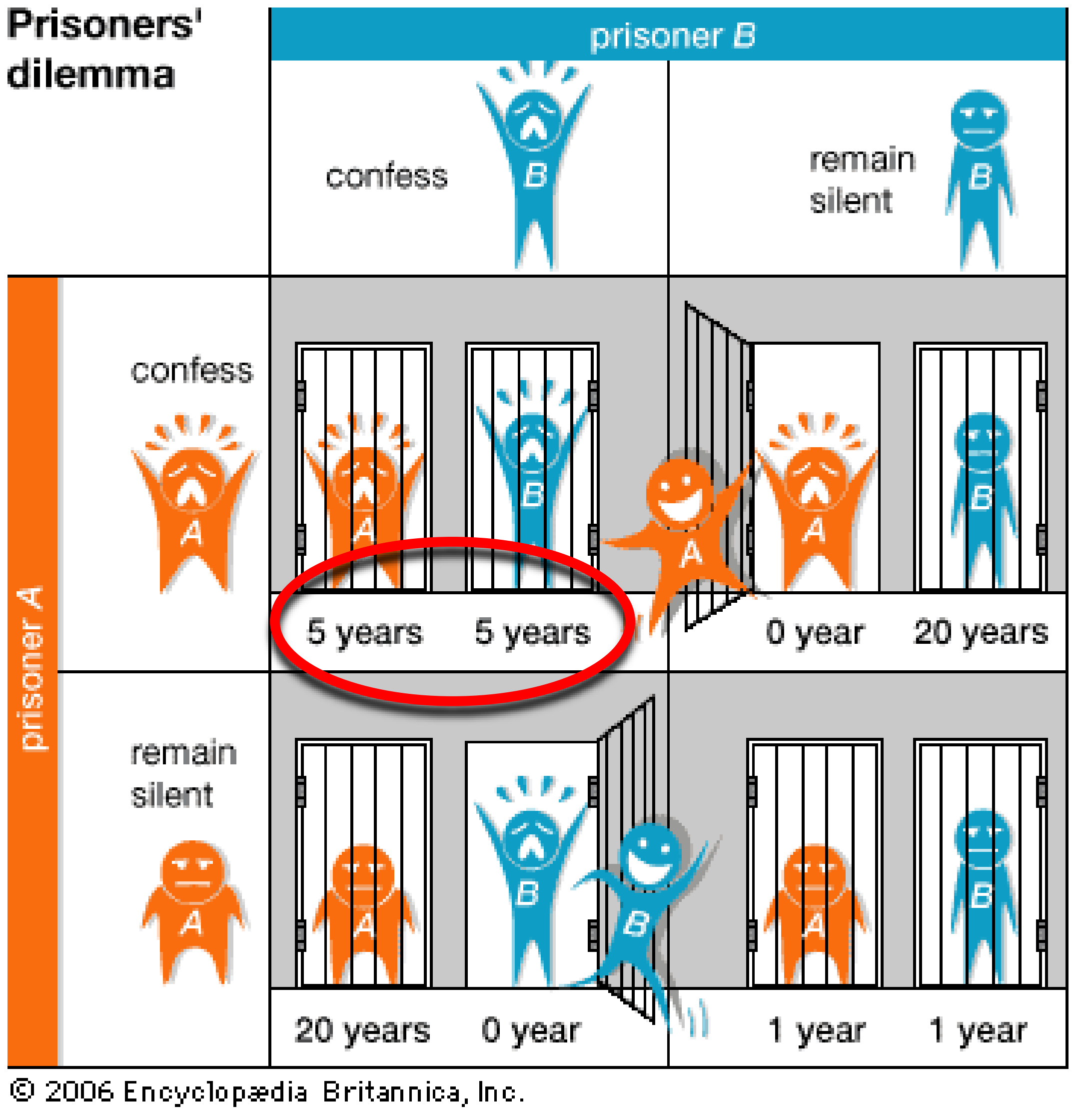


Some Questions:

- Is Nash an **optimal** strategy?
- What is the difference between a Pareto-efficient equilibrium and a Nash Equilibrium?
- Why do players play Nash? Do they?

Human Cooperation: Prisoner Dilemma (PD)



Nash Equilibrium in **Real** Life

- **Raphael** is the night guard of the National Fisheries Institute at lake Victoria in Tanzania
- His salary is one dollar per night
- He replaced the old guard who was murdered on duty
- He understands the concept of Nash equilibrium

Nash Equilibrium in **Real** Life

"Darwin's Nightmare" documentary (2004)

Why Cooperating in a Prisoner Dilemma?

- If the a Prisoner Dilemma is played only once, there is ***no reason to cooperate*** *(for rational individuals)*

- **Shadow of the future** (discount parameter)
  - if the probability of meeting again is large enough, it is better to be nice…

The Evolution of Cooperation (Axelrod, 1984)

- Axelrod organized two *computer tournaments*:
  - A number of experts were invited to submit a strategy
  - Each strategy had to play one iterated PD against itself, every other strategy, and the RANDOM strategy
  - The total score of a strategy was the average payoff of all these iterated PDs.

- Different rules for ending the game:
  - *Finite game*: game ends after 200 rounds (*first tournament*)
  - *Indefinite game*: game continues with a probability of w = 0.99654 (*second tournament*).

The Evolution of Cooperation (Axelrod, 1984)

- Winner of the tournament: **Tit for Tat**
  - **be nice**: cooperate first
  - then do what **your opponent did in the last round** (punish defection; reward cooperation)
- Other possible strategies:
  - Always cooperate / always defect
  - Tit for tat, but defect on first round
  - Win–Stay, Lose–Shift: repeat behavior if successful
- Shadow of the future
  - probability that there will be a next round

The Evolution of Cooperation (Axelrod, 1984)

Nice:

- A nice strategy never defects without being provoked by an opponent's previous defection.
- Nice strategies can realize mutual cooperation with other nice strategies.
- Wouldn't it be better to exploit nice players?
- Yes, but only if nice players do not retaliate!

The Evolution of Cooperation (Axelrod, 1984)

Retaliatory (Provocable):

- A retaliatory strategy (immediately) defects after an “uncalled for” defection of the opponent
- A retaliatory strategy protects itself from exploitation
- “Challengers” do not profit from a retaliatory strategy
- How can cooperation be restored after a retaliatory reply?

The Evolution of Cooperation (Axelrod, 1984)

Forgiving:

- A forgiving strategy returns to cooperation after the opponent stopped to defect.
- Avoid “lock-in effects” after a single defection of its opponent.
- Tit for Two Tat

The Evolution of Cooperation (Axelrod, 1984)

- Cooperation is possible in a Prisoner’s Dilemma (PD) and it is based on **reciprocity**
- Cooperative strategies can be successful in the repeated 2-person PD if these strategies are:
  - nice,
  - retaliatory,
  - forgiving
- and if the (expected) duration of the game is long enough (“shadow of the future”).

The Evolution of Cooperation (Axelrod, 1984)

- However, in real social life, players may change their strategies:
  - Imitation of successful others
  - Selection for successful strategies
  - Random mutations
  - Learning from own history

- Can the reciprocity strategy survive against mutating strategies?

Evolutionary Game Theory

- Classical Game Theory suffers from a number of conceptual weaknesses (hyper-rational players, selection problem of strategy, static theory)
- Evolutionary Game Theory introduces evolutionary dynamics for **strategy selection**, i.e. the evolutionary most stable strategy dominates the system dynamics
- Players are rational about their own decisions but do not need to know the strategies (and reasoning) of all other players!
- Suited for agent-based modeling approaches as it allows for learning and adaption of agents

Evolutionary Learning

- The main assumption underlying evolutionary thinking is that the entities which are *more successful at a particular time will have the best chance of being present in the future.*

- *Selection*
- *Replication*
- *Mutation*

Evolutionary Learning

- **Selection** is a discriminating force that favors some specific entities rather than others.
- **Replication** ensures that the entities (or their properties) are preserved, replicated or inherited from one generation to another
- Selection and replication work closely together, and in general tend to reduce *diversity*
- The generation of new diversity is the job of the **mutation** mechanism

How Do Agents Learn?

- **Imitation:** People copy the behavior of others, especially behavior that is popular or appears to yield high payoffs.
- **Reinforcement:** People tend to adopt actions that yielded a high payoff in the past, and to avoid actions that yielded a low payoff.
- **Best reply:** People adopt actions that optimize their expected payoff given what they expect others to do. Subjects choose best replies to the empirical frequency distribution of their opponents' previous actions, i.e. "Fictitious Play". Agents may also update their beliefs about others' behavior.

Evolutionary Cooperation

- A common pattern in evolutionary simulations is at the beginning unfriendly strategies thrive at the cost of “naive cooperators” who soon die out
- Once this has happened, the unfriendly strategies run out of prey, and they can also not benefit from exploitation of reciprocity strategies
- In the end, only reciprocity strategies survive.

Migration

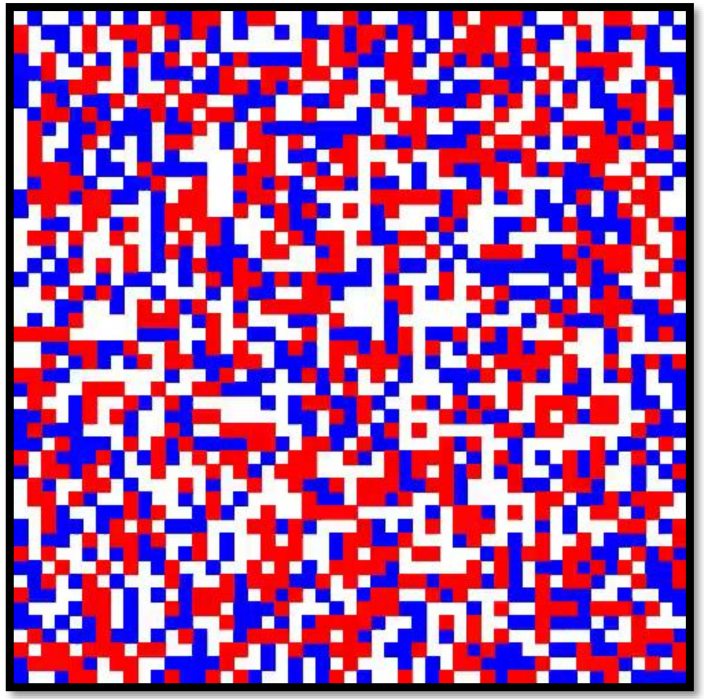
- Migration can also support cooperation

