

# EXPERIMENTAL GAME THEORY

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# A brief overview over Experimental GT: our goals for today

- A focus on human behavior in strategic interactions
- Provide an overview over the different approaches of Experimental GT
- Talk about the case of “Voluntary Contributions Games” and other laboratory fruit flies
- Spend some time on “Learning in Games”
- See also Andreas Diekmann’s course *Experimentelle Spieltheorie* (FS/HS)

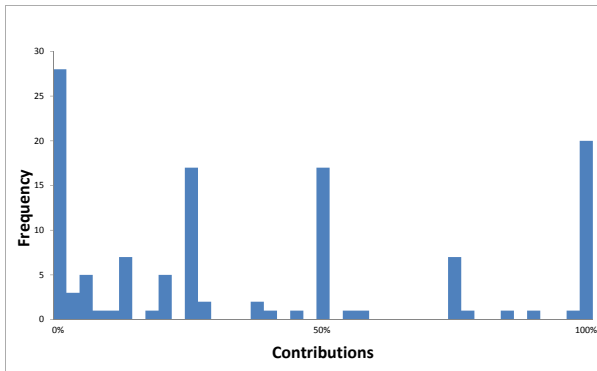
# Voluntary Contributions Game: let's play!

## Rules:

- ① **Players:** All of you: <https://scienceexperiment.online/vcg/vote>
- ② **Voluntary contributions:** Choose a contribution  $c_i$  between 0 and 20. Whatever you do not contribute is yours automatically.
- ③ **Outcome:** The total *public good* created will be  $PG = 3 \times \sum_{i \in N} c_i$ .
- ④ Each of you will enjoy an equal share of the public good:  
$$S_i = PG/n = \frac{3}{n} \sum_{i \in N} c_i.$$
- ⑤ **Payoffs:** So you will earn a total of  $20 - c_i + S_i$ .
- ⑥ I will pay one randomly selected person in CHF (dividing payoffs by 10).



Check out our lab for **<https://www.descil.ethz.ch/>** more details about how we run these experiments!



This is what subjects typically do in such a game when they play it for the first time (from Nax et al., JEBO 2016).

How can we describe human behavior in strategic interactions?

# Some historical background: Experiments in Economics

## Experiments on decision problems/risk/1-player games:

Allais 1953, Ellsberg 1961, Ainslie 1975, Kahneman and Tversky 1979: experiments that challenge the axioms of standard decision theory and with it the notion of man as a “perfectly rational” expected utility maximizer (Ramsey 1931, von Neumann and Morgenstern 1944, Savage 1954)

Recall Lecture 3 on utilities: The clean “theory of expected utility maximization” (Ramsey-Savage-von Neumann) contradicted by simple experiments such as those by Allais/ Ellsberg/ Kahneman-Tversky lead to **Behavioral Economics!**

# Background: Experiments in Biology

## Experiments on animal behavior:

Thorndike 1898, Morgan 1903, Pavlov 1927, Thorpe 1956: classic experiments that reveal that the “law of effect”, i.e. a consequentialist view of trial and error, explains animal behavior (later formalized as “radical behaviorism”/“reinforcement learning” Skinner 1974, Hoppe 1931, Estes 1950, Bush and Mosteller 1955, Heckhausen 1955, Herrnstein 1961, Roth and Erev 1995, Erev and Roth 1998)

Follow the path of success/ avoid the path of failure.



# Homo oeconomicus: “perfect rationality strawman”

## *Perfect rationality*

- **common knowledge:** about the structure of the game, about the structure of payoffs
- **common beliefs:** players have beliefs about each others' behavior, and these beliefs are correct
- **optimization:** individual behavior is governed/ described by optimization/ maximization in terms of expected utilities

## *Pure self-interest*

- **narrow self interest:** agent cares about own material payoff only
- no concern for other players' payoffs
- no consideration of the effects of his actions on upholding higher-order norms or similar
- decisions are not subject to social influence

# Perhaps more **realistic** environments

## *Knowledge and information*

- the game structure is often unknown, or at least large parts of it
- players may not be able to observe information about relevant players' in the game, may sometimes not know they even exist
- a player may know little about others' utility functions, about how he affects them and how they affect him
- i.e. the information content may be too low for the neoclassical assumptions to make sense

