Supplemental material

to

Parochial vs. universal cooperation:

Introducing a novel economic game of within- and between-group interaction

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Contents

Game-theoretical analysis

In this section, we provide a stylized game-theoretical analysis of the Intergroup Parochial and Universal Cooperation (IPUC) game, the Intergroup Prisoner's Dilemma-Maximizing Difference (IPD-MD; Halevy, Bornstein & Sagiv, 2008), and the Nested Social Dilemma (NSD; Wit & Kerr, 2002). We report (i) formalized game descriptions and derive (ii) payoff functions as well as (iii) payoff-maximizing strategies based on different individual preferences.

Formalized game descriptions

The IPUC is played by N players i (with $N \geq 4$) who are assigned to two different groups. Groups are equal in size, that is, each group has $n = \frac{N}{2}$ players, with $I = \{1, \ldots, n\}$ denoting the set of players in the in-group and $O = \{n + 1, \ldots, N\}$ denoting the set of players in the out-group. Each player is endowed with e tokens and decides in private how many (if any) tokens to contribute to pool A (g_A, with $0 \leq g_A \leq e$), pool B (g_B, with $0 \leq g_B \leq e$), and/or pool C (g_C, with $0 \leq g_C \leq e$), with $g_A + g_B + g_C \leq e$).

Contributions to pool A are multiplied by a constant k (with $1 < k < n$) and are equally distributed among all in-group players, hence, each in-group player receives $\frac{kg_A}{n}$ from a player's contribution g_A. Additionally, contributions to pool A are multiplied by a constant l (with $0 < l \leq k$) and reduce the payoff of each out-group player equally by the amount $\frac{lg_A}{n}$ from a player's contribution g_A. In a similar vein, contributions to pool B are multiplied by a constant k and equally distributed among all in-group players, such that each in-group player receives $\frac{kg_B}{n}$ from a player's contribution g_B. However, there is no effect on out-group players' payoffs from contributions g_B. Lastly, contributions to pool C are multiplied by a constant m (with $m > k$ and $\frac{m}{N}$

< $\frac{k}{n}$ < 1) and equally distributed among all in-group and out-group players, hence, each in-group player and out-group player receives $\frac{mg_C}{N}$ from a player's contribution g_C. Tokens not contributed to either pool are kept by the respective player and do not affect the payoff of either in-group or out-group players.

The IPD-MD is similar to the IPUC except that players can only contribute to pools A and B, but there is no pool C available.[1] The NSD is similar to the IPUC except that players can only contribute to pools B and C, but there is no pool A available.

Payoff functions

Based on the formalization described above, the individual payoff for each player i in each of the games equals:

IPUC: $u_i = e - g_{Ai} - g_{Bi} - g_{Ci} + \frac{k}{n}\sum_{p=1}^{n}(g_{Ap} + g_{Bp}) + \frac{m}{N}\sum_{q=1}^{N} g_{Cq} - \frac{l}{n}\sum_{r=n+1}^{N} g_{Ar}$

IPD-MD: $u_i = e - g_{Ai} - g_{Bi} + \frac{k}{n}\sum_{p=1}^{n}(g_{Ap} + g_{Bp}) - \frac{l}{n}\sum_{r=n+1}^{N} g_{Ar}$

NSD: $u_i = e - g_{Bi} - g_{Ci} + \frac{k}{n}\sum_{p=1}^{n} g_{Bp} + \frac{m}{N}\sum_{q=1}^{N} g_{Cq}$

[1] Note that in the present experiments, the absolute value of the benefit for each in-group member from contributions to pool A is larger than the absolute value of the loss for each out-group member, i.e., $k > l$. In detail, each in-group member receives 0.5 MUs for each token contributed to pool A and B, and each out-group member loses 0.25 MUs for each token contributed to pool A. In contrast, in previous research using the IPD-MD, typically $k = l$, i.e., 0.5 MUs (e.g., Halevy et al., 2008, 2012; Weisel & Böhm, 2015). However, for a player with a preference in strong parochial altruism, contributions to pool A always maximize the player's utility given that $l > 0$ because they reduce the out-group members' payoff. As such, $k = l$ is a special case in which the gain for each in-group member equals the loss for each out-group members for each token contributed to pool A.