The Outbreak of Cooperation (Helbing, Yu 2009)

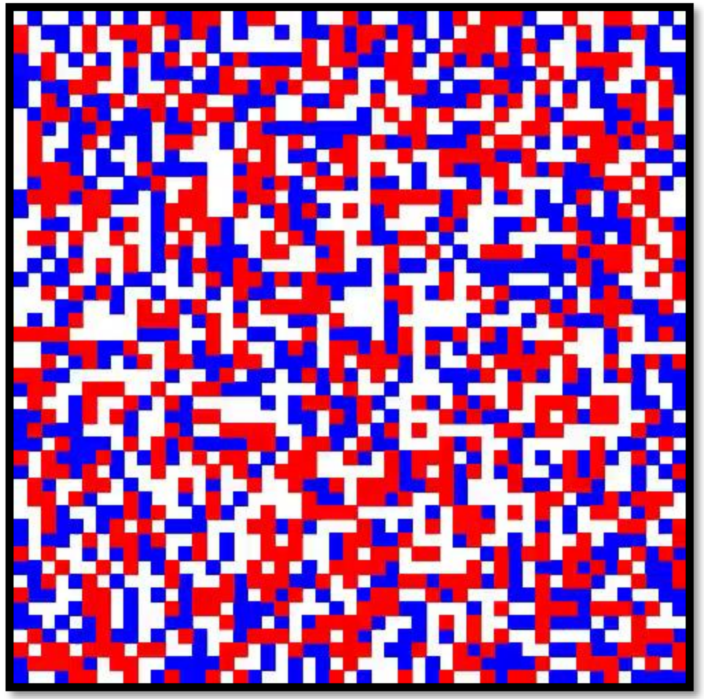
P = 0
R = 1
S = 0
T = 1.4

Blue = C
Red = D

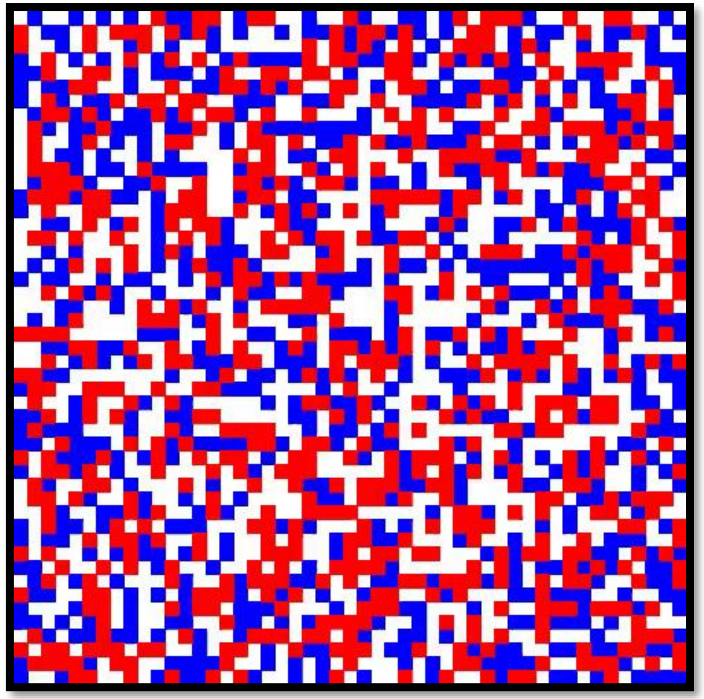
Imitation



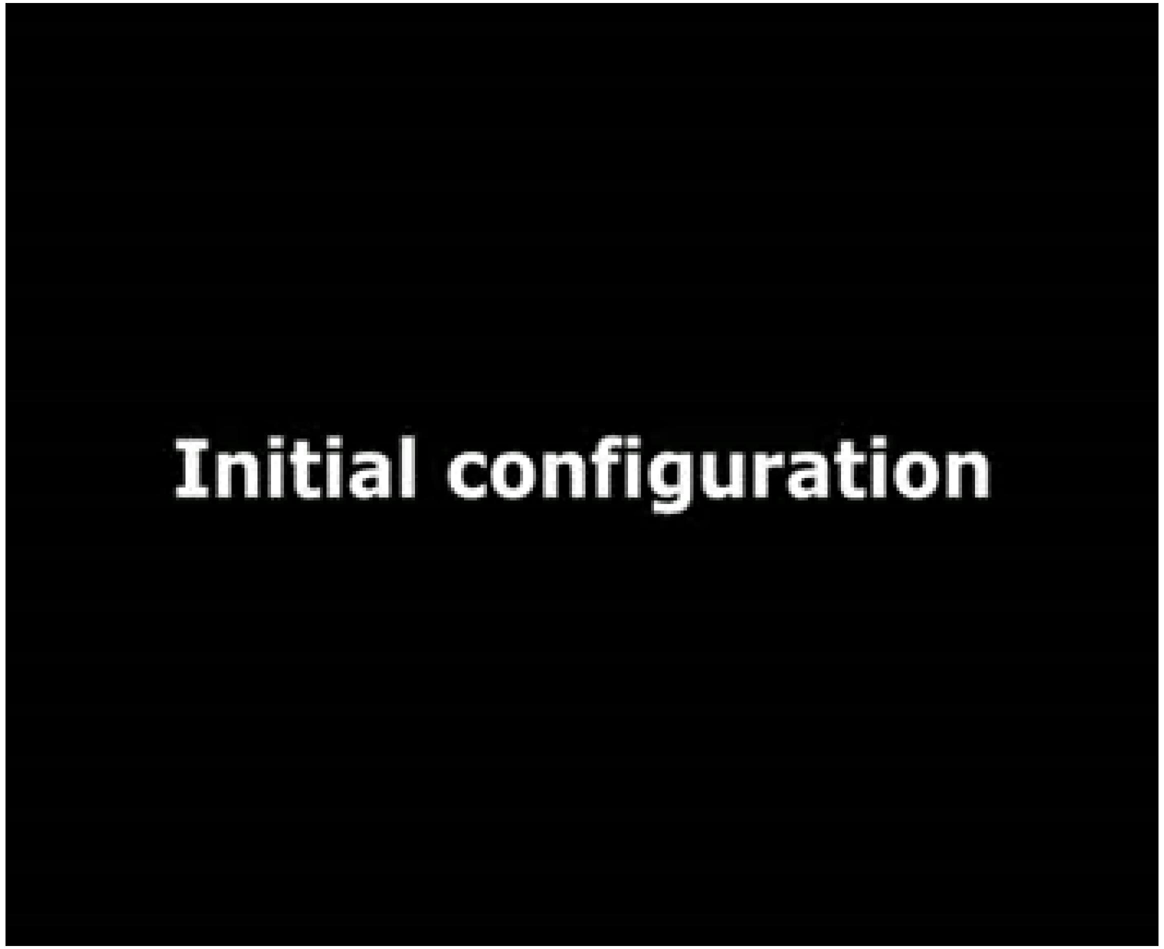
Migration



Imitation & Migration

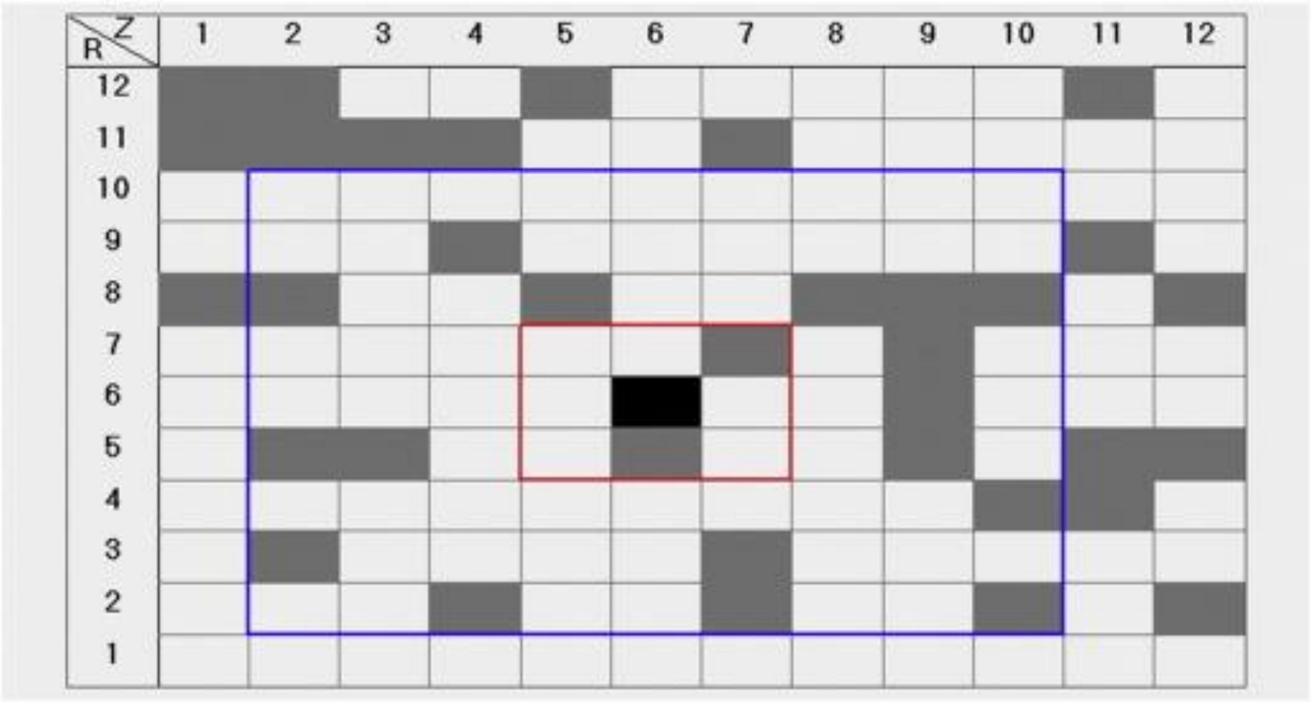


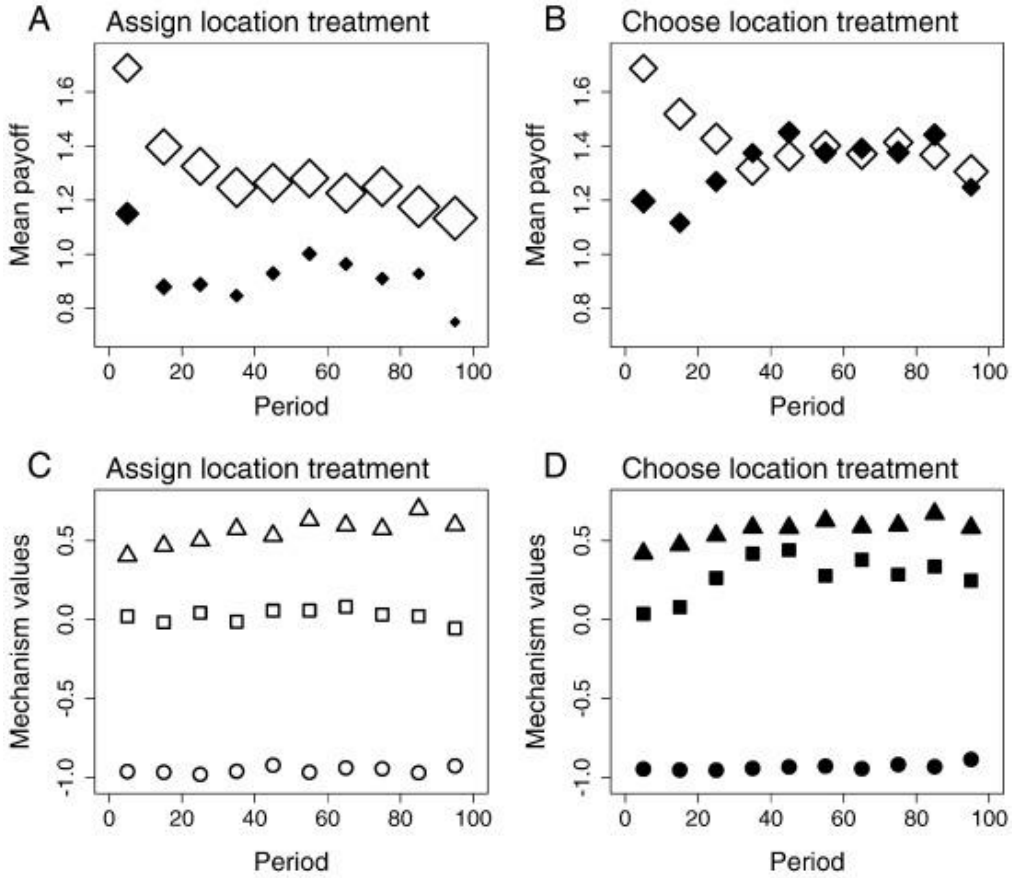
The Outbreak of Cooperation (Helbing, Yu 2009)



Even starting from a population of defectors only cooperation can thrive

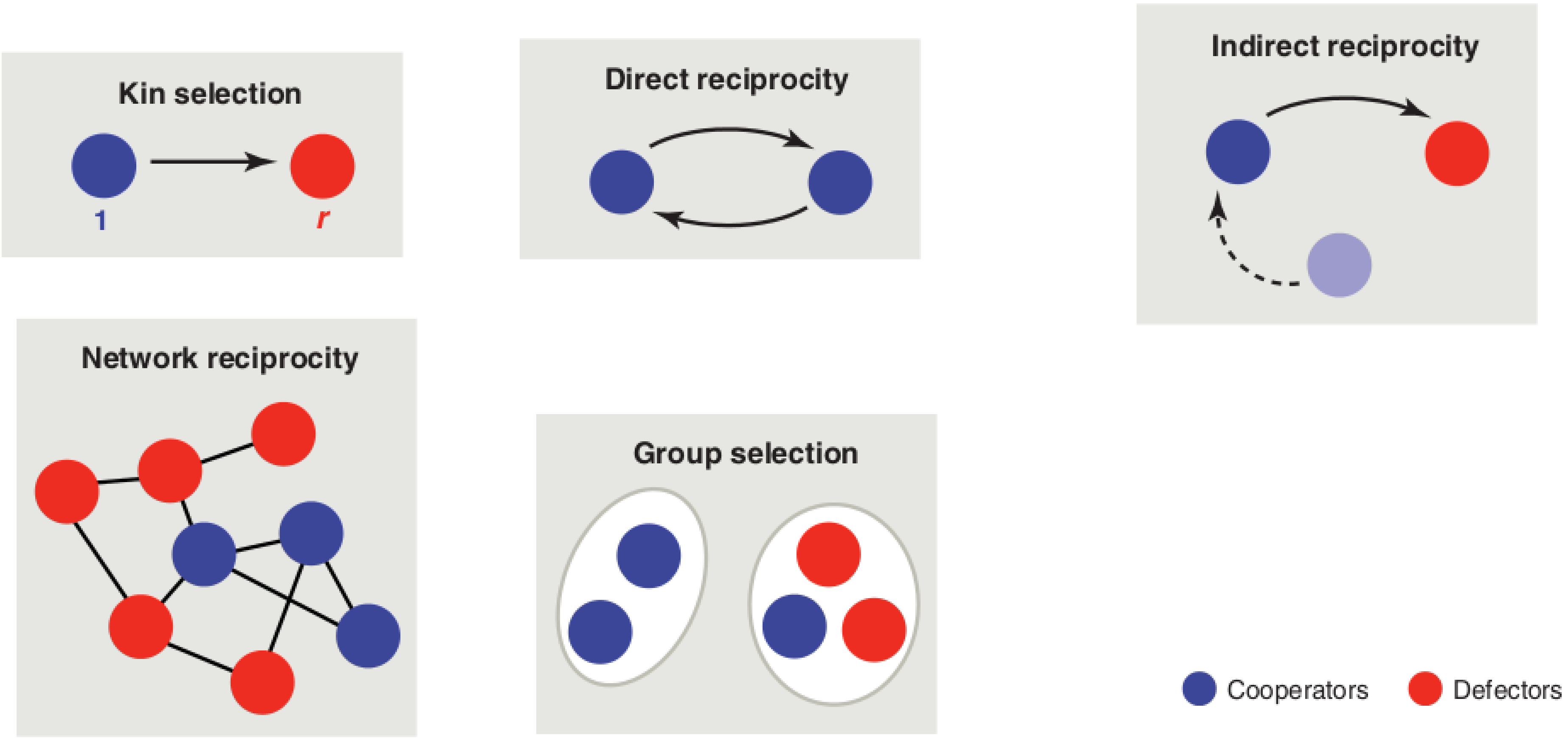
Sustained Cooperation by Running Away from Bad Behavior (Efferson et al.,2016)





- **Panel A and B.** Payoff for defecting (open diamond) and cooperation (solid diamond).
- **Panel C and D.** Decomposition difference in payoffs between cooperation and defection into: small group effect (triangles), assortment effect (squares), and retain endowment effect (circles).

5 Rules for the Evolution of Cooperation



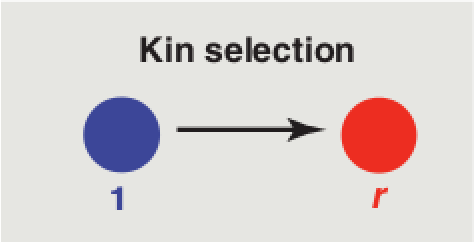
Nowak (2006)

Kin Selection