## *Behavior and motivations*

- instead of optimizing behavior, players may follow behavioral heuristics
- players may learn about the game and which strategies to play as the game goes on
- instead of narrow self interest, an agent may also care about others' payoffs and/ or the distribution of payoffs
- agents may follow social norms, and may be subject to explicit or implicit social influence

# Today's focus is on human behavior in 2 games: Drosophila

## *Ultimatum game*

- one side **proposer** moves first: makes a proposal as to how to split a cake
- the other side **recipient** responds: either accepts the offer so that it will be realized, or destroys the cake (both get zero)
- **Nash equilibria:** any proposal made, responder accepts
- **Subgame perfection:** proposer takes all, accept nevertheless

## *Public goods game*

- the game we just played
- contributions are socially valuable (increase total payoffs as  $R > 1$ )
- but each individual has an incentive to withhold his own contribution (free-ride as  $R/n < 1$ )
- **Nash equilibrium:** universal non-contribution

# What is studied with these games?

## Ultimatum game

- introduced to model negotiations by Gueth et al. (1982), Binmore et al. (1985) and Gueth and Tietz (1987), Ochs and Roth (1989)
- A: Nash equilibrium (responder should always accept)
- B: Subgame perfection (proposer gives nothing)
- C: Reputation models (Kreps and Wilson 1982) in case of repetition
- D: Social preferences such as fairness, pro-sociality, spitefulness

## Public goods game

- introduced to model social dilemma situations by Bohm (1972, 1983), Dawes (1980), Isaac et al. (1985), Isaac and Walker (1988), Andreoni (1988)
- A: Nash equilibrium
- D: Social preferences such as fairness, pro-sociality, conditional cooperation, reciprocity
- E: Mechanisms such as punishment, rewards, etc.

We can think of different **information settings** for these experiments

### Ultimatum game

- **high information:** players know the structure of the game, know their own position in the game, know the payoff structure, the game is anonymous
  - proposer: moves first, knows who the responder is / how he is selected
  - responder: moves second, observes the offer

### Public goods game

- **high information:** players know the structure of the game, know their own position in the game, know the payoff structure, the game is anonymous
  - players decide how much to contribute
  - learn about others' decisions of past rounds as the game goes on

# or less information

## Ultimatum game

- **low information:** players do not know the payoff structure of the game, do not observe others' actions, learn only about payoffs as they realize
  - proposer: moves first picking a number between zero and everything, knows nothing about the nature of his "proposal"
  - responder: selects either option A ("accept") or option B ("reject") without knowing their significance

## Public goods game

- **low information:** players do not know the payoff structure of the game, do not observe others' actions, learn only about payoffs as they realize
  - players decide how much to enter into a "black box"
  - players learn about the payoff consequences of their own actions only, receive no information about others

# Motivation for experimental game theory:

A large body of economic theory presumes rather extreme behaviors in terms of

- rationality
- optimization
- strategizing

**What do real humans do?**

# Experiments

The “clean” equilibrium predictions based on the theories of von Neumann-Nash contradicted by simple experiments such as the ones we will talk about today (Ultimatum Games/ Voluntary Contribution Games). These experiments lead to **Experimental/Behavioral Game Theory**. (Zurich being one of ‘the’ places in the world where this line of research is pursued.)



# Recall our two games

## **Ultimatum Game:**

- One player offers a share of a pie, then the other accepts or rejects.

## **Voluntary Contributions Game:**

- Players simultaneously decide how much to contribute to a joint effort that creates a public good.

# Game 1: Ultimatum Game

- Gueth et al. (1982), one-shot
- Rubinstein (1985), multiple rounds
- Review: “Thirty years of UG” (Gueth and Kocher 2013)

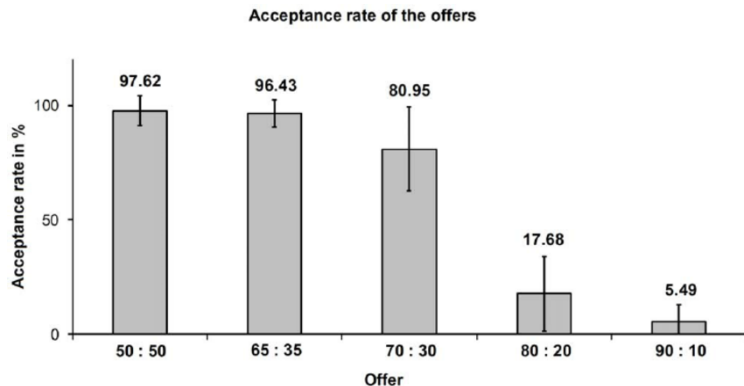
## THE GAME

- ① the proposer (player 1) suggests a split between him and the receiver (player 2)
  - ② Player 2 can either accept or reject:
    - ① If he accepts, the shares proposed by player 1 realize
    - ② If he rejects, both players receive nothing.
- **Nash equilibria:** any split supportable as a Nash equilibrium
  - **Unique subgame-perfect Nash equilibrium:** (1 all, 2 nothing)