Payoff-maximizing strategies

Based on the formalizations and payoff functions just described, we identify the behavioral strategies that correspond with egoism (i.e., maximization of the personal payoff), weak parochialism (i.e., maximization of the in-group's aggregated payoff while minimizing externalities on the out-group), strong parochialism (i.e., maximization of the in-group's aggregated payoff while minimizing the out-group's aggregated payoff), and universalism (i.e., maximization of all players' aggregated payoff, irrespective of group membership), respectively. Given that a player *i* chooses a unique strategy (note that there are no payoff maximizing mixed strategies in either game), Table S1 shows the payoff-maximizing strategies for each of these preferences.[2] The strategies are payoff-maximizing irrespective of what other (in-group or out-group) players do.

The intuition is as follows: Because contributions to all pools are costly from the individual perspective, i.e., $\frac{m}{N} < \frac{k}{n} < 1$, not contributing any tokes is the strictly dominant strategy. Accordingly, keeping all tokens (i.e., not contributing them to any pool) constitutes the unique Nash-equilibrium in each game, indicating that players are always better off by not contributing any tokens, irrespective of what other players of the in-group or out-group do. The other preferences lead to distinct maximization strategies in the IPUC but are partially intertwined in the IPD-MD (both weak parochialism and universalism are maximized by full contribution to

[2] A player may also have more than one preference, which can be captured in an additive utility function with different weights for each preference (e.g., Luce & Raiffa, 1957). See Table S5 for shares of different 'contribution types' with either a pure, partial, or zero preference in Experiments 1-3 based on the amount contributed to each pool in the IPUC.

pool B) and in the NSD (both weak and strong parochialism are maximized by full contribution to pool B).

Table S1. Payoff-maximizing strategies for each preference by game.

Motivation	Game		
	IPUC	IPD-MD	NSD
Egoism	Keep	Keep	Keep
Strong parochialism	Pool A	Pool A	**Pool B**
Weak parochialism	Pool B	**Pool B**	**Pool B**
Universalism	Pool C	**Pool B**	Pool C

Note. The bold cells indicate preferences that are maximized by the same behavioral strategy within the respective game.

Supplemental analyses

Table S2. Zero-order correlations of preferences per game (Experiment 1).

	1	2	3	4	5	6	7
1. Weak PC/UC IPD-MD		-.472*	-.668*				
2. Strong PC IPD-MD			-.340*				
3. Egoism IPD-MD							
4. Weak PC IPUC					-.093	-.444*	-.309*
5. Strong PC IPUC						-.352*	-.243*
6. UC IPUC							-.488*

7. Egoism IPUC							

Note. PC = parochial cooperation, UC = universal cooperation. * $p < .05$.

Table S3. Zero-order correlations of preferences per game (Experiment 2).

	1	2	3	4	5	6	7
1. Strong/Weak PC NSD		-.343*	-.518*				
2. UC NSD			-.626*				
3. Egoism NSD							
4. Weak PC IPUC					-.231*	-.383*	-.387*
5. Strong PC IPUC						-.344*	-.240*
6. UC IPUC							-.395*
7. Egoism IPUC							

Note. PC = parochial cooperation, UC = universal cooperation. * $p < .05$.

Table S4. Zero-order correlations of preferences per game (Experiment 3).

	1	2	3	4
1. Weak PC IPUC		-.083	-.276*	-.497*
2. Strong PC IPUC			-.197*	-.244*
3. UC IPUC				-.566*
4. Egoism IPUC				

Note. PC = parochial cooperation, UC = universal cooperation. * $p < .05$.

Table S5. Contribution types (Experiments 1-3).

Individual Preference	Pure preference (c = 10)	Strong partial preference (5 < c < 10)	Weak partial preference (0 < c < 6)	Zero preference (c = 0)
Universal cooperation				
Experiment 1	17.7%	6.5%	45.2%	30.6%
Experiment 2	6.4%	14.9%	48.9%	29.8%
Experiment 3	7.2%	7.8%	42.2%	42.8%
Weak parochial cooperation				
Experiment 1	6.5%	11.2%	42%	40.3%
Experiment 2	5.3%	14.9%	56.4%	23.4%
Experiment 3	3.9%	6.7%	53.3%	36.1%
Strong parochial cooperation				
Experiment 1	3.2%	3.3%	25.8%	67.7%
Experiment 2	4.3%	1.0%	38.3%	56.4%
Experiment 3	0.6%	1.1%	30%	68.3%
Egoism				
Experiment 1	9.7%	12.9%	38.7%	38.7%
Experiment 2	5.3%	8.5%	56.4%	29.8%
Experiment 3	15.6%	14.4%	51.1%	18.9%

Note. Parameter c represents the tokens contributed to the behavioral option in the IPUC capturing the respective preference. Contributions may vary between 0 and 10. Percentages in each row add up to 100%.

References

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