Voluntary Cooperation in Local Public Goods Provision An Experimental Study

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Abstract

In a circular neighborhood with each member having a left and a right neighbor, individuals choose two contribution levels, one each for the public good shared with the left, respectively right, neighbor. This allows for general free riders, who do not contribute at all, and general cooperators, who contribute to both local public goods, as well as for differentiating contributors who contribute in a discriminatory way. Although the two-person local public good games are structurally independent, we investigate whether intra- as well as interpersonal spillover effects arise. We find that participants do not behave as if they are playing two separate public good games, hence that both inter-personal and intra-personal behavioral spillovers occur. To investigate more clearly motives for voluntary cooperation via analyzing individual adaptations in playing two structurally independent games, we design treatments differing in cooperation incentives (i.e. different MPCR) and structural (a)symmetry of local public goods. We find that when the MPCR is asymmetric, free-riding occurs less, and contributions are more stable over time. We also find that contributions in the asymmetric treatment when MPCR is low are higher than contributions in symmetric treatments with higher MPCR.

Keywords: Public goods, experiments, voluntary contribution mechanism.
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1. Introduction

Network studies usually assume external effects to become weaker the larger the distance from the source node to the affected node, i.e. the larger the number of necessary links between

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source and destination node. We do not investigate network formation but instead rely on an exogenously given neighborhood, namely 8 individuals, each separately located on a circle. What is new and hopefully interesting, is that there are no external effects beyond the nearest neighbors: all individuals play two structurally independent two-person public good games, one involving only their left and one their right neighbor only.

Thus in total 8 structurally independent two-person games are played by overlapping player sets. Each member confronts 2-person games, namely one with the left and one with the right direct neighbor, i.e. each member contributes to the left public good and to the right public good with both choices being independent. Obviously a member only has to consider his right choice when dealing with his right neighbor, respectively his left choice with the neighbor on the left.

This structural independence of each two-person public good game may however not imply their behavioral independence. Even with feedback on only local past contributions there can be purely behavioral "spillover" effects. It is the existence and evolution of these purely behavioral spillovers which we want to analyze experimentally. In doing so we will distinguish between intrapersonal spillovers meaning that individual members will try to align their left and right hand contributions what, when prevailing more or less generally, imply interpersonal spillovers in the sense of related play of neighboring public good games.

Before presenting our research questions, let us discuss the relevance of our scenario for the field. We do not want to justify the specific neighborhood implemented experimentally, even if we can safely imagine real-world situations of "circle town" , in which every member has one left and one right direct neighbor. What is more debatable is that only two direct neighbors interact strategically and that each individual member is involved in two structurally independent 2-person linear public good games one involving his right, the other his left neighbor.[1] Only direct neighbors are strategically interacting what, in our view, seems quite realistic: two neighboring houses sharing, for instance, a garden will find it more enjoyable when better maintained.

[1]The linearity assumption is due to its simplicity. For non-linear, e.g. quadratic and convex, contribution costs one can induce the opportunistic as well as the efficient behavior as interior choices what might help when diagnosing the reasons for certain choices, e.g. when distinguishing conscious intentions from noise.

Furthermore, the assumption of only one-sided and direct neighborhood impact applies to emissions, like noise and smell, without any long-distance effects.

The structural independence of an individual's two neighborhoods, likely to exists in the field, is captured by our experimental setup which allows us to explore purely behavioral, intra as well as inter-personal, spillover effects and hypotheses related to them. Will an individual participant want to achieve similar outcomes in both games when these games are symmetric or even when they differ? *Intrapersonal spillovers* would be due to individual attempts to enjoy similar voluntary cooperation on both sides. If such intrapersonal spillovers apply also for one's neighbors they would *interpersonally spillover*, and possibly simply that across all direct neighborhoods of "circle town" one observes a similar degree of voluntary cooperation. We refer to such behavioral interdependence as *purely behavioral spillovers*.

However, direct neighborhood games may differ due to different motives and behavioral attitudes. We do not exclude such heterogeneity in motivation and outcomes and actually suggest it by an asymmetric treatment with different payoff parameters in one's right or left neighborhood game. Since irritation can also be caused by past behavior, we study how experience shapes behavior: neighbors interact repeatedly for either 8 or 16 rounds. What we will confirm are purely behavioral spillovers and possibly extending chains of nearly equal positive, not necessarily maximal, contributions: initially increasing and then stable contribution levels of those involved in such chains before the end of game.

We predicted purely behavioral spillovers and thus expected initial or possibly extending chains of neighbors with nearly equal positive, mostly maximal, contributions and increasing contribution levels of those involved in such chains, but did not exclude endgame effects (see Selten and Stoecker, 1986). Since we were interested in the revival of voluntary cooperation after a possible decline, all experimental games end either after 8 or after 16 rounds of play by the same participants. Will there already be a breakdown of voluntary cooperation in the early stopping round? And, if so, will voluntary cooperation spread again across the circle when the game afterwards continues?

Section 2's focus is on purely behavioral aspects of local public goods games as captured by our design. The experimental data are analyzed and discussed in section 3. Sections 4 and 5 provide statistical analyses. Heterogeneity of individual behavior across the circular neighborhood as well across neighborhoods, based on the same treatment, are visually presented in section 6. The concluding remarks, section 7, discuss our findings and methodological issues. The Appendix provides the English translation of the instructions and additional data analyses.

2. On purely behavioral spillovers

In repeated public good experiments there is robust evidence of substantial voluntary cooperation up to termination effects at intermediate levels which, more often than not, are declining across rounds.[2] This evidence is usually based on more than two anonymous contributors, which in our setup, with each individual playing two independent 2-person public good games, is avoided. Due to feedback information only to the local and payoff-relevant contributions of one's direct neighbors one can signal own trustworthiness and receive signals about others' trustworthiness only by local feedback information about past plays with one's two direct neighbors who, in turn, receive only local feedback etc. so that one only later may be affected indirectly by more distant neighbors.