- J.B.S. Haldane: *"I would lay down my life for two brothers or eight cousins."*

- Kin selection is the evolutionary strategy that **favors the reproductive success of one's relatives**, even at the cost of one's own survival

- ***Selfish Gene***: genes maximize the fitness of the group, not of the invidividual, to ensure spreading in future generations



Empirical Evidence

- **Social insects**: bees, termites, ants

- Surrogate mothers adopt related orphaned **red squirrel** puppies but not unrelated ones.

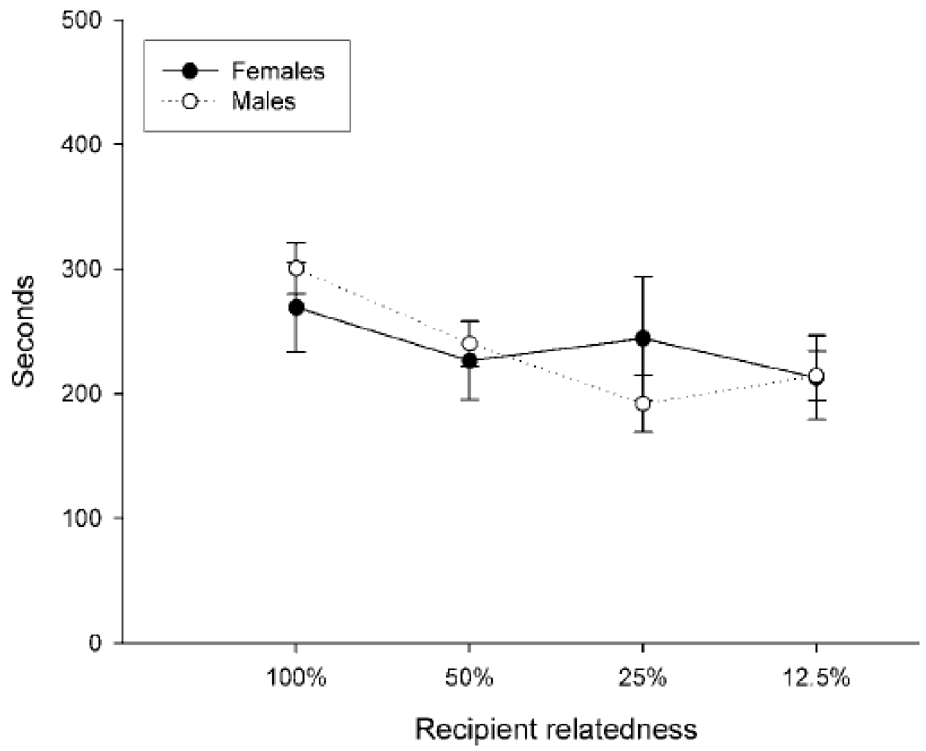
- **Ground squirrels** alters of dangers others more often when relatives are nearby

- **Sea rockets** grow compete for soil nutrients by aggressive root growth. When they share the pot with non-sibling plants

Hamiltonian Rule: Empirical Evidence

- r > c/b
  - r coefficient of relatedness
  - c cost of cooperation
  - b benefit of cooperation

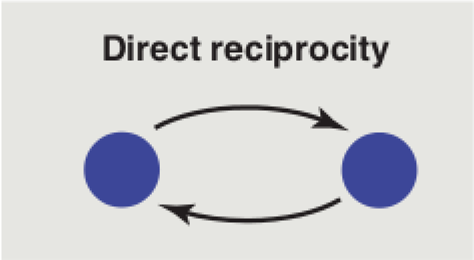
- Relatedness must exceed the cost-to-benefit ratio of the altruistic act