# Testing the extreme SPNE prediction

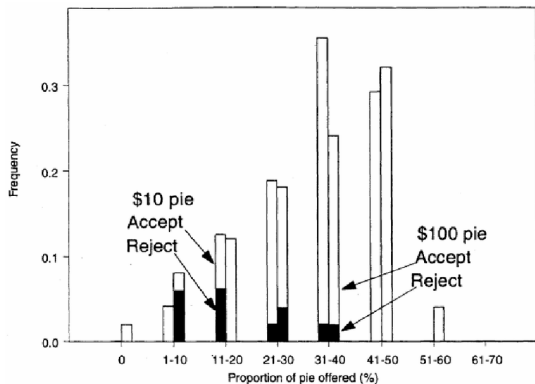
- The unique subgame-perfect Nash equilibrium is an extreme allocation
- Any rejection by the responder kills own and other's payoff
- Any positive proposal, presuming (rational) acceptance, seems like a gift;
- however, presuming (off the equilibrium-path) rejection of low offers, a substantial proposal may be strategically rational
- hence, it may be rational to have a **rejection reputation**
- Meta-analysis suggests
  - proposals of roughly 40%;
  - high rejection rates for proposals under 20%, intermediate rejection rates for proposals of 20%-40%, and almost zero rejection rates for proposals >40%
  - Over time, decline or no decline of proposals depending on experimental/matching protocol

# Acceptance rates



from Hollmann et al., PLoS ONE 2011

# Offers



from Hoffman et al., IJGT 1996

## Game 2: Voluntary Contributions Game

- Marwell and Ames (1979), one-shot
- Andreoni (1988): random (re-)matching
- **Review:** “Sustaining cooperation in laboratory public goods experiments” (Chaudhuri 2011) - older review by Ledyard (1995)

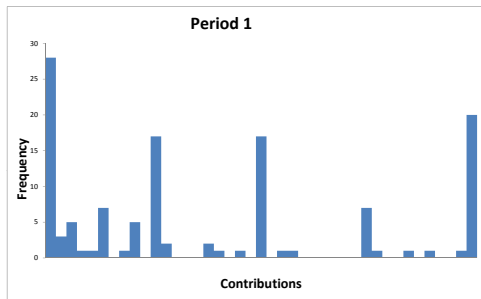
### THE GAME

- ① the game we played
$$\phi_i(c) = (B - c_i) + \sum_{j \in N} mpcr * c_j$$
- ② **Unique Nash equilibrium** if agents are selfish: all give nothing.

# Characteristics of the NE

- Again, the Nash equilibrium is an extreme allocation
- Lowest social welfare
- Pareto-dominated by social optimum
- Any positive contribution decreases own payoff but increases those of others and increases total welfare
- Meta-analysis suggests
  - average contributions of roughly 40%-50% when game is played once or in the first round when repeated;
  - when repeated (with random re-matching w/o any mechanism): over time, contributions roughly halve every 10-20 periods depending on matching protocol

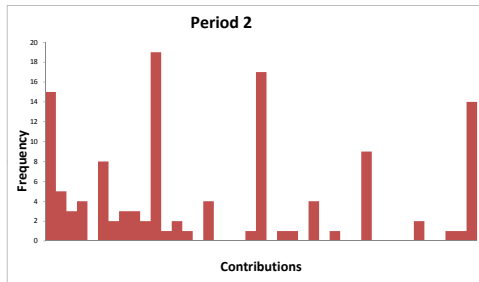
# Contributions 1



from Nax et al., JEBO 2016

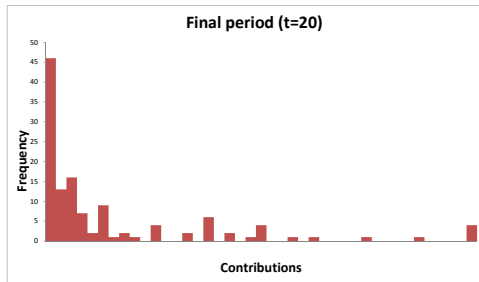


## Contributions 2



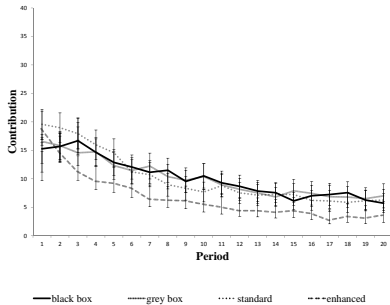
from Nax et al., JEBO 2016

# Contributions final



from Nax et al., JEBO 2016

# Contributions trend

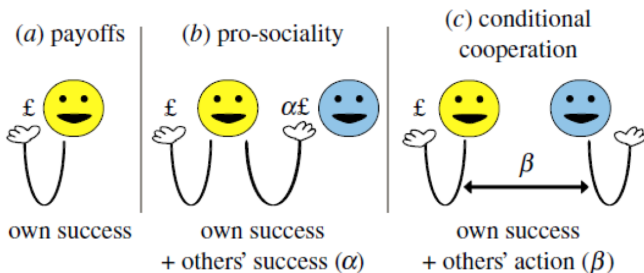


from Nax et al., JEBO 2016

# Interpretation 1: The ‘subjective utility correction project’

- The failure to play according to Nash equilibrium as predicted by pure self-interest is explained using alternative payoff functions that include social preferences and concerns for other players’ payoffs such as
  - Fairness considerations (Fehr-Schmidt)
  - Inequality/inequity aversion (Bolton-Ockenfels)
  - Altruism (Fehr-Gächter, Gintis-Bowles-Boyd-Fehr, Fehr-Fischbacher)
  - Reciprocity (Fischbacher-Gächter-Fehr)
- Note: This approach (by the Zurich school) mirrors the various “corrections” to utility functions motivated by ambiguity aversion, etc.

# Homo Oeconomicus and Friends

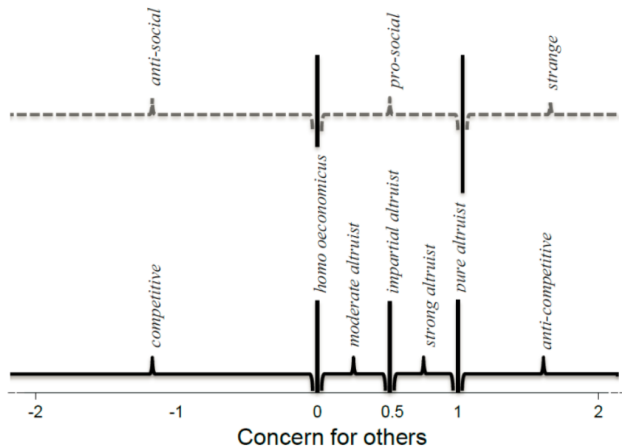


Rational choice theory assumes individuals to be fully rational and thus capable of expressing their preferences perfectly through the consequences of their actions (Becker 1976).

## What would someone according to the ‘subjective utility correction project’ do in the voluntary contributions game?

- In the one-shot game and in the final period of a repeated game, he would contribute zero.
- However, if his utility contains a concern for the other player, and is, for example, Cobb-Douglas of the form
$$u_i(c) = (\phi_i^{1-\alpha_i} * \phi_{-i}^{\alpha_i}),$$
- where  $\phi_{-i}^{\alpha}$  is the average payoff to players  $j \neq i$ , then...

...we have a range of social personas...

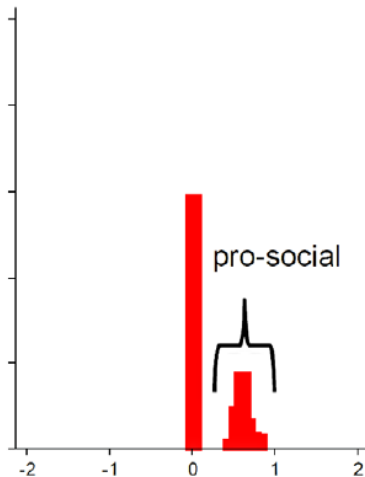


And positive contributions are evidence of concerns for others in this range:

- $(0,0.5)$   $\longrightarrow$  moderate altruist
- $0.5$   $\longrightarrow$  impartial altruist
- $(0.5,1)$   $\longrightarrow$  strong altruist
- $1$   $\longrightarrow$  pure altruist



...and in the final period we have...



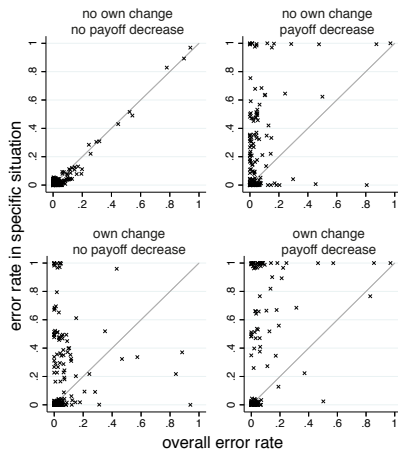
## Interpretation 2: Mistakes equilibrium

The failure to play according to Nash equilibrium as predicted by pure self-interest is explained by relaxing the rationality assumption. Examples of such models include

- “Noise”/ QRE (Palfrey-Prisbey)
- Intuitive versus contemplative players (Rubinstein)

According to such a model, positive contributions are evidence of “less” or bounded rationality.

# Deviations



Players best respond but deviate (Maes and Nax, JET 2016)

## Interpretation 3: Learning

The failure to play according to Nash equilibrium as predicted by pure self-interest is explained by adaptive processes of learning to play the game.

Examples of such models include

- Reinforcement learning (Roth-Erev)
- Directional learning (Selten)
- Perturbed best reply (Young)
- Belief-based learning (Fudenberg-Levine)
- EWA (Camerer-Ho)

# Is there a way to tell what is what?

- Can we distinguish between motivations?
- How much can we attribute to which explanation?

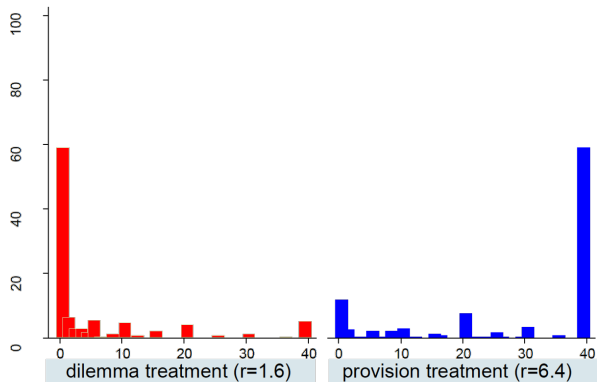
# Experiments: Set-Up

- Experiments were conducted @ CESS Nuffield of University of Oxford (involving 236 subjects in 16 sessions)
- In each session, 16 players played four of our games
- The *mpcr* was 0.4 or 1.6
- The budget was 40 coins each round
- Each game was repeated for 20 rounds
- Players received instructions containing different amounts of information about the game and sometimes (anonymous) feedback about previous-period play
- Play was incentivized with real money (e.g. one coin=0.01 CHF)

# Consistent deviations from homo oeconomicus?

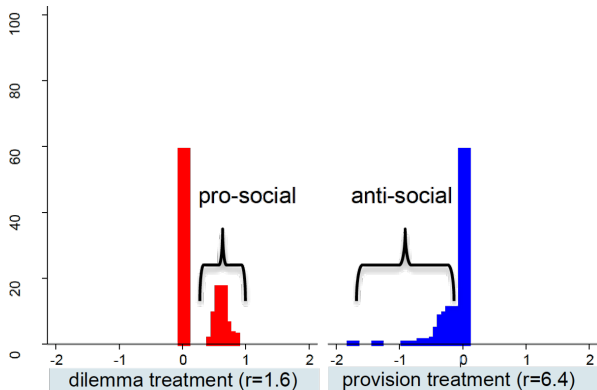
- By design of the experiment, games differed with respect to whether contributing zero was a strictly dominant strategy
- In half of the games, contributing everything was a strictly dominant HOE strategy (e.g. by setting the  $mpcr = 1.6 > 1$ )
- In half of the games, contributing nothing was a strictly dominant HOE strategy (e.g. by setting the  $mpcr = 0.4 < 1$ )

## Contributions (final round)

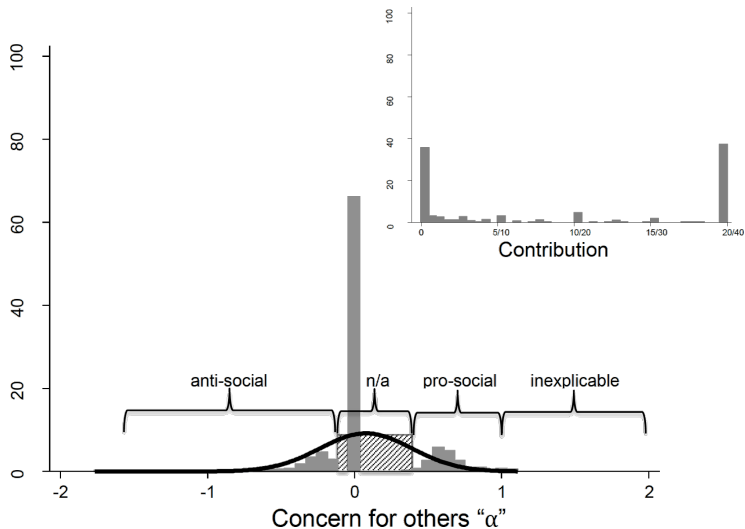




# Implied Preferences (final round)



# Combined Preferences



# Summary

In total, there therefore are

- 46.7% players consistent with homo oeconomicus.
- 15.4% are consistent and anti-social.
- 21.4% are consistent and pro-social.
- 16.5% are inconsistent, meaning pro-social in one and anti-social in the other — mistakes
- The median is neutral, the mean close to neutral.
- Note that inconsistent players in terms of social preferences may be consistent in terms of ‘erroneous play’

# Dynamics: the role of learning and conditional cooperation

- Games differed with respect to the amount of information about the structure of the game, and about other players' past actions and payoffs,
- allowing us to look into the question whether and how players react to what others do and how they learn from experience.

# Two types of information

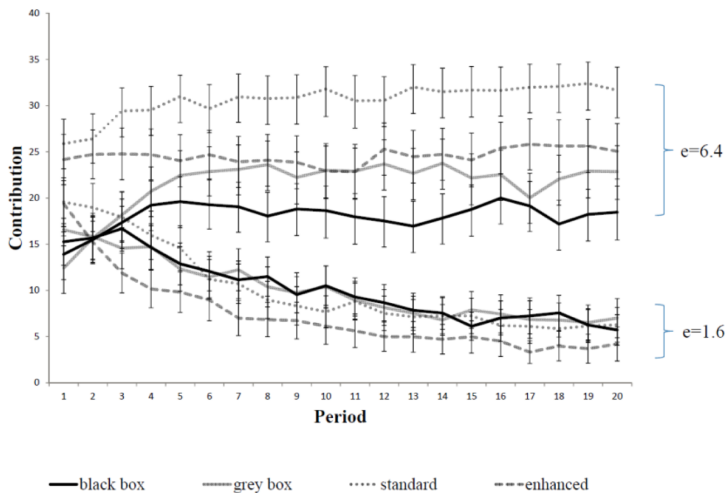
## **Black box**

- Players do not know the structure of the game
- Players learn nothing about other players' actions or payoffs
- Players know their own history of actions and payoffs only

## **Standard (enhanced)**

- Players know the structure of the game
- Players learn what others did in the past as the game is repeated
- (Players are explicitly told what payoffs others got)

# Patterns in different treatments



# Learning: a simple model

Suppose players initially make random contributions. Thereafter,

- they follow the direction of payoff increases
- they avoid the direction of payoff decreases

Notice such a learning rule is completely uncoupled (Foster and Young 2006) from information about others' actions and payoffs, relying only on own realized payoffs.

# Conditional cooperation

Suppose players contribute/free-ride if others do too (Fischbacher et al, EL 2001).

- the increase their contributions if others increase their contributions
- they decrease their contributions if others decrease their contributions

Notice such a learning rule is uncoupled (Hart and Mas-Colell 2003) from information about others' payoffs, relying only on own realized payoffs and others' actions.



## Evidence of conditional cooperation in standard treatment

	black box	standard	enhanced
payoff-based learning	✓ 0.30*	✓ 0.25*	✓ 0.14*
pro-social learning <sup>a</sup>	✗ −0.13*	✗ −0.23*	✗ −0.29*
conditional cooperation <sup>a</sup>	n.s. 0.05	✓ 0.21*	n.s. −0.001

\*significance < 0.001.

<sup>a</sup>Controlling for payoff-based learning.

# A richer Black box learning model

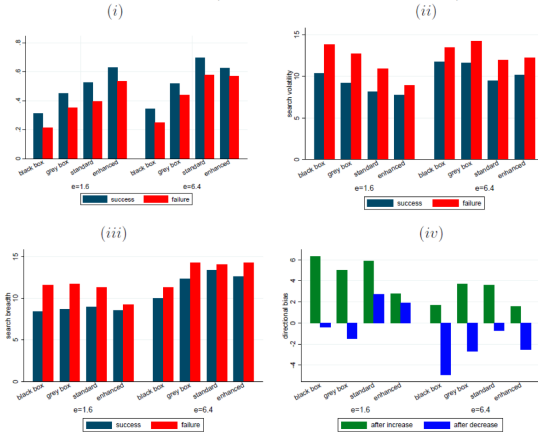
Suppose players initially make random contributions. Thereafter, adjustments follow four regularities:

- ① **Asymmetric inertia:** stay with your current strategy more often after success than after failure
- ② **Search volatility:** search for new strategies more randomly after failure than after success
- ③ **Search breadth:** search for new strategies further away after failure than after success
- ④ **Directional bias:** follow the direction of payoff increases, and avoid the direction of payoff decreases

Does this remind you of something?



Figure 7: SEARCH (all treatments, both rates of return).



The bar charts summarize the four search components in all treatments for both rates of return separately. The respective panels are: (i) inertia, (ii) search volatility, (iii) search breadth, (iv) directional bias. For (ii) – (iv), the y-axis are units of contributions; for (i), the y-axis are probabilities.

# Summary: theoretical game theory versus reality

Mainstream game theory relies on rather extreme assumptions such as

- complete information,
- common knowledge,
- unbounded rationality, and
- optimizing behavior.

In many real-world situations, these assumptions are untenable because

- the game may be too complex,
- behavior of others may be unobservable,
- players may not know others' utility functions, and
- the structure of the game may be unknown.

In addition, real-world humans care about others, and follow certain rules/norms.

# The economic laboratory promises some answers

- Play often does not coincide with the Nash equilibrium predictions.
- There are robust deviations from predictions, and many experiments have made similar observations.
- To explain these deviations, we must
  - abandon the assumption of narrow self-interest in favor of social preferencesand/or
  - abandon the assumption of strictly optimizing behavior in favor of behavior that allows for heuristics/learning

# Learning

- Over time, play approaches equilibrium in most settings, including those where very limited information is available.
- There is a rich theoretical literature on these convergence properties, but relatively little of it has been tested in the laboratory.
- And there is a lack of acknowledgement in experimental research of the fact that simple heuristics may explain behavior not only in low-information but also in richer information environments.
- There is plenty of room for innovative experimental-theoretical work in this area.

# Voluntary Contributions Game: let's play again!

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- ⑤ **Payoffs:** So you will earn a total of  $20 - c_i + S_i$ .
- ⑥ I will pay one randomly selected person in CHF (dividing payoffs by 10).



# Some concluding remarks

- Aristotle called man a “rational animal” (“zoon logikon” or “zoon logon echon”)
- There is a side to human nature which is rational, describable by (corrected) utility maximization
- Utility may include components concerning others’ material payoffs too
- There is also a side not describable that way – but instead by heuristics and by learning models
- It is my belief that such ‘rules’ may themselves be more rational than is usually considered

# Thanks!

As always, please contact me under [hnax@ethz.ch](mailto:hnax@ethz.ch) if you have any questions, or (even better) come by my office before next lecture (15-16) or see me outside this lecture hall (16-17).

## References (some own work)

- M Burton-Chellew, HH Nax & S West, “Payoff-based learning explains the decline in cooperation in public goods games”, Proceedings of the Royal Society of London B, 2015
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- K Binmore & A Shaked, “Experimental Economics: What Next?” Journal of Economic Behavior and Organization, 2010. (see also the accompanied responses in the same issue by Fehr-Schmidt and Eckel-Gintis, and a rejoinder by Binmore-Shaked)