Regarding the literature investigating purely behavioral spillovers, which we predict to exist and to survive, our study seems to be related to the so-called Forbearance Hypothesis (see Phillips et al., 1992). It considers conglomerate firms which compete in more than one market, where all these markets are, however, strategically independent. The Forbearance Hypothesis nevertheless predicts more cooperative behavior of these firms than, for instance, of firms which are also active on multiple markets but encountering each other in only one market. Cooperating could be due to fearing that a local (e.g. price) "war" can easily escalate to a global one (see Güth et al. 2015 for an experimental study).

Another strand of literature to which our study can be related are the so-called Folk Theorems (see Aumann, 1967) for supergames where the same constant base game is repeated

[2]For a survey see Ledyard (1995) and more recently Chaudhuri (2011).

finitely or infinitely often. If all subgames of such supergames are isomorphic, the differences in past play leading to them should have no influence on subgame behavior. Nevertheless Folk Theorems claim purely behavioral spillovers from past play on behavior in the subgame following it, e.g. in the form of tit-for-tat as firm strategies. Furthermore such purely behavioral path dependence has been robustly confirmed (see Selten and Stoecker 1986).

In our view, having to play two independent games with two directly unrelated co-players can be seen as a multiple-selves[3] contribution game: each self faces a different other person. If a person suffers when both own selves face very differently behaving co-players and contribute discriminatingly, attempts to align both own contribution levels could be triggered. Such aligning may take the form of adjusting both contributions downward. If one attempts, however, to align contributions at the larger level, voluntary cooperation would evolve: an aversion to contributing different amounts in one's 2-games can be described as an intrapersonal spillover from one own self to the other.[4] And if such spillovers apply to several members of the neighborhood, they might trigger interpersonal ones, either harmonic or diversified. Therefore, we state the opposite hypotheses we will explore:

> Harmony: irrespective of the past, a non-negligible share of participants will want to align their two contribution levels by increasing their lower contribution in an attempt to attain equal levels of voluntary cooperation on both sides.

and

> Diversification: few participants will engage in diversification by freeriding in one and voluntarily cooperating in their other game.

Whereas in (usual) public good experiments an individual participant has only a contribution choice, in our setup an individual participant can do both freeride in one interaction and

[3]Ideas of multiple selves date back to Plato (2006) who distinguished between passion and reason what can be related to system 1 and 2 (see Kahneman, 2011); for recent discussions see Elster (2009).

[4]In our view, it is cognitively more demanding and stressful when having to maintain different contribution levels with one's left and right neighbor. Of course, these may be obvious reactions to their different contribution levels in the past.

aim at voluntary cooperation in the other. In our view, this may seem appealing when our neighborhood game is played only once. For supergame experiments, however, early freeriding could turn out to be very harmful, which is why we expect at best scarce evidence of Diversification.

Finally, for endgame behavior one will expect the same decline of both contributions. Since one may want to avoid preemption by either direct neighbor one might expect the same begin of endgame behavior as in 3-person public good experiments. On the other hand, a long history of voluntary cooperation with one's two neighbors might question or at least delay endgame behavior. We thus expected to confirm

Termination: endgame behavior is restricted to the very last (possible) round.

2.1. Experimental Setup

In the experimental scenario (see for more details also the translated instructions, see Appendix 1) eight participants are positioned in the circular neighborhood of Figure 1 featuring an individual participant i (lighter color) at the bottom position.

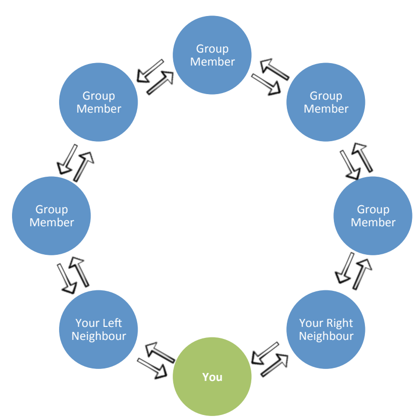

Figure 1: The circular neighborhood

In the interaction with the left neighbor $i-1$, participant i's contribution is denoted c_i^L, while in the interaction with the right neighbor $i+1$ participant i's contribution is denoted c_i^R (see Figure 2). Both contributions are integers ranging from 0 to 9.

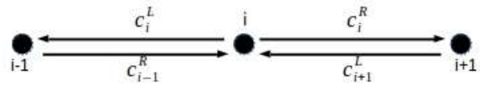

Figure 2: The interacting neighbors

For each of his two two-player games, a participant receives an endowment of 9 experimental currency unit (ECU, with 1 ECU corresponding to 1 euro) in every period. If in the left (right) interaction the MPCR is α_L (α_R), participant i earns

$$\begin{aligned}\left[9 - c_i^L + \alpha_L(c_i^L + c_{i-1}^R)\right] + \left[9 - c_i^R + \alpha_R(c_i^R + c_{i+1}^L)\right] \\ = 18 - (c_i^L + c_i^R) + \alpha_L(c_i^L + c_{i-1}^R) + \alpha_R(c_i^R + c_{i+1}^L) \qquad (1)\end{aligned}$$

with $0 < \alpha_n < 1 < 2\alpha_n$ for $n = L, R$, guaranteeing that freeriding, i.e. $c_i^L = 0 = c_i^R$, is dominant and fully contributing, i.e. $c_i^L = 9 = c_i^R$, efficient (maximizing the joint payoff of the two direct neighbors).

The supergame implementation assumes constant neighborhoods playing either 8 or 16 rounds. Participants only learn after round 8 whether they interact over 8 or 16 rounds. We hope to confirm the

> Anticipated Restart: in round 8 contributions will only slightly decrease but quickly recover when the (super)game continues and more sharply decline is in round 16.

After each supergame, we reshuffle neighborhoods via randomly repositioning participants such that at least one new neighbor is guaranteed. The same 8 participants experience four successive rounds of playing such supergames. In each period of each supergame, all 8 participants choose their contributions c_i^L, c_i^R simultaneously being aware of α_L and α_R. After each round feedback information was provided only on own and direct neighbors' contributions. To limit diversification attempts, payment is the average payoff of one randomly selected round, i.e. supergame.