Madsen et al. "Kinship and altruism: A cross-cultural experimental study"(2010)

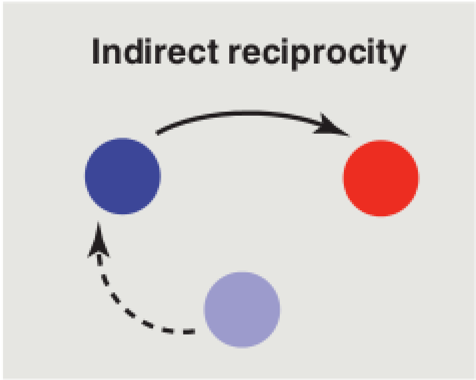
Direct Reciprocity

- Assuming that there are enough repeated encounters between the same two individuals
- It is rational to behave cooperatively with each other
- 'I help you and you help me'



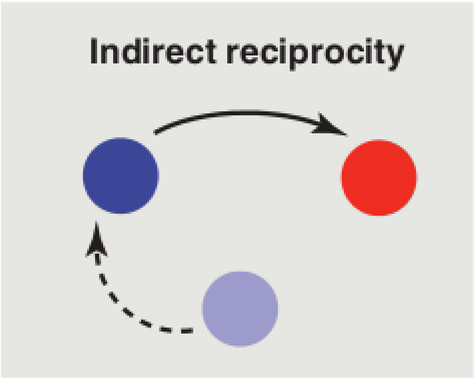
Indirect Reciprocity

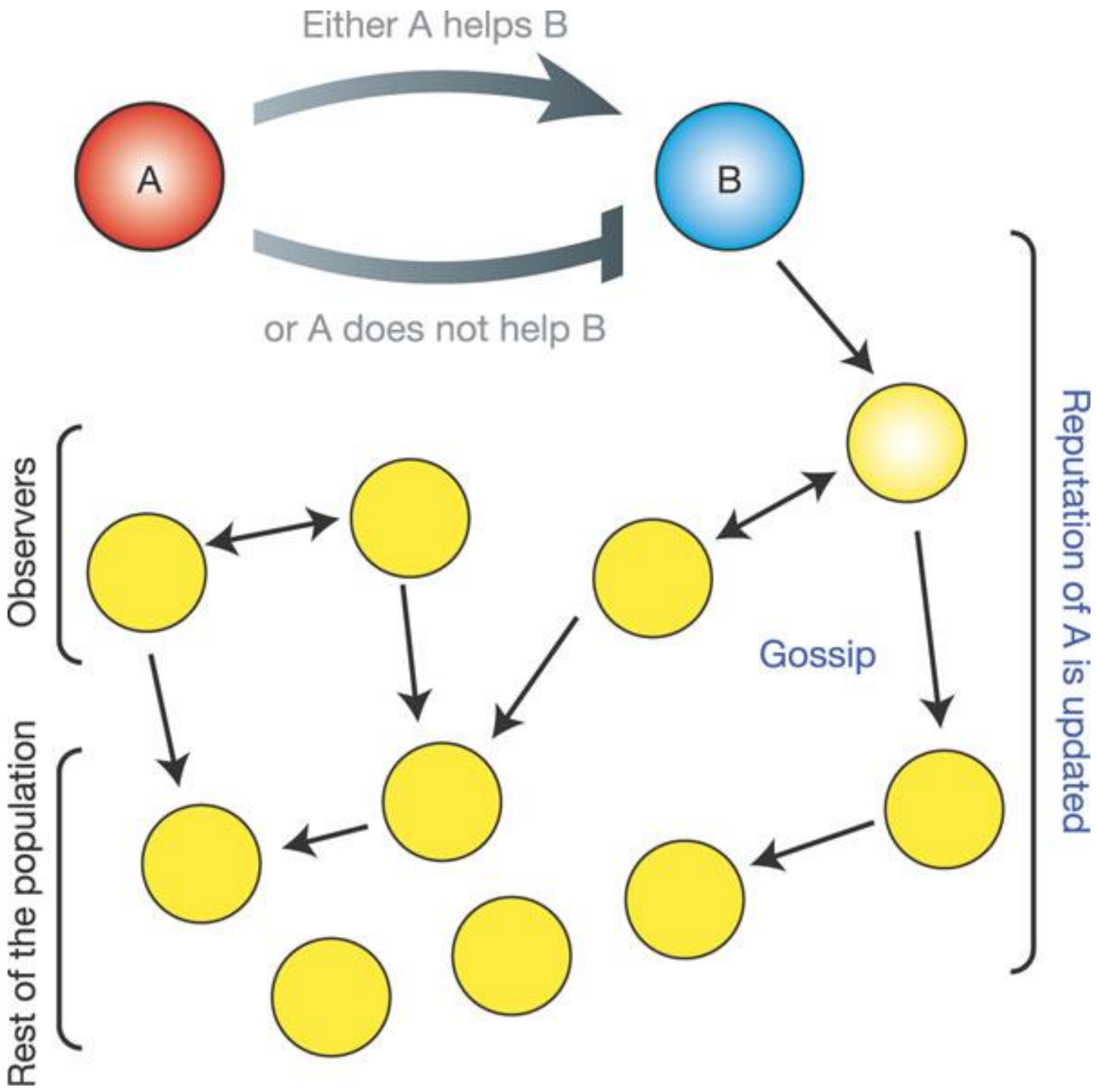
- People help those who have helped others.
- People refuse to help those who have refused to help others.
- Helpful people have a higher payoff in the end.
- ‘give and you shall receive’
- **Reputation** makes it possible



Indirect Reciprocity

- Gossip spreads reputation
- People help those who help others

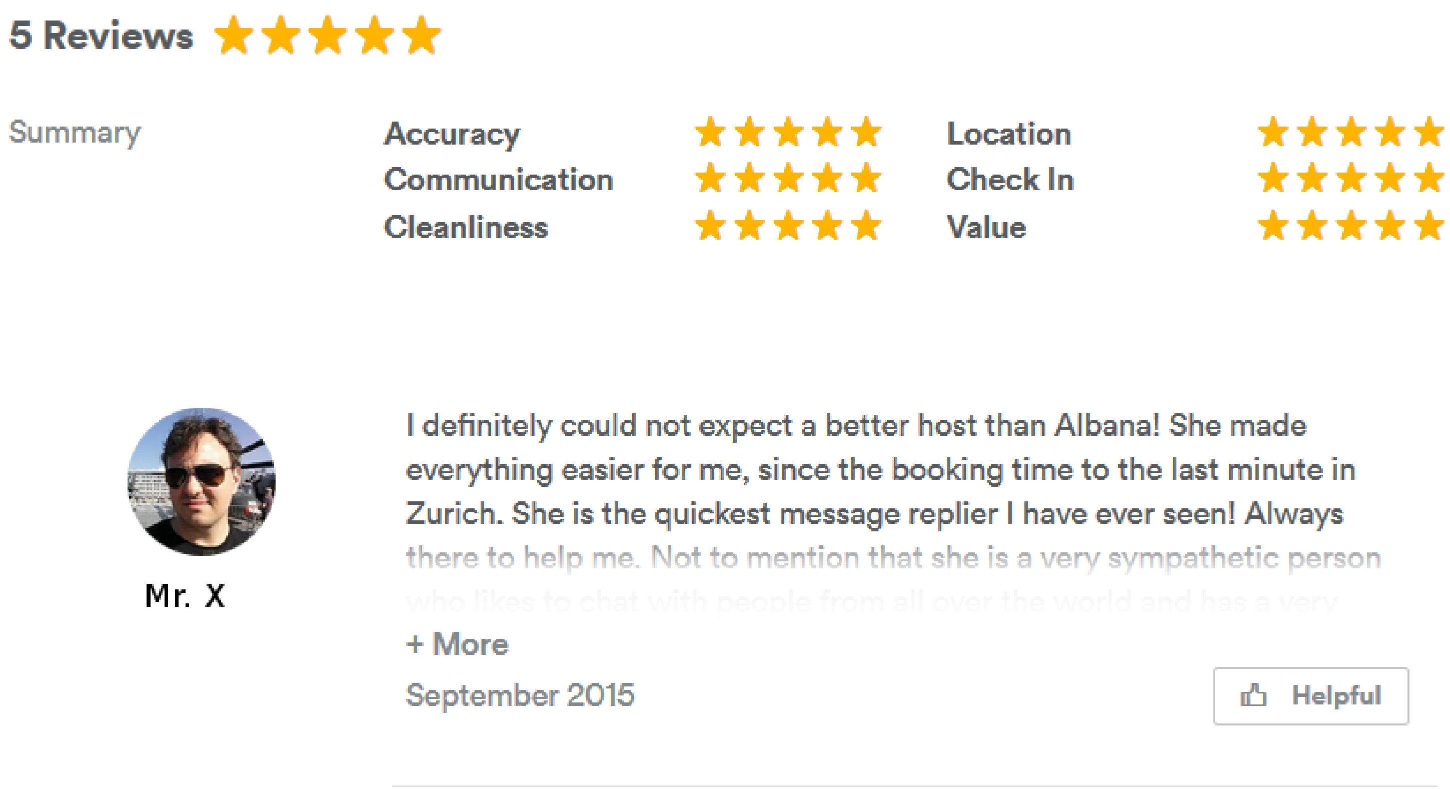




Indirect Reciprocity

- Indirect reciprocity is **cognitively demanding**: agents need to monitor their social network
  - evolution of social intelligence
- Individuals must be able to talk to each other (e.g., about reputation)
  - evolution of human language
- For direct reciprocity you need a face. For indirect reciprocity you need a name. Or… ?

