EXPERIMENTAL GAME THEORY i/ii

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A brief overview over Experimental GT: our goals for today

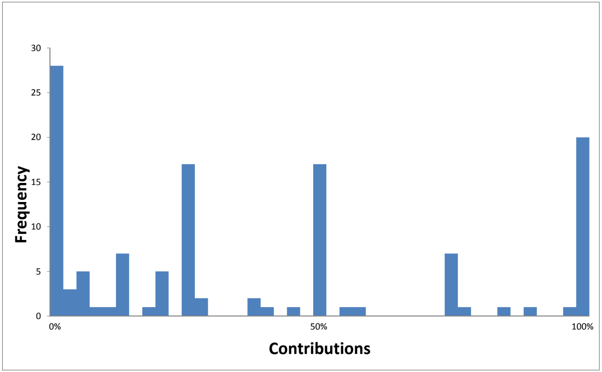
- A focus on human behavior in strategic interactions
- Provide an overview over the different approaches of Experimental GT
- Talk about the case of "Voluntary Contributions Games" and other laboratory fruit flies
- Spend some time on "Learning in Games"
- PLAY!

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 a lab for 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)

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

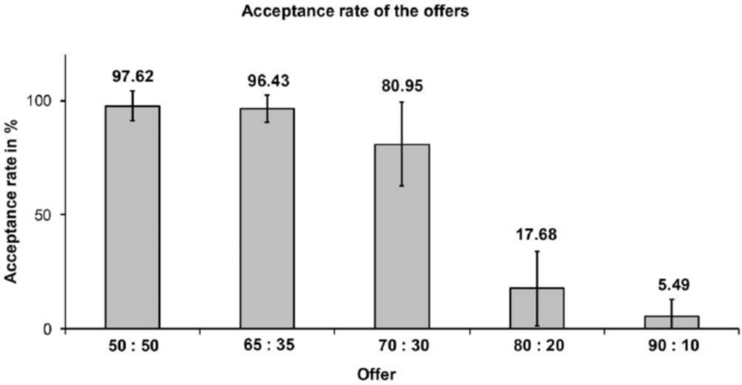
1. the proposer (player 1) suggests a split between him and the receiver (player 2)
2. Player 2 can either accept or reject:
    1. If he accepts, the shares proposed by player 1 realize
    2. If he rejects, both players receive nothing.

- **Nash equilibria:** any split supportable as a Nash equilibrium
- Unique **subgame-perfect Nash equilibrium**: (1 all, 2 nothing)

Testing the extreme SPNE prediction

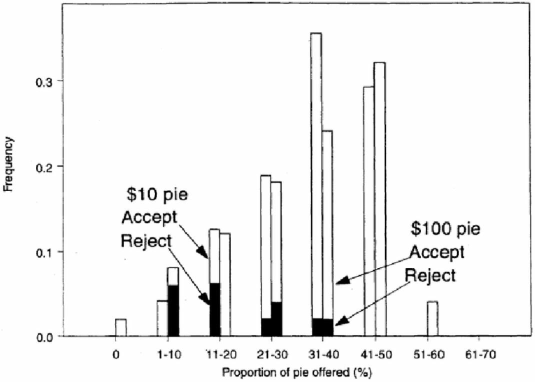
- The unique subgame-perfect Nash equilibrium is an extreme allocation
- Any rejection by the responder kills own and other's payoff
- Any positive proposal, presuming (rational) acceptance, seems like a gift;
- however, presuming (off the equilibrium-path) rejection of low offers, a substantial proposal 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)

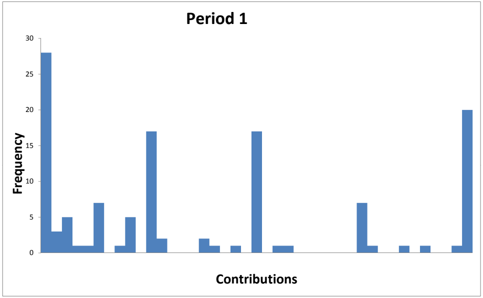
THE GAME

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

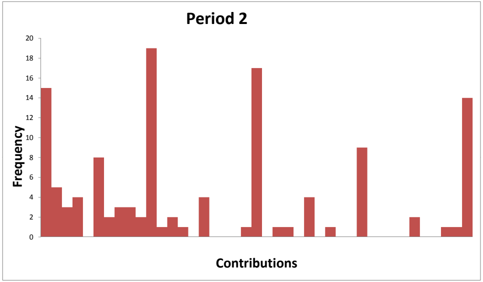
- Again, the Nash equilibrium is an extreme allocation
- Lowest social welfare
- Pareto-dominated by social optimum
- Any positive contribution decreases own payoff but increases those of others and increases total welfare
- Meta-analysis suggests
  - average contributions of roughly 40%-50% when game 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