Overall we consider four treatments. In the asymmetric treatment T_a, with $\alpha_L = 0.6$ and $\alpha_R = 0.8$, one contributed unit more generates an effect of $\alpha_L = 0.6$, respectively $\alpha_R = 0.8$, for both directly concerned neighbors in case of c_i^L, respectively c_i^R. The other three, symmetric, treatments are controls for the asymmetric one: treatment T_l, with $\alpha_L = \alpha_R = \min\{0.6, 0.8\} = 0.6$, treatment T_m with $\alpha_L = \alpha_R = (0.6 + 0.8)/2 = 0.7$, and finally treatment T_h with $\alpha_L = \alpha_R = \max\{0.6, 0.8\} = 0.8$. One could reasonably expect to confirm

> Monotonicity: Initial and average contributions are higher for T_h than for T_m, and for T_m than for T_l

> Bimodality: In T_a one has neighborhoods whose average contribution levels resemble either those of T_l or T_h with the latter being more frequent.

For treatment T_l and T_h, we ran 2 sessions with a total of, 48 and 40 subjects, respectively. For treatment T_m and T_a we instead ran 4 and 5 sessions with a total of 96 subjects each. Altogether 280 participants had self-registered for participation at CESARE lab (Luiss University). Each session lasted about an hour. Earnings (including a show-up fee of 5 euros) ranged from 11.4 euro to 32.4 euro, with an average of 20.55 euro.

3. Data Description

Table 1 lists the average contributions across treatments, with percentages of freeriding $(c_i^L, c_i^R) = (0, 0)$ contributions as well as average positive contributions. According to this table, there is not much variation in variances but quite surprising differences in average contributions; for example, average contributions of T_a exceed far those of T_m although their mean productivity is the same.[5]

> Result 1: Average contributions increase when being more effective, with the asymmetric treatment T_a ranking second, half way between T_m and T_h.[6]

[5] Table 11 and 12 in Appendix list average contributions also separately for both phases (periods 1-8 and periods 9-16).

[6] This is in line with previous findings, see e.g. Isaac et al. (1994)

	T_l	T_m	T_a	T_h	Total
Mean	2.591	2.992	3.478	3.872	3.183
Std. Dev.	2.327	2.762	2.523	2.808	2.650
Freq.	2688	5568	4672	1856	14784
Share of (0,0)	23.85%	28.75%	14.88%	17.40%	22.05%

Table 1: Average contribution by treatment.

In spite of the same mean productivity, the asymmetric treatment T_a triggers higher average contributions and less freeriding than T_m (14.88% versus 28.75%), especially in periods 8 to 16[7,8]. In T_a participants are apparently more guided by their high productivity. Actually, behavior in T_a corresponds in freeriding percentage with average contributions much closer to T_h than to T_m. Therefore, our Monotonicity and Bimodality Hypotheses are confirmed.

More in detail, Table 2 shows the average differences in left (c_i^L), respectively right (c_i^R), contributions in treatment T_a and the average contributions in T_l, respectively T_h. In spite of the same productivities, these differences are both positive but more than four times larger for T_l than for T_h. In our view, this presents the first striking evidence for intrapersonal spillovers and support for the Harmony Hypothesis.

$c^L(T_a) - \dfrac{c^L(T_l) + c^R(T_l)}{2}$	0.646
$\dfrac{c^L(T_h) + c^R(T_h)}{2} - c^R(T_a)$	0.153

Table 2: Differences in left $\left(c^L\right)$ and right $\left(c^R\right)$ contributions (average values).

<u>Result 2</u>: When confronting different productivity parameters in their left and right interaction (as in T_a) participants tend to close the gap in contributions towards the higher.

The following figures confirm these results by displaying the evolution of mean contributions (Figure 3) as well as to both, left (Figure 4) and right (Figure 5) public goods. As predicted average contributions slightly decline with a minor drop in period 8 but recover, partly to

[7] So far tests assume choices as independent and should be interpreted as descriptive assessments only.
[8] See see Table 11 and 12 in the Appendix

the same level as before and drop more sharply only in the last possible period 16. It is striking in figure (4) that $T_a's$ left contributions are nearly always above those of T_m although contributions in T_m are more efficient. Figure 5 of mean right contributions reveal nearly no differences between T_a and T_h for the first 11 periods.