Reputation Systems

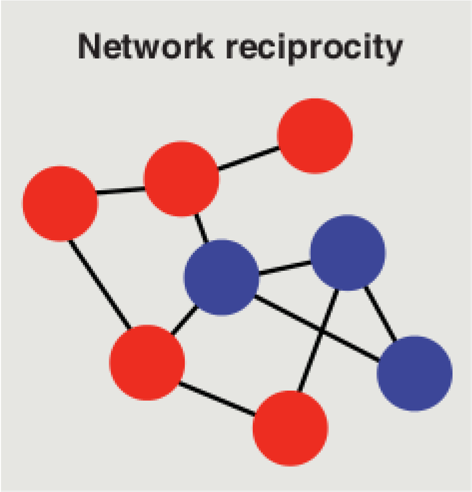


A Rule for Indirect Reciprocity

- $q > c / b$
  - q: probability to know someone’s reputation
  - c: cost of cooperation
  - b: benefit of cooperation

Network (or spatial) Selection

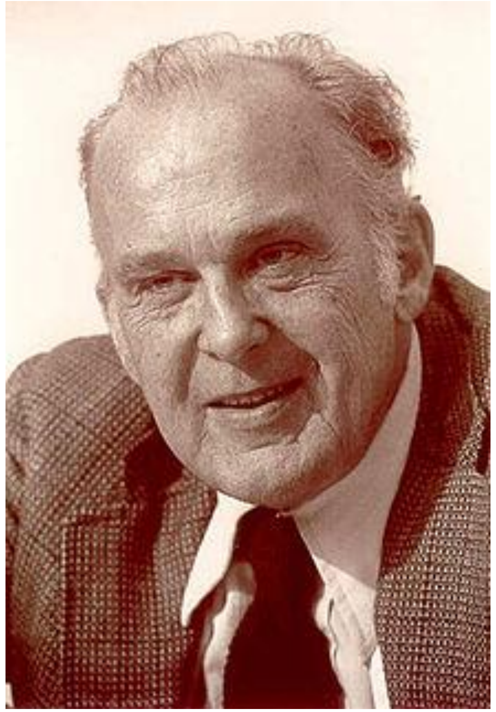
- Cooperators pay a cost **c** for each neighbor to receive benefit **b**
- **Graph selection favors cooperation if b/c>k, where k is the average number of neighbors**



Nowak and May (1992),"Evolutionary games and spatial chaos." Nature

Group Selection

How can one explain the pervasive human willingness "to fight and die for the in-group ...which makes lethal war possible?" (Campbell,1965,p . 293)



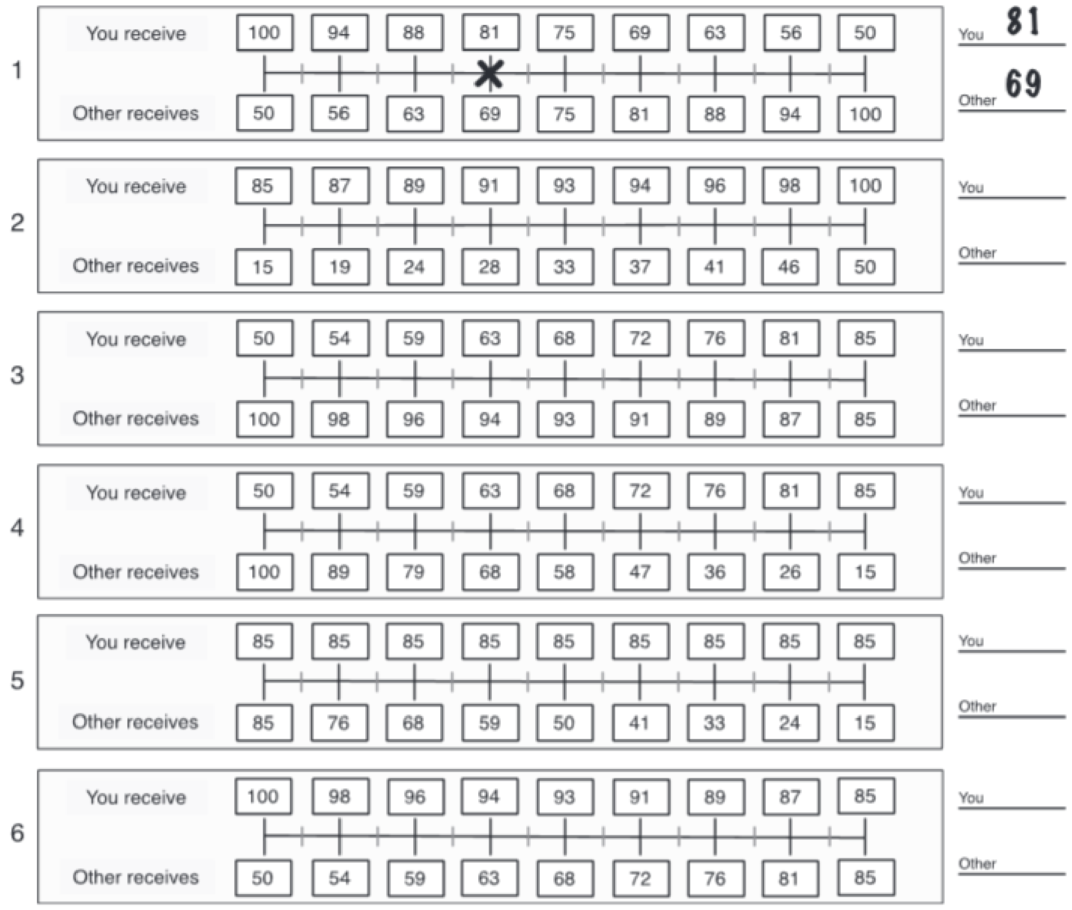
Group Selection

- **Intergroup Prisoner's Dilemma (IPD)** (Bornstein 1992, 2003)
  - 2 groups of 3 players, 10 tokens per player
  - Player keeps the token -> 2MU (monetary unit)
  - Player invest the token in group -> +1MU per group member, -1MU from other group
- Dominant individual strategy: ? *contribute nothing!*
- Dominant group strategy: ? *contribute fully!*
- **Result:** ? *contribution levels ~35%*

Conditional Cooperators

- Many participants of laboratory experiments are **“conditional cooperators”** (Chaudhuri 2009)
- Contributions are positively correlated with the beliefs about the *average group contribution*
- Conditional cooperators usually start with an high level of contributions and decline as they update their beliefs due to being matched with defectors
- ***“Homo reciprocans”***

Behavioral Traits: Social Value Orientation (SVO)



Murphy and Ackermann (2013)

You:	85	85	85	85	85	85	85	85	85
Other:	85	76	68	59	50	41	33	24	15

You:	85	87	89	91	93	94	96	98	100
Other:	15	19	24	28	33	37	41	46	50

You:	50	54	59	63	68	72	76	81	85
Other:	100	98	96	94	93	91	89	87	85

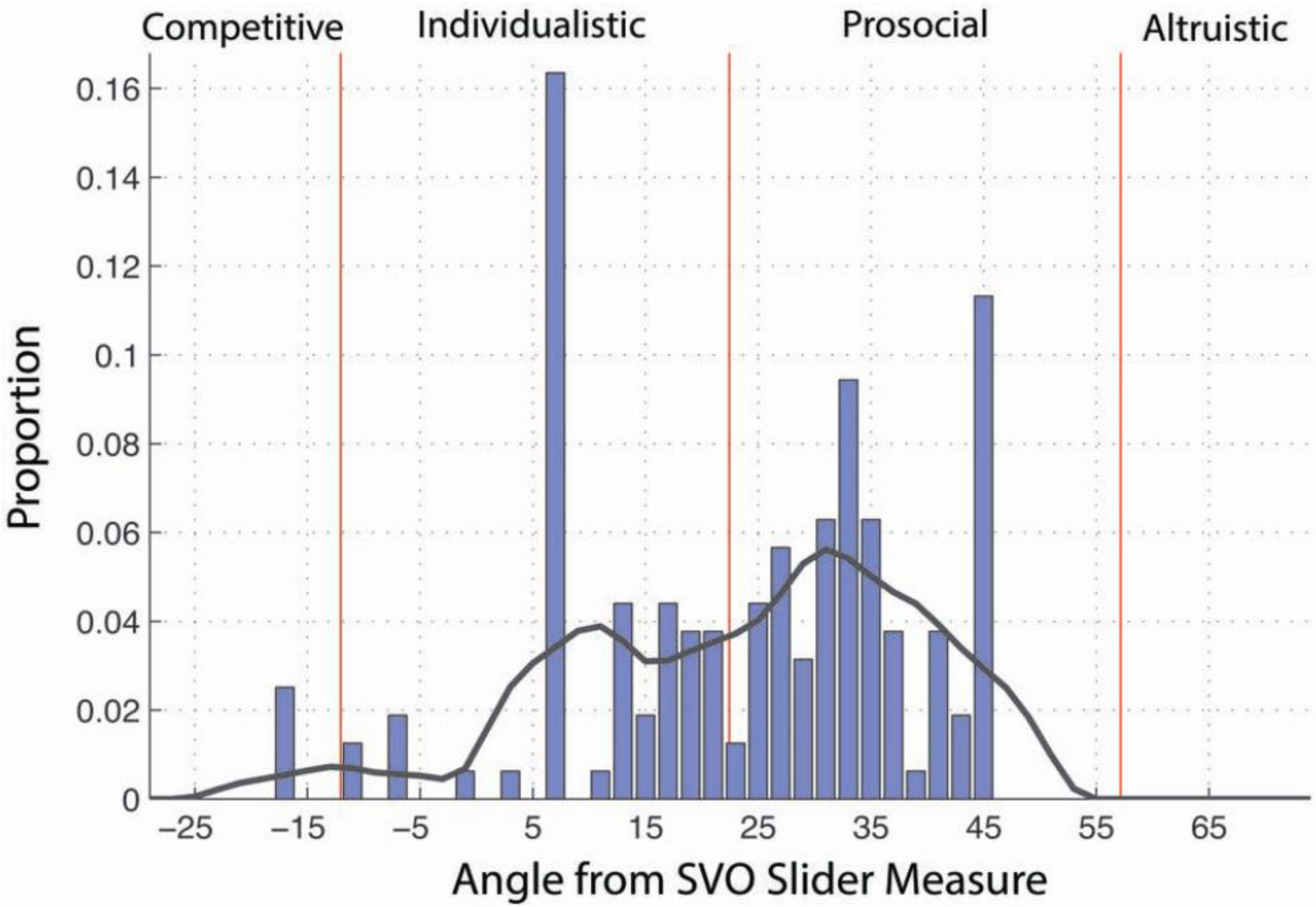
You:	50	54	59	63	68	72	76	81	85
Other:	100	89	79	68	58	47	36	26	15

You:	100	94	88	81	75	69	63	56	50
Other:	50	56	63	69	75	81	88	94	100

You:	100	98	96	94	93	91	89	87	85
Other:	50	54	59	63	68	72	76	81	85

nodeGame SVOGauge Widget

Distribution of Behavioral Traits (SVO)