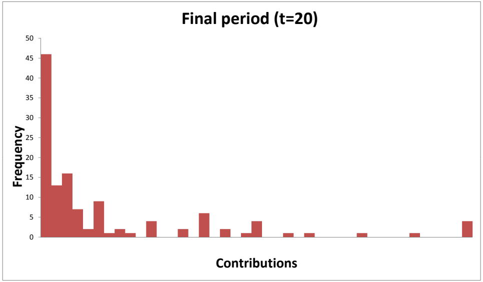
from Nax et al., JEBO 2016

Contributions 2



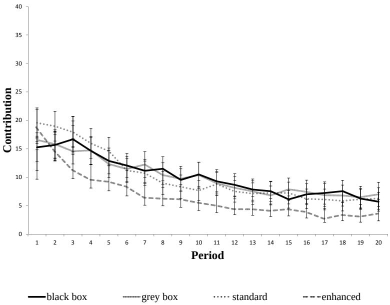
from Nax et al., JEBO 2016

Contributions final



from Nax et al., JEBO 2016

Contributions trend

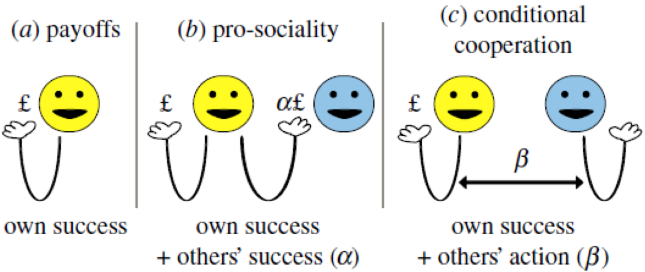


from Nax et al., JEBO 2016

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-Gachter, Gintis-Bowles-Boyd-Fehr, Fehr-Fischbacher)
  - Reciprocity (Fischbacher-Gachter-Fehr)
- Note: This approach (by the Zurich school) mirrors the various “corrections” to utility functions motivated by ambiguity aversion, etc.

Homo Oeconomicus and Friends

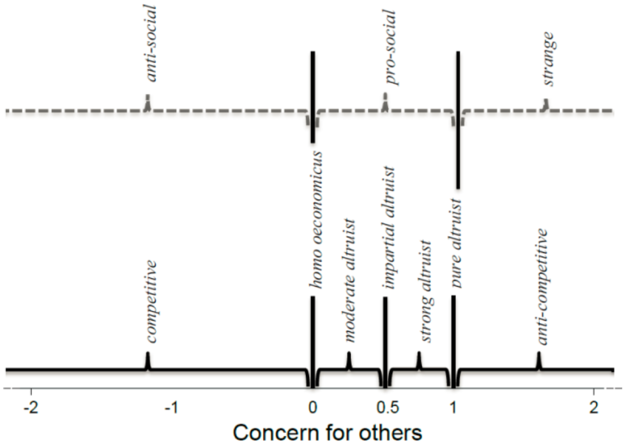


Rational choice theory assumes individuals to be fully rational and thus capable of expressing their preferences perfectly through the consequences of their actions (Becker 1976).

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 ϕ_{-i}^{α} is the average payoff to players $j \neq i$, then...

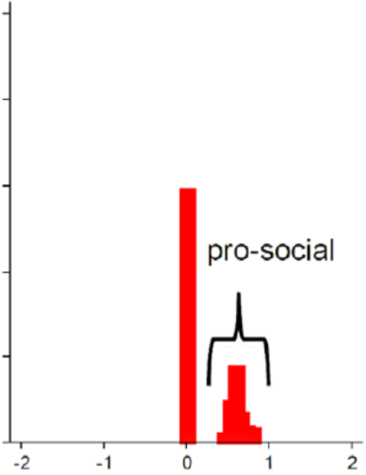
...we have a range of social personas...



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...



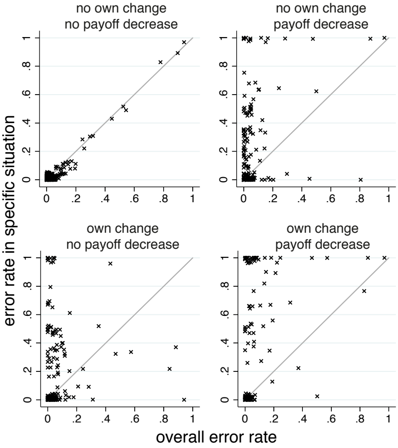
Interpretation 2: Mistakes equilibrium

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?