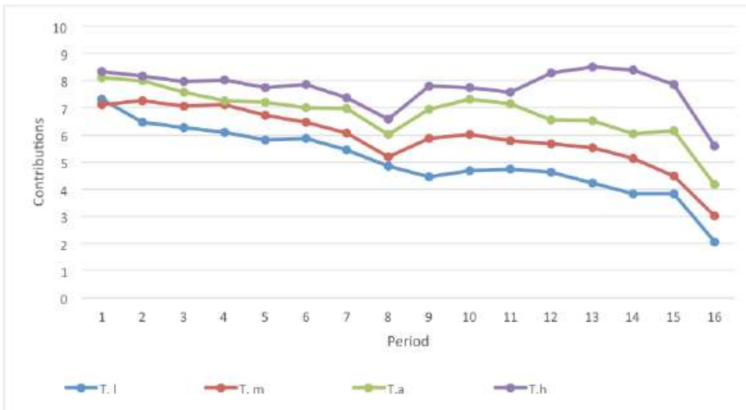

Figure 3: Mean Contributions to both PG

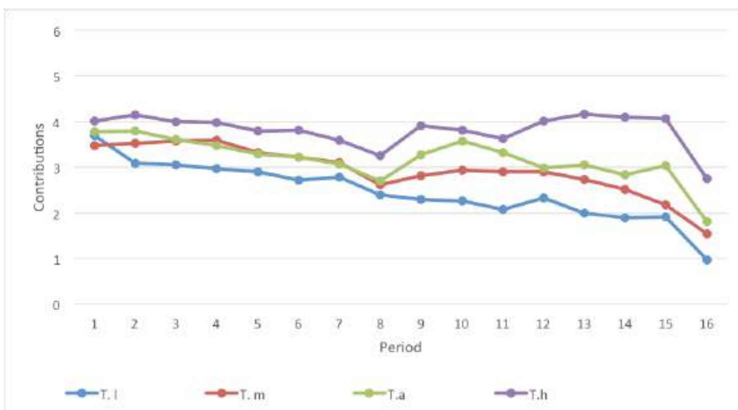

Figure 4: Mean Contributions to left PG

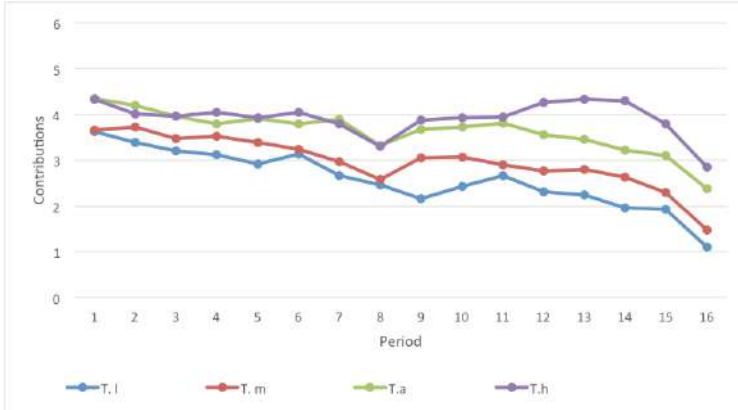

Figure 5: Mean Contributions to right PG

We summarize these findings in the following result:

Result 3: In spite of their structural independence contributions to both local public goods are behaviorally interdependent and in the asymmetric treatment T_a more guided by the more productive public good (in Figure 5, T_a contributions are closer to T_h than in Figure 4).

To confirm both our Termination and Anticipated Restart Hypotheses, we looked at the evolution of contributions across period and we found that

Result 4:

- during the first eight periods contributions slightly decline as in other linear public good experiments, with a minor drop in period 8,
- but strongly recover and decline less when learning that the (super)game continues,
- before the more drastic decline in the last possible round.

Figure 6 distinguish contribution choices via percentage share of zero, low $(1, 2, 3)$, intermediate $(4, 5, 6)$, an high $(7, 8, 9)$ contributions for all four treatments where, in case of T_a, it differentiates between left (denoted $T_{a,l}$) and right (denoted $T_{a,r}$).

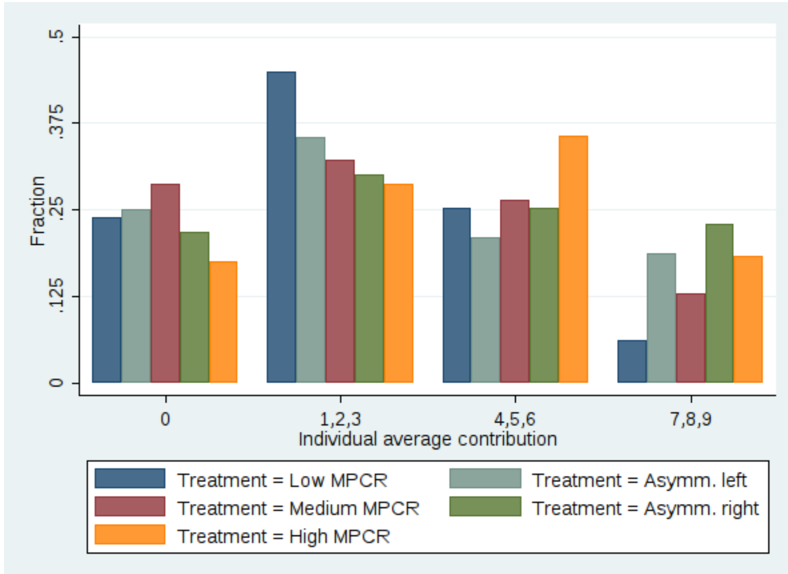

Figure 6: Contribution ranges by treatment

> Result 5: In all treatments, there is a considerable share of 0−contributions which is, however, lowest in T_a and T_h. The peaks of contributions are at $(1, 2, 3)$ except for T_h with its peak at $(4, 5, 6)$. Interestingly, the share of high $(7, 8, 9)$ contributors in T_{ar} is higher than in T_h.[9]

The bottom line of the above results, namely that individual behavior is more similar in T_{ar} and T_h than in other treatments, is confirmed by the simple statistical analysis implemented by comparing contributions across treatments with and without the last period (8, resp. 16).[10]

Comparison across treatments is based both on (i) all average local plays (the 8 average plays by two neighbors each in all groups of a given treatment), and on (ii) individual averages (the average $(c_i^L + c_i^R)/2$ or c_i^L resp. c_i^R in T_a) across all periods.[11] Table 3 and Table 4 show that, for both methods, treatment effects exist, but are weaker for treatment T_{ar} and T_h.[12] Observe that, differently from $T_{a,r}$ and T_h, treatments T_l and $T_{a,l}$ differ significantly, which

[9] We find no essential differences between periods 1 to 8 and 9 to 16, as shown in Tables 11 and 12 in the Appendix.

[10] In what follows, we concentrate on the analysis including the end period effect; the results excluding the last period are not significantly different, and therefore we present them in the Appendix.

[11] We also compared treatments based on neighborhood averages but found no significant treatment effects due to the small sample size.

[12] The same tests performed without endgame periods (8 and 16) can be found in the Appendix, see Table 13 and Table 14

again supports our previous results.

Result 6: depending on the unit (i), (ii) of observation treatments differ

- significantly across the board for (i), where the difference between $T_{a,r}$ and T_h is only weakly significant (.062, see Table 3),
- significantly, but more weakly, for (ii), except for $T_{a,r}$ and T_h (see Table 4)

	T_l	$T_{a,l}$	T_m	$T_{a,r}$	T_h
T_l		-0.646 (0.000)	-0.401 (0.000)	-1.128 (0.000)	-1.281 (0.000)
$T_{a,l}$			0.245 (0.000)	-0.482 (0.000)	-0.635 (0.000)
T_m				-0.727 (0.000)	-0.880 (0.000)
$T_{a,r}$					-0.153 (0.062)
T_h					

Table 3: Two sample t-test on average local plays.

	T_l	$T_{a,l}$	T_m	$T_{a,r}$	T_h
T_l		-0.546 (0.029)	-0.437 (0.073)	-1.012 (0.000)	-1.193 (0.000)
$T_{a,l}$			0.109 (0.665)	-0.465 (0.036)	-0.647 (0.028)
T_m				-0.575 (0.015)	-0.756 (0.016)
$T_{a,r}$					-0.182 (0.302)
T_h					

Table 4: Two sample t-test on individual contributions across all periods.