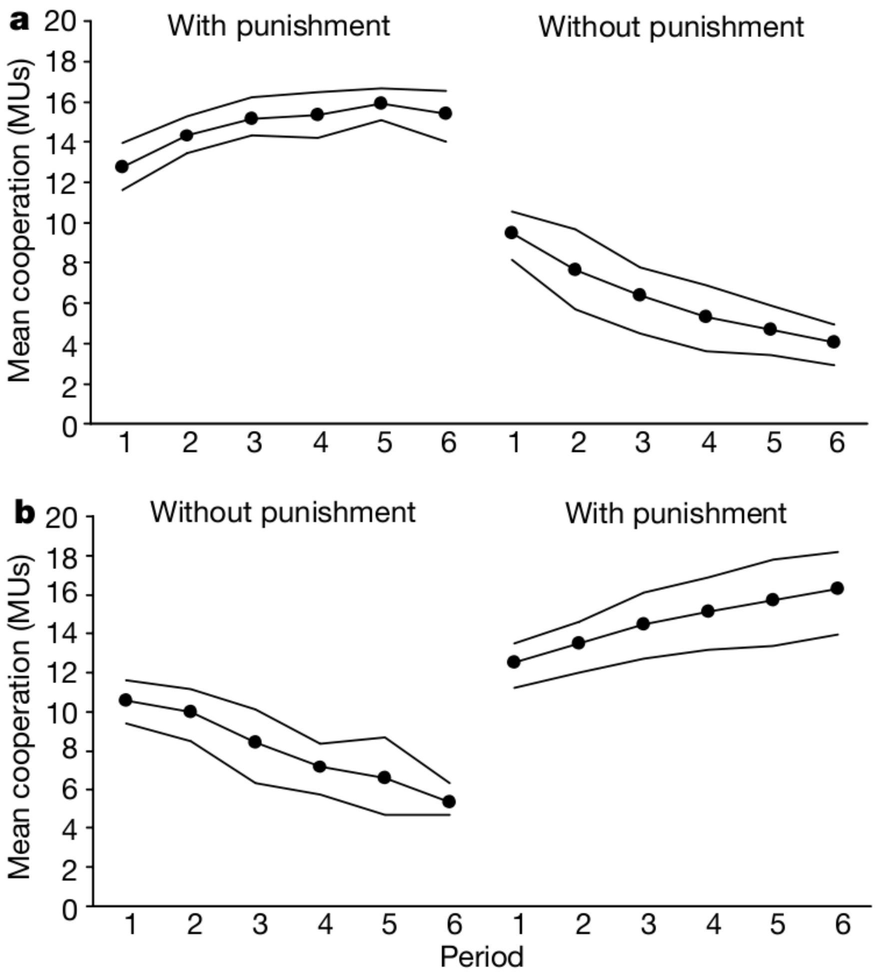
Murphy and Ackermann (2013)

Punishment Can Improve Cooperation

- Punishment provide a material benefit for future interaction partners of the punished one but not for the punisher

- The punisher bears a cost, and provides a benefit to *other members* of the population by inducing potential non-cooperators to cooperation

- For this reason, the act of punishment is an **altruistic act.** *Or is it?*

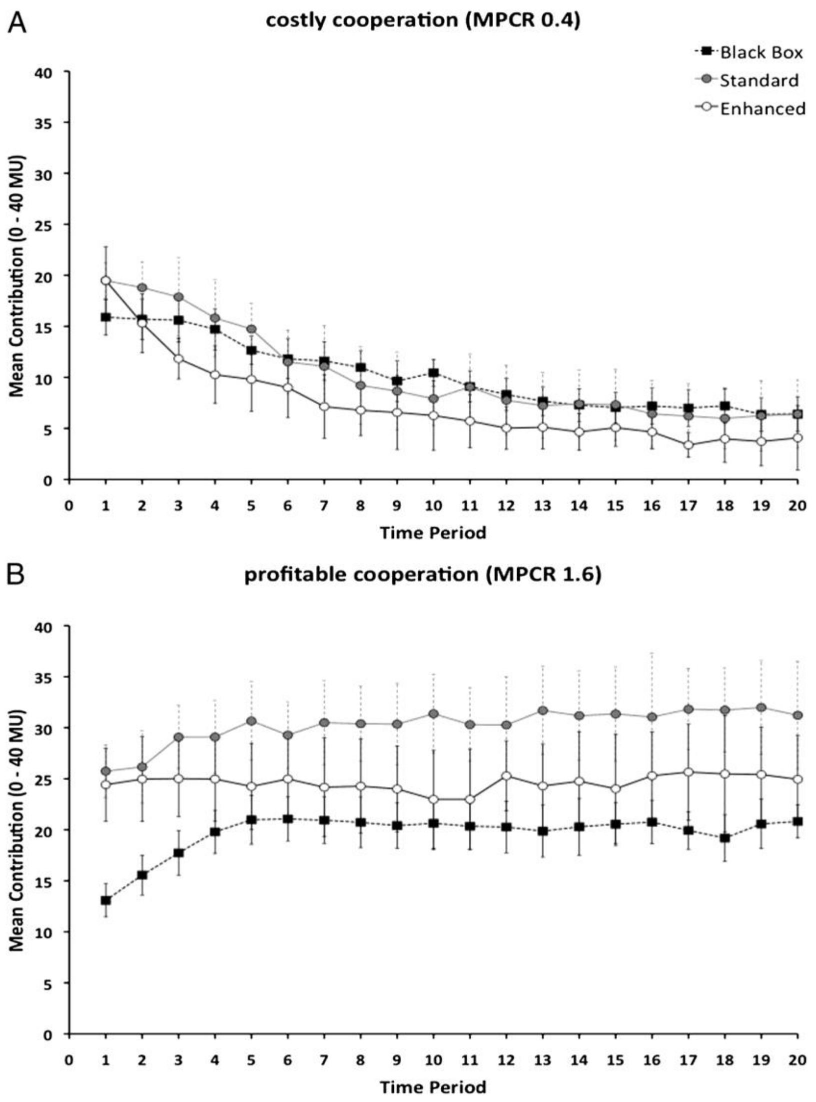


Fehr and Gaechter (2002)

The Black Box

- Humans have “*prosocial preferences*” that lead to higher levels of cooperation (e.g. altruistic punishment)

- However, experimental results show that humans cooperate at similar levels even when they have no knowledge of the game dynamics (how their behavior benefits others)



Burton-Chellew and West (2013)

Peer Punishment

"We're from the Neighborhood Watch committee. We've heard you're wearing a fake Rolex."

Leo Cullum, The New Yorker, February 23, 1998.

Pool Punishment

Punishment is a "leaky bucket"

- Mechanisms as punishment tend to be “leaky buckets” (Okun, 1975)
- Some of the efficiency gains generated by the increase in contributions are spent in order to uphold them (e.g., on punishment costs).
- An alternative mechanism is: **meritocratic matching** (Nax, Balietti, Murphy, and Helbing, 2018) or “group-based meritocratic mechanism” (Gunnthorsdottir et al., 2010)

Meritocracy

- **Definition:** "rule by those with merit / rule rewarding merit"
  - old concept with a surprisingly new name (Young 1958),
  - present in early modern societies including China, Greece, Rome,
  - examples include selection of officials/ councilmen, military reward/ promotion schemes and access to education,
  - proposed by thinkers such as Confucius, Aristotle and Plato.
- **Criticism:** "inequality-efficiency trade-off"
  - "The pursuit of efficiency necessarily creates inequalities. And hence society faces a tradeoff between equality and efficiency." (Okun 1975)
  - Identified also in the book by Arrow, Bowles and Durlauf (2000).

Standard Public-Goods Game

P1	12
P2	3
P3	5
P4	8
P5	20
P6	16
P7	1
P8	4

Standard Public-Goods Game

P1	12
P2	3
P3	5
P4	8
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P6	16
P7	1
P8	4

Standard Public-Goods Game

Payoff Computation:

Amount player kept for him/her ✚ Return from Group Account

$$B - C_i \qquad m * \sum_{k=0}^{n} C_k$$

P5	20
P6	16
P1	12
P4	8
P3	5
P8	4
P2	3
P7	1

Standard Public-Goods Game

- The least a player contributes, the higher his/her payoff.
- We have "**zero meritocracy**."

17.2	P5	20
19.2	P6	16
20.2	P1	12
21.2	P4	8
24.7	P3	5
25.2	P8	4
25.7	P2	3
26.7	P7	1

Standard Public-Goods Game

- The only Nash equilibrium possible is *complete free-riding*.
- Full free-riding has *minimum efficiency*, but at the same time *maximum equality*.

0	P5	20
0	P6	16
0	P1	12
0	P4	8
0	P3	5
0	P8	4
0	P2	3
0	P7	1

Standard Assortative Public Goods Game

Group 1

Avg. Contribution: 14

Group Return: **26.5**

26.5	P5	20
30.5	P6	16
32.5	P1	12
38.5	P4	8

Group 2

Avg. Contribution: 3.25

Group Return: **6.5**

21.5	P3	5
22.5	P8	4
23.5	P2	3
25.5	P7	1

Standard Assortative Public Goods Game

- A new near-efficient equilibrium emerges where the vast majority of players fully contributes and a small minority free-rides. (Gunnthorsdottir et al. 2010)

26.5	P5	20
30.5	P6	16
32.5	P1	12
38.5	P4	8

21.5	P3	5
22.5	P8	4
23.5	P2	3
25.5	P7	1

Standard Assortative Public Goods Game

- This setup is also **“meritocratic”** because those who contribute more receive more on average from the group account.

26.5	P5	20
30.5	P6	16
32.5	P1	12
38.5	P4	8

21.5	P3	5
22.5	P8	4
23.5	P2	3
25.5	P7	1

Noisy Assortative Public Goods Game

- Now we add Gaussian noise (*0,V*) to all contributions in order to create an **"imperfect meritocracy."**

P5	20
P6	16
P1	12
P4	8

P3	5
P8	4
P2	3
P7	1

Noisy Assortative Public Goods Game

Group 1
Avg. Contribution: 11
Group Return: **22**

22	P5	20
38	P8	4
30	P1	12
32	P4	8

Group 2
Avg. Contribution: 6.25
Group Return: **12.5**

27.5	P3	5
16.5	P6	16
29.5	P2	3
31.5	P7	1

Noisy Assortative Public Goods Game

Group 1

Avg. Contribution: 8.5

Group Return: **17**

17	P5	20
33	P8	4
25	P1	12
29	P4	8

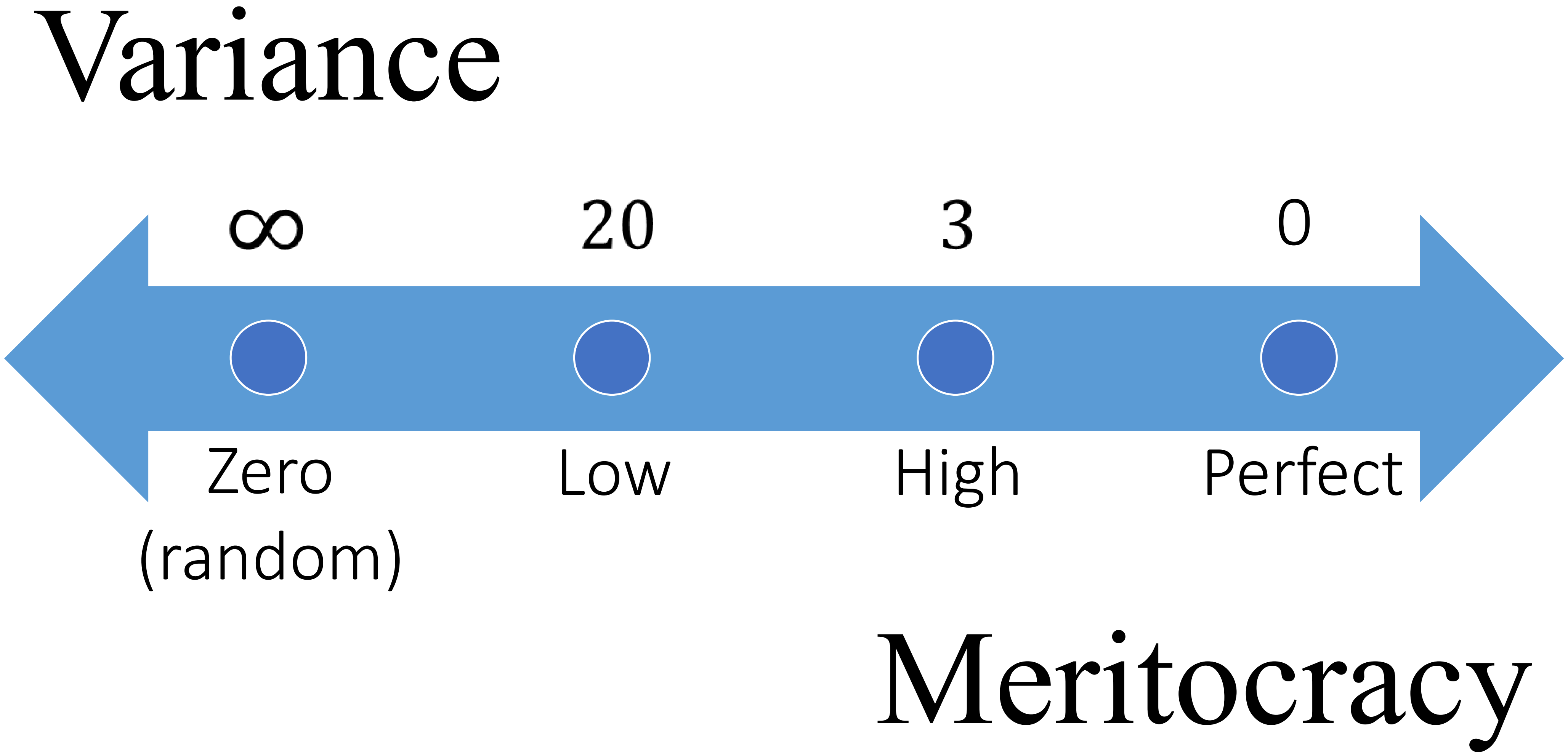
Group 2

Avg. Contribution: 8.75

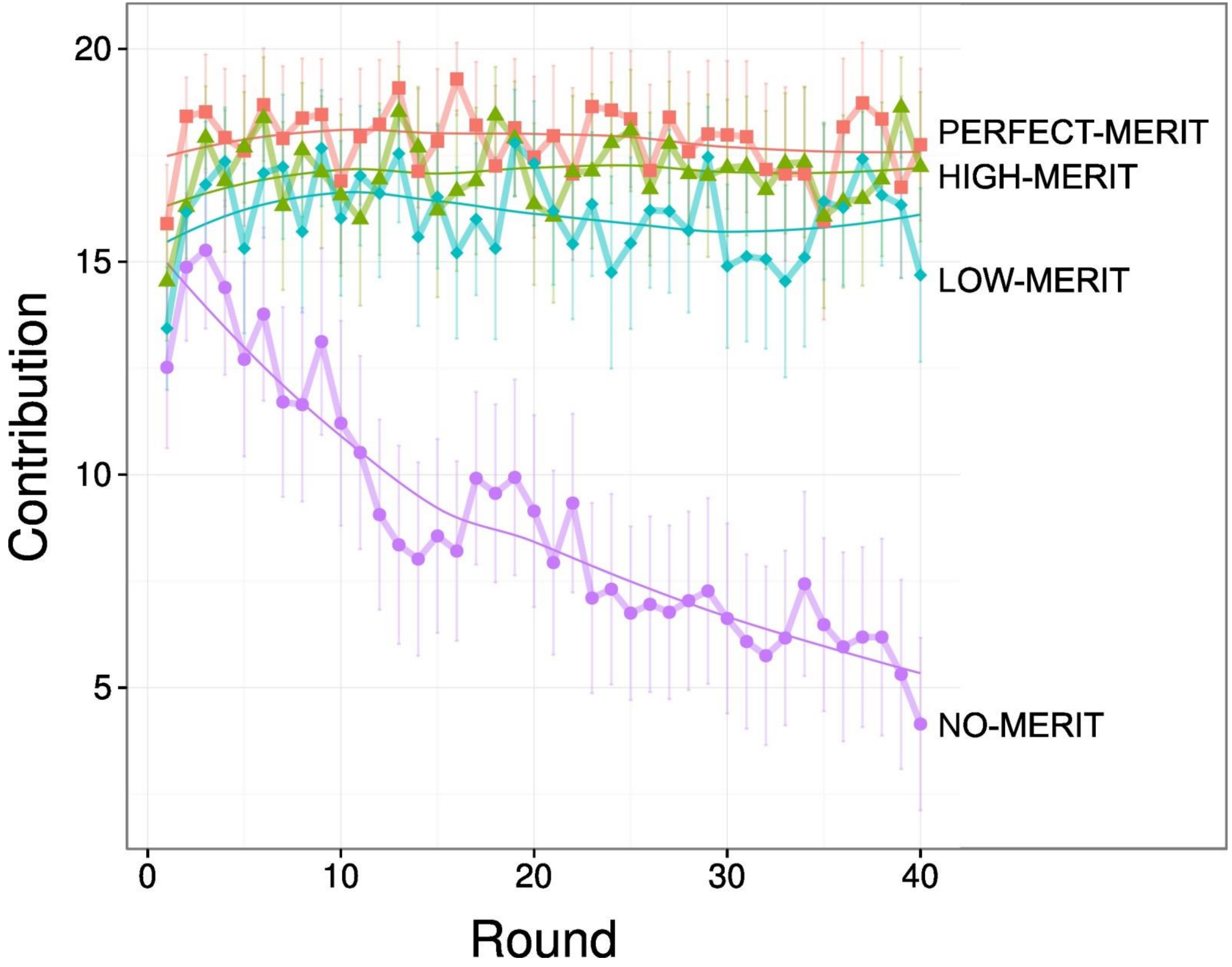
Group Return: **17.5**

21.5	P3	5
22.5	P6	16
23.5	P2	3
25.5	P7	1

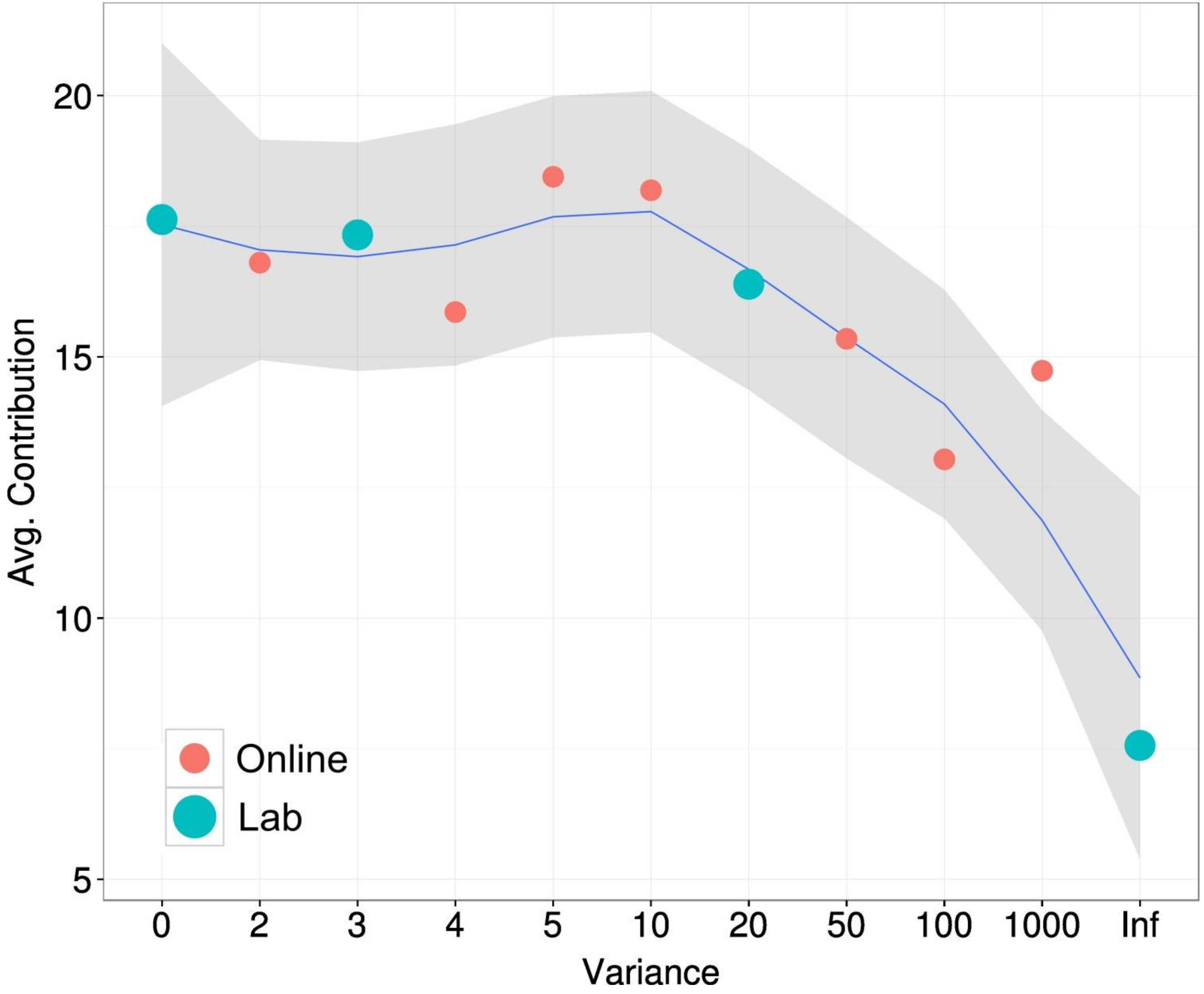
Variance Levels and Meritocracy



Meritocracy sustains high contributions



Contributions Online and in the Lab



Meritocratic Fairness

Definition:

Agent *A* considers the outcome of the game "unfair" if another agent *B* contributed less than *A*, but *B* was placed in a better group.

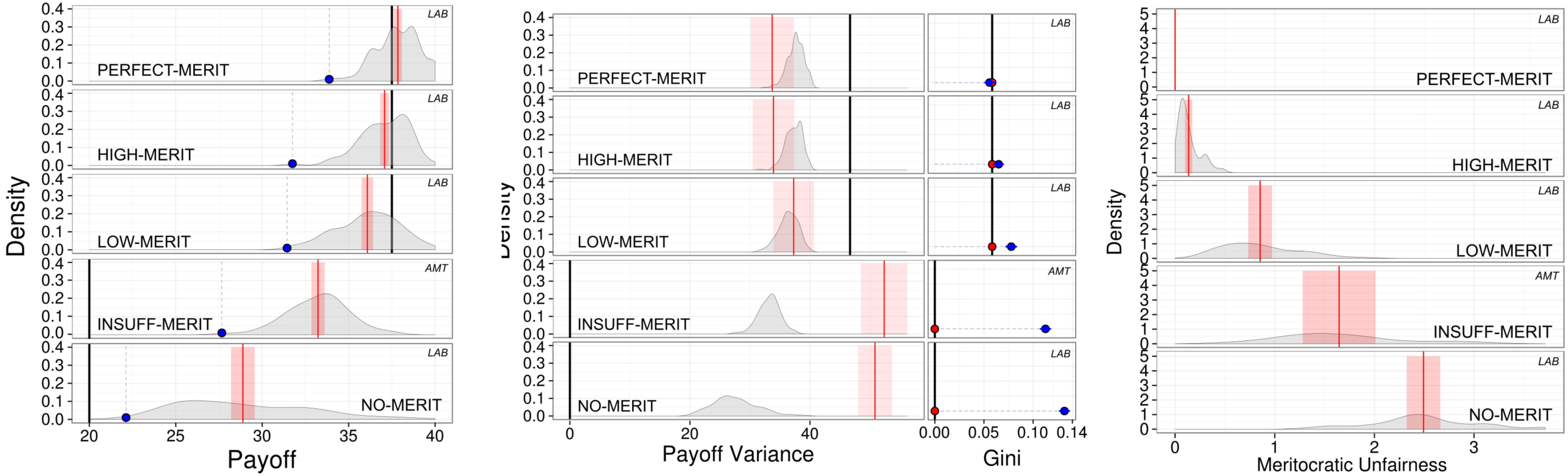
$$\underbrace{\frac{1}{n-4}\sum_{j\in N}\max(\Delta_{ij},0)*\max(\Delta_{G_jG_i},0),}_{\text{disadvantageous unfairness}}\quad \underbrace{\frac{1}{n-4}\sum_{j\in N}\max(\Delta_{ji},0)*\max(\Delta_{G_iG_j},0)}_{\text{advantageous unfairness}}$$

leads to contribution decrease

leads to contribution increase

Extends (Fehr & Schmidt 1999) and (Ockenfels & Bolton 2000).

Equality Increases with Meritocracy



Lower level of noise in meritocratic matching leads to both higher efficiency (payoff) and higher equality (less payoff variance, lower GINI, and higher payoff for the worst-off). Accordingly, meritocratic unfairness scales with the level of matching noise.

black solid lines: theoretical prediction
red solid lines: average empirical level
red-shaded areas: 95% CI mean
blue dots: payoff worst off

Check Point

- Think about the game played at the beginning of the lecture
- Why cooperation (in)decreased over rounds?
- Which mechanisms were involved? How could they be improved?
- What emotions did it cause you?

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Learning:

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- https://github.com/Sandermatt/ETHAxelrodNoise

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Kinship:

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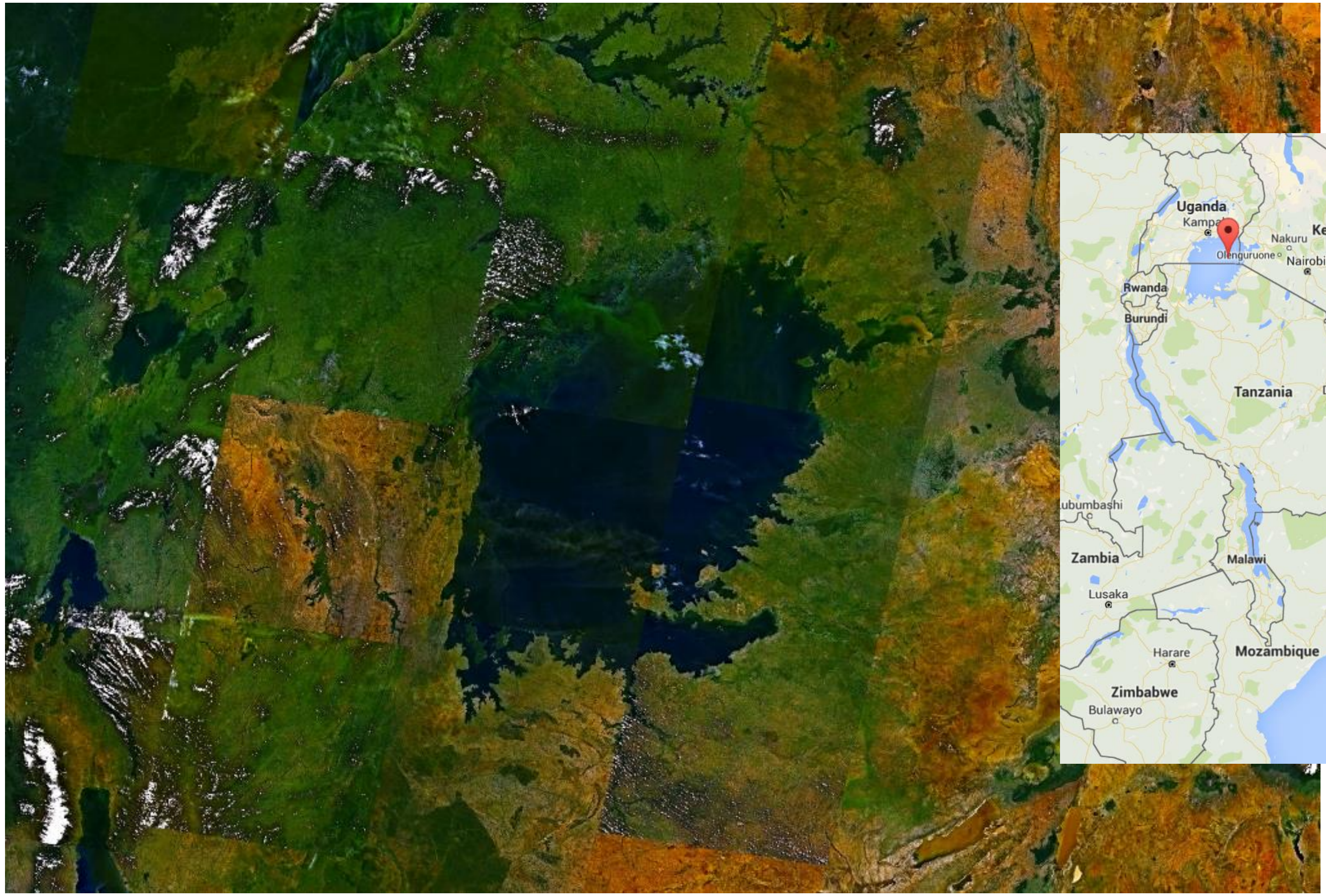
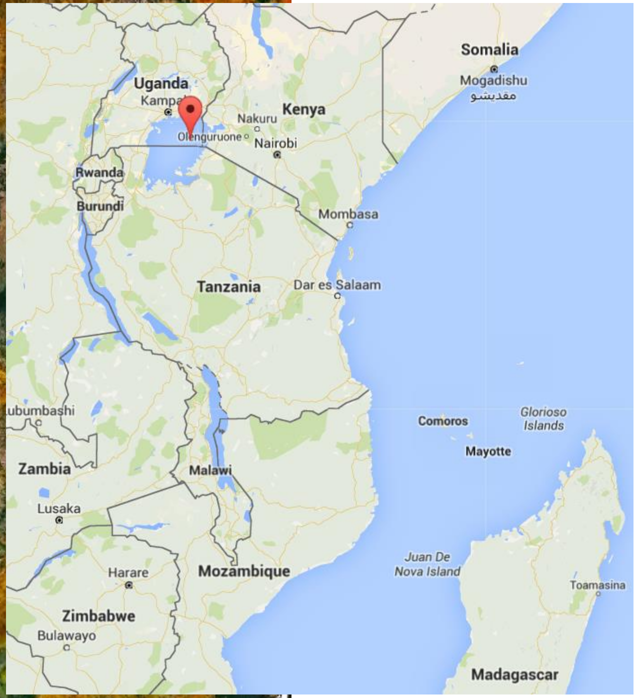
Darwin's Nightmare





Lake Victoria, East Africa

Darwin's Nightmare (2004)

- The *Nile perch* was introduced to Lake Victoria in the 1950s
- Since then it has caused the *extinction* or near-extinction of several hundreds of native species
- It has also created *economic development* due to a booming number of industrial fisheries which can employ up to one thousand people
- Story featured in Darwin’s Nightmare documentary (2004)