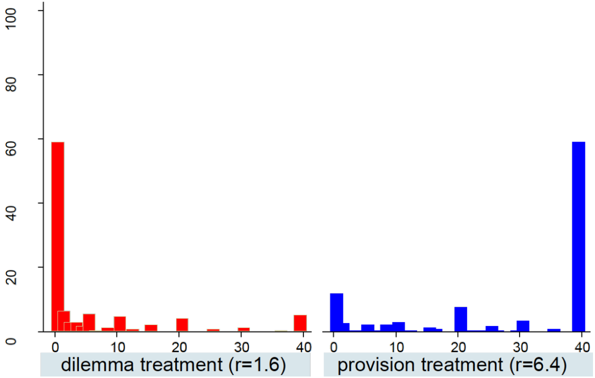
Experiments: Set-Up

- 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)

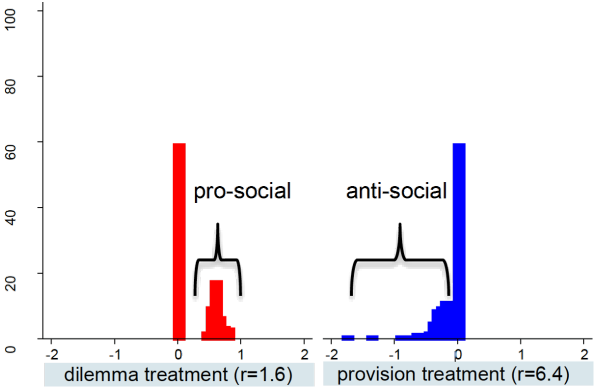
Consistent deviations from homo oeconomicus?

- 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 $mpcr = 0.4 < 1$)

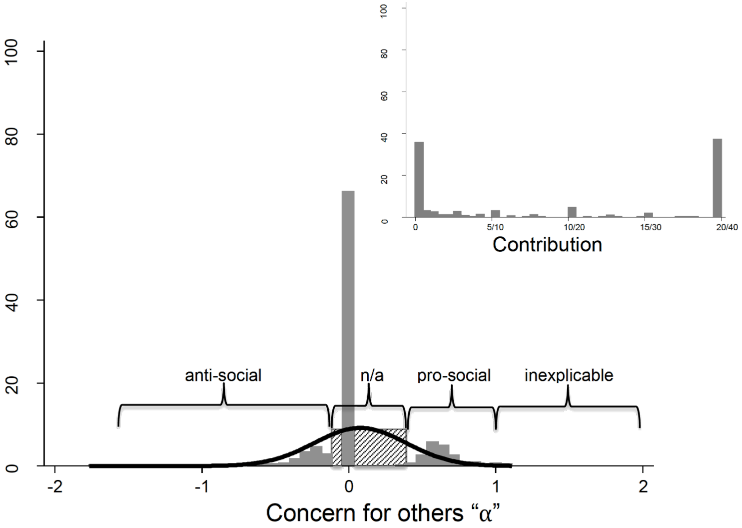
Contributions (final round)



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 by 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

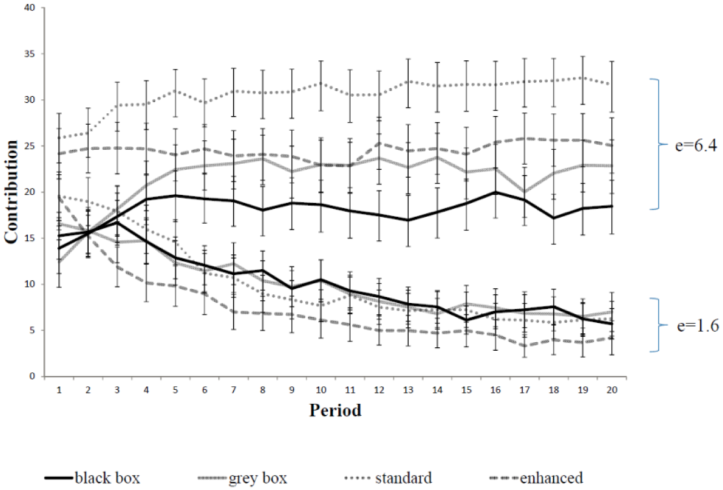
Black box

- 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[a]	−0.13*	−0.23*	−0.29*
conditional	n.s.	✓	n.s.
cooperation[a]	0.05	0.21*	−0.001

*significance < 0.001.
[a]Controlling for payoff-based learning.

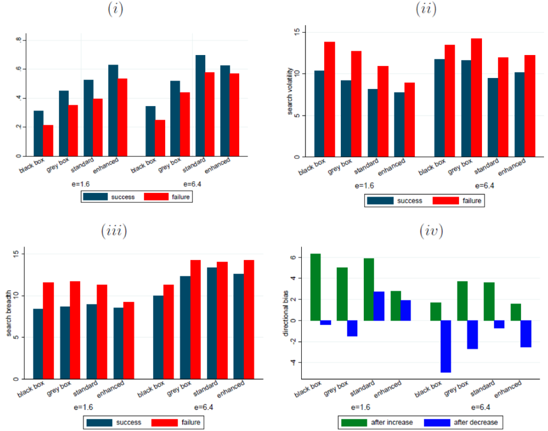
A richer Black box learning model

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

Fun parallels!

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 preferences

  and/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!

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).

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 if you have any questions!

References (some own work)

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