4. Behavioral Spillovers

To assess interpersonal spillovers we use the play of a local good by its two direct neighbors in period t. Interpersonal spillovers predict that this play in period t affects the neighboring public good plays in period $t+1$ which these neighbors play with their other direct neighbors and in period $t+2$ the public good plays of these others with their other neighbors etc, where we use only shortest lag structure for testing interpersonal spillovers.

Table 5 compares for High and Low contributors, respectively, and for all others (Everyone else) their average contribution with the average lagged contributions of their respective direct neighbors back to them. Table 6 looks at how one's own contributor "type" affects direct neighbors' contributions to their other direct neighbors, again based on shortest delay for such interpersonal spillovers.

	Mean	Std. Dev.	Freq.
High contributors	6.163	2.274	1196
Everyone else	2.985	2.174	12468
Low contributors	1.683	1.814	4428
Everyone else	4.021	2.213	9236
Total	3.263	2.361	13664

Table 5: Lagged neighbors' contributions.

	Mean	Std. Dev.	Freq.
High contributors	4.453	2.295	1196
Everyone else	3.154	2.216	12468
Low contributors	2.550	2.192	4428
Everyone else	3.611	2.200	9236
Total	3.267	2.253	13664

Table 6: Lagged neighbors' contributions to other direct neighbor.

What the results in Tables 5 and 6 reveal is that a high contributor later triggers much higher contributions by his two neighbors who do not only reward him, but also their other direct neighbors. This evidence suggests direct (direct neighbors reward high contributions) and indirect (the direct neighbors of high contributors reward their other neighbors) reciprocity.[13]

This direct and indirect reciprocation in kind (high/low contributor type is generously/poorly rewarded and triggers generous/poor other contribution) is our first clear confirmation of interpersonal spillovers.

> <u>Result 7</u>: Allowing for only minimally required delay high (low) contributors first positively (negatively) affect contributions of their direct neighbors who not only

[13] More generally, direct reciprocity means that an actor, consciously helping or harming a reactor, is rewarded in kind, i.e. helped or harmed, by the reactor whereas indirect reciprocity means that the reactor responds in kind only or also, as in our setup, to others.

reciprocate in kind back to them but also contribute more (less) to their other direct neighbors.

In Tables 7 and 8 we apply this analysis to treatment T_a only to see how spillovers evolve in this treatment. The fact that we find qualitatively similar results in T_a as in the other treatments, even for the low productivity ($\alpha_L = 0.6$), reveals a striking interaction effect of intrapersonal and interpersonal spillovers: in spite of their different productivity T_a-participants rely on the same reciprocal reactions in their two local public good games.

	Left neighbor			Right neighbor		
	Mean	Std. Dev.	Freq.	Mean	Std. Dev.	Freq.
High contributors	6.503	2.686	326	5.877	3.143	326
Everyone else	3.571	2.956	3962	3.110	2.804	3962
Low contributors	2.381	2.899	1075	1.637	2.189	1075
Everyone else	4.266	2.935	3213	3.883	2.923	3213
Total	3.794	3.038	4288	3.320	2.924	4288

Table 7: Lagged neighbors' contributions (T_a only).

	Left neighbor			Right neighbor		
	Mean	Std. Dev.	Freq.	Mean	Std. Dev.	Freq.
High contributors	4.960	3.097	326	4.610	3.307	326
Everyone else	3.199	2.875	3962	3.740	3.008	3962
Low contributors	2.428	2.777	1075	2.926	2.993	1075
Everyone else	3.635	2.917	3213	4.101	2.999	3213
Total	3.333	2.929	4288	3.806	3.040	4288

Table 8: Lagged neighbors' contributions to other direct neighbor (T_a only).

Result 8: A high (low) contribution in treatment T_a triggers, on average, a lagged higher (lower) contribution by one's direct right neighbor (even when this neighbor's productivity is low) not only back to him but also to the other direct neighbor of his direct neighbors (see Table 8).

When comparing in Treatment T_a the effects of high and low contributors via their own direct neighbors on the other direct neighbors one has to keep in mind that they are indirectly connected via a member with low left and high right productivity. The effects, reported in Tables 7 and 8, are nevertheless similar to those in Tables 5 and 6 which Result 7 is based on. Since treatment T_a seemed like a worst-case scenario, for interpersonal spillovers (diffusion of voluntary cooperation could be hindered by interrupted reciprocation), this proves the robustness of purely behavioral spillover effects.

Result 9: Purely behavioral spillover effects are robustly confirmed.

4.1. Regression analyses of behavioral spillovers

To analyze the data more thoroughly and to validate the findings econometrically, we regress individual left (right) contribution at time t on own lagged left (right) contribution, round, period and both neighbors' average contribution at time $t-1$ (see Table 9).

Left contribution $c_i^L(t)$					
VARIABLES	T_l	$T_{a,l}$	T_m	$T_{a,r}$	T_h
$c_i^L(t-1)$	0.690***	0.721***	0.945***		0.917***
	(0.025)	(0.018)	(0.021)		(0.032)
round	-0.128**	-0.031	-0.080		-0.058
	(0.057)	(0.047)	(0.052)		(0.081)
period	-0.032**	-0.042***	-0.089***		-0.047**
	(0.014)	(0.011)	(0.013)		(0.022)
$c_{i-1}^L(t-1)$	0.478***	0.339***	0.428***		0.342***
	(0.028)	(0.021)	(0.023)		(0.035)
$c_{i+1}^R(t-1)$	0.144***	0.127***	0.058***		0.060*
	(0.026)	(0.020)	(0.021)		(0.033)
Right contribution $c_i^R(t)$					
$c_i^R(t-1)$	0.700***		0.944***	0.800***	0.889***
	(0.025)		(0.021)	(0.018)	(0.033)
round	-0.068		-0.120**	-0.105**	0.017
	(0.057)		(0.054)	(0.047)	(0.082)
period	-0.042***		-0.085***	-0.043***	-0.033
	(0.014)		(0.014)	(0.012)	(0.022)
$c_{i-1}^L(t-1)$	0.150***		0.090***	0.053***	0.077**
	(0.026)		(0.022)	(0.020)	(0.033)
$c_{i+1}^R(t-1)$	0.442***		0.473***	0.336***	0.387***
	(0.028)		(0.023)	(0.021)	(0.035)
Observations	2,496	4,288	5,184	4,288	1,696
Standard errors in parentheses					
$**p < 0.01, **p < 0.05, *p < 0.1$					

Table 9: Tobit regression of individual contributions.

Result 10: Left and right contributions depend significantly[14] on their past level, partly on round and period but also – in line with interpersonal spillovers – on direct neighbors' past contributions across all treatments. Past contributions of direct neighbors trigger own higher contribution, i.e. contributing to one's local public goods spreads like a disease across time.

The fact that left (right) contribution of a subject is very significantly affected by both right and left neighbors' contributions to him in the previous period $(t-1)$ even if they are

[14]When regressing differences $(c_i^L(t) - c_i^L(t-1))$, respectively $(c_i^R(t) - c_i^R(t-1))$ on lagged differences $(c_i^L(t-2) - c_i^L(t-3))$, respectively $(c_i^R(t-2) - c_i^R(t-3))$, the significance levels are less clearcut, see Table 15 in Appendix

two separated decisions, yet again proves behavioral spillovers.

Further details are (see Table 9) that "round" i.e. which supergame (of four successive ones), is not systematically significant, whereas "period " has a small negative but significant coefficient, in line with Result 3 (except for c_i^R and treatment T_h).

To trace interpersonal spillovers across the whole neighborhood with eight members we also assess the lagged effects of more distant contributions. Due to feedback only about contributions by direct neighbors, more distant contributions require larger lags as in the following definitions:

$$F_i^0(t) = \frac{[c_{i-1}^R(t) + c_i^L(t) + c_i^R(t) + c_{i+1}^L(t)]}{4},$$

summarizes all the determinants of i's payoff about which $i = 1, .., 8$ becomes informed after period t. $F_i^0(t)$ can affect only the contributions of i's direct neighbors in period $t+1$ whose average contribution feedback is

$$F_i^1(t+1) = \frac{[c_{i-2}^R(t+1) + c_{i-1}^L(t+1) + c_{i+1}^R(t+1) + c_{i+2}^L(t+1)]}{4}.$$

With the help of this notation, aggregate interpersonal spillovers can be measured by the difference

$$D_i^1(t+1) = F_i^0(t) - F_i^1(t+1),$$

where we constrain our analysis to all periods t from second to second-last period. Similarly, the further distant and delayed interpersonal spillovers of $F_i(t)$ can be measured by

$$D_i^2(t+2) = F_i^0(t) - F_i^2(t+2) \quad \text{and} \quad D_i^3(t+3) = F_i^0(t) - F_i^3(t+3)$$

with

$$F_2^1(t+2) = \frac{[c_{i-3}^R(t+2) + c_{i-2}^L(t+2) + c_{i+2}^R(t+2) + c_{i+3}^L(t+2)]}{4}$$

$$F_3^1(t+3) = \frac{[c_{i-4}^R(t+4) + c_{i-3}^L(t+3) + c_{i+3}^R(t+3) + c_{i+4}^L(t+3)]}{4}$$

Observe that, $i-4$ is the same society member as $i+4$, namely i's most distant neighbor. In this aggregated way the more or less delayed interpersonal spillovers can be traced across the circle via the averages of $D_i^1(t+1)$, $D_i^2(t+2)$, $D_i^3(t+3)$ across all members $i = 1, ..., 8$ and across all periods t for which they are defined. We refer to these average as D^1, D^2 and D^3 which are based on the minimal delays by which $F_i^0(t)$ can possibly influence $F_i^1(t+1)$, then $F_i^2(t+2)$, and finally $F_i^3(t+3)$.

Figure 7 depicts the dynamics of D^1, D^2, and D^3 across periods[15]: less distance and shorter delay generate smallest positive $D-$levels which grow initially and remain then essentially constant till the last possible period, when contributions, and thus their differences, decline sharply. Table 10 proves that this lagged influence, and thus the behavioral spillovers, are significant.

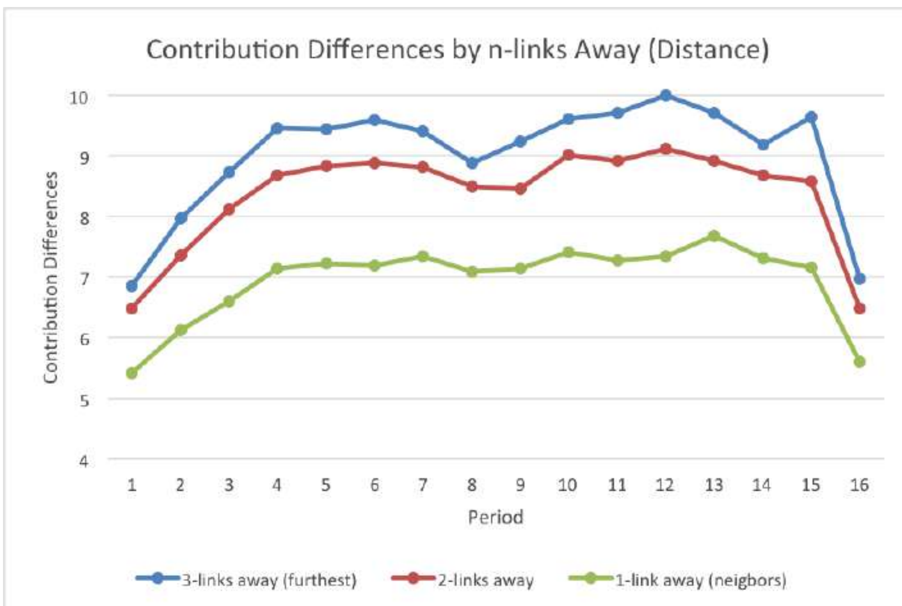

Figure 7: Contribution differences by n-link away

Result 11: Even when allowing only for minimal delays, behavioral spillovers affect significantly the whole neighborhood.

Note that the increase in contribution differences occurs only in the first four periods of each phase. This is particularly interesting since four represents exactly the number of periods needed for every member of the neighborhood to get indirect information, through intertemporal spillovers, from the most distant members of the group (3 links away). Once this information

[15]Table 16 in the Appendix report the numerical data regarding distances.

	D_i^n		
n	Mean	Std. Dev.	Freq.
1	6.974	6.029	13568
2	8.503	6.909	12160
3	9.245	7.505	10752
Total	8.153	6.851	36480

(a)

	D_i^n	
	Coef.	Std err.
2.distance	1.529***	(0.085)
3.distance	2.271***	(0.088)
Observations	36,480	
R-squared	0.019	

(b)

Table 10: Summary statistics (a) and regression (b) of difference in $n-$link away contribution by n (*** p<0.01, ** p<0.05, * p<0.1)

have been "taken into account" , the contribution differences between different distances become stable. This has been observed for all treatments. Once stabilized, the differences in contribution even between distant neighbors do not change over time. Since in some treatments contributions change between periods, this shows that the change in contributions happens almost simultaneously, i.e. behavior spreads with the shortest possible lag, through the neighborhood.

5. Heterogeneity Within and Across Treatment-Specific Neighborhoods

Before concluding, let us graphically illustrate that the robustly confirmed purely behavioral spillovers do not exclude individual heterogeneity across constant neighborhoods nor heterogeneity across neighborhood of the same treatment. We illustrate average contribution of individual members,[16] by grouping individual average contribution across periods as "Low", "Medium" and "High"[17]. Neighborhoods are ordered according to the following criteria:

(i) the homogeneity in contributions (the same color shade across all 8 members)

(ii) the local concentration of high contributors (neglecting dark color spots)

(iii) the partly singular high contributors (isolated dark color spots).

[16]Average contribution does not include periods 8 and 16 to exclude endgame behavior.

[17]Ranges for individual average contributions follow the same rationale of discrete ranges of Figure 6; since c^i is an average across periods, it is a continuous variable and so are the associated ranges.

In spite of only 35 neighborhoods, one can represent 47 societies by using the corresponding graphs, because when distinguishing for T_a, the asymmetric treatment, left and right contributions. We include these graphs since they visualize (by offering so-called "eyeballing") how voluntary contributions vary across and between neighborhoods and depend on treatments. In our view, statistical results do not always provide such an intuitive and immediate impression. Just to inspire "eyeballing" we state a few remarks.

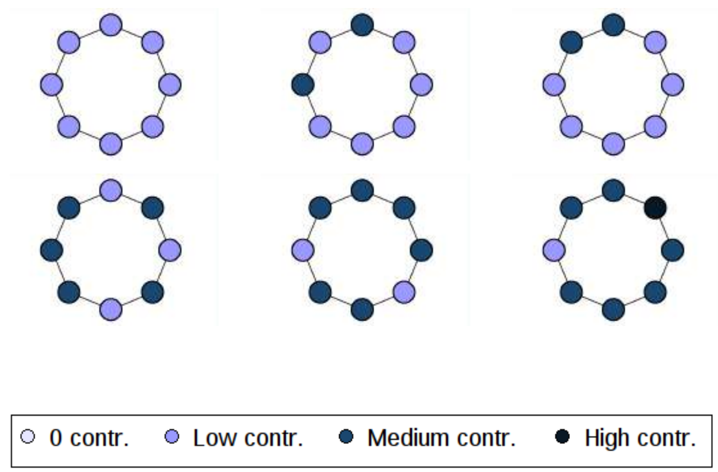

Figure 8: Treatment T_l

Remark 1: the upper left and lower right neighborhood differ most (in contributions).

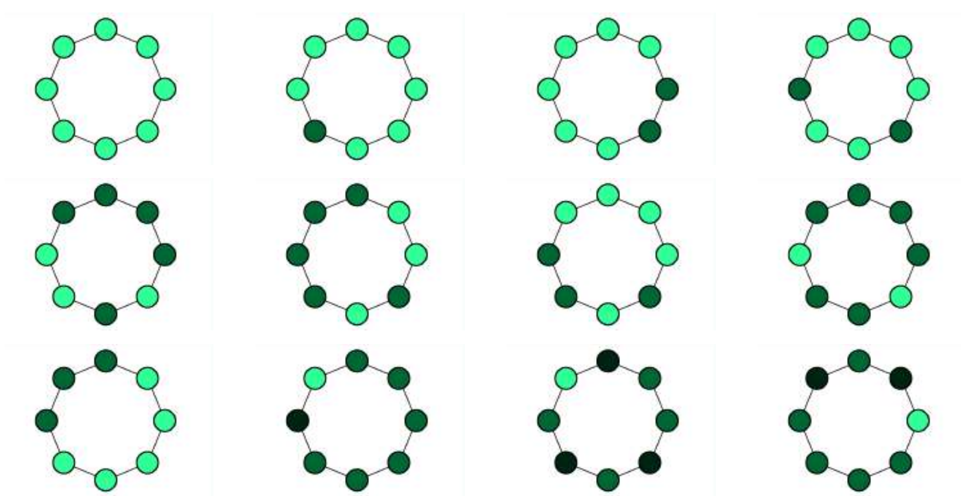

Figure 9: Treatment $T_{a,l}$

Remark 2: There are single lower as well as higher contributors even when there exists another contribution cluster in the circle

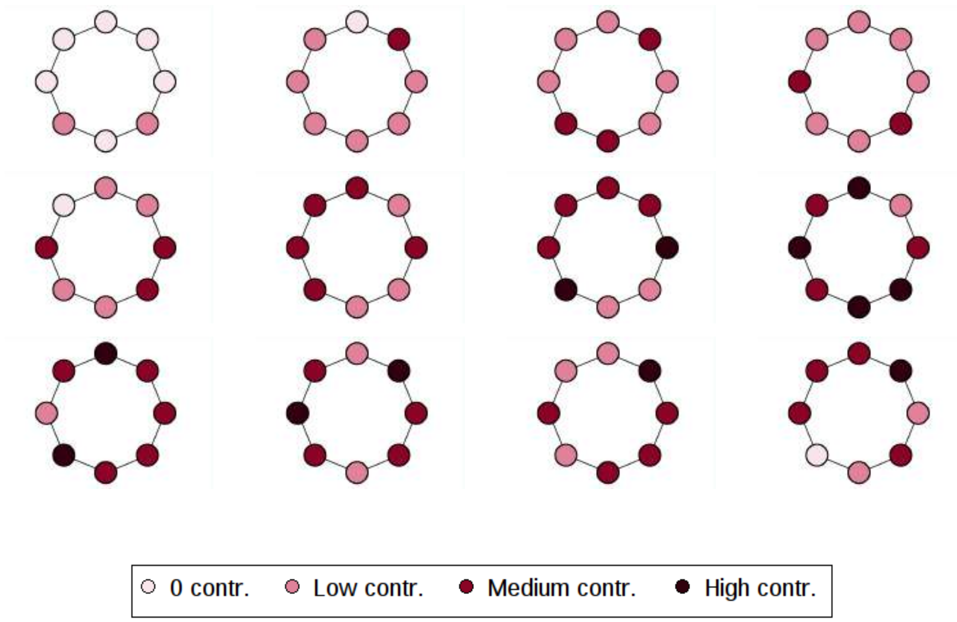

Figure 10: Treatment T_m

Remark 3: The upper left corner is the least cooperative one which apparently has unraveled voluntary contributions of nearly all members

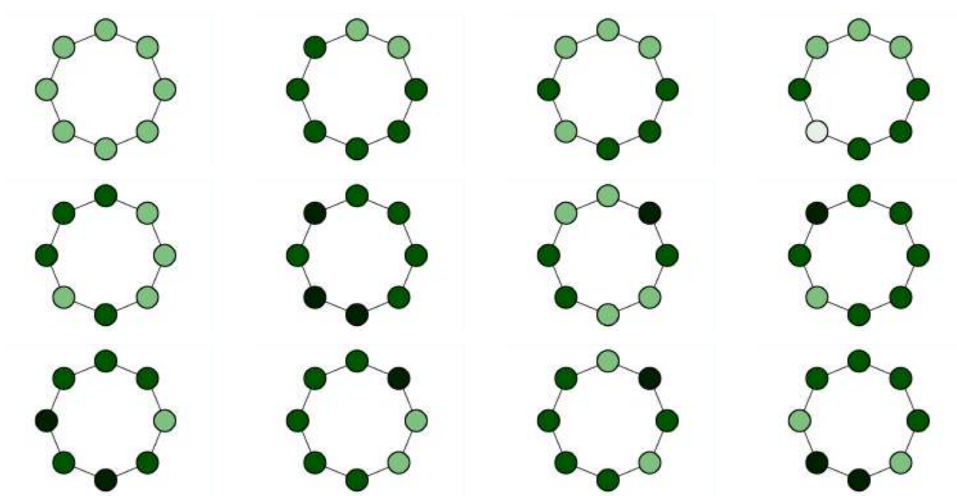

Figure 11: Treatment $T_{a,r}$

Remark 4: One homogeneous "medium" neighborhood (it exists also in treatment T_h)

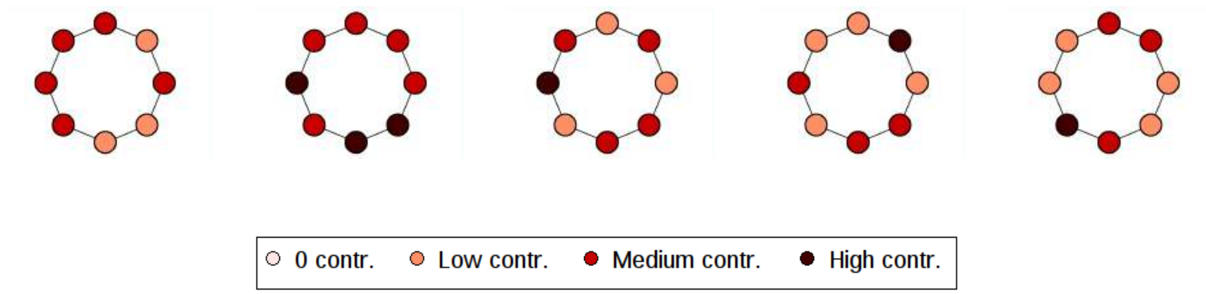

Figure 12: Treatment T_h

Graphs confirm, at a glance, the existence of behavioral spillovers, i.e. almost in each treatment one can identify one or more groups of homogeneous contributions (as an example upper left and lower right graphs for treatment T_l). Such homogeneity shifts towards higher homogeneous contributions passing from treatment T_l to treatment T_h, and confirms our previous results by showing an interesting similarity between $T_{a,r}$ and T_h.

6. Conclusions

What we have demonstrated with the help of our data may seem trivial from a social-psychological and sociological perspective: a neighborhood with eight members, who play two structural independent games, is more than just parallel play of isolated games with two players each.

Since all eight society members are connected by more or less bilateral interactions, they seem to become a "whole", e.g. in the sense of a collectivity whose members try to establish a rather high degree of voluntary cooperation, which they quickly re-establish when the anticipated restart occurs.

In our view, this does not justify, however, giving up methodological individualism. Actually by our data analysis we could demonstrate how the behavior of more distant society members first influences their direct interaction partners, then those direct interaction partners of their direct interaction partners, etc. ... form of a diffusion process according to which individuals consciously adapt their contribution choices even when receiving only local feedback information.

More specifically, we have shown that

- a decision maker facing completely unrelated interaction partners, e.g a commercial firm selling in two otherwise completely independent markets like those to which the Forbearance Hypothesis applies, nevertheless generates the choice behavior in a holistic way,

- local experiences become gradually appreciated by more and more members of of the neighborhood via learning even though learning is restricted only by local feedback information, and

- endgame behavior is anticipated and quickly forgiven when one is aware that the neighborhood may be prematurely terminated.

Furthermore, our results suggest that a local, asymmetric public good game can reduce not only freeriding, but also foster unconditional cooperation because, by some form of harmonic behavior, it favors symmetric cooperation aligned towards higher contributions. This could have an interesting policy implication since it reduces the costs of fostering cooperation.

Future research could study the coexistence and the co-evolution of purely behavioral and structural spillovers, based on experimental designs which hopefully allow distinguishing both. One idea could be that neighborhoods with one or some sub-neighborhoods consist of members that are all structurally interrelated whereas other members only confront bilateral interaction with direct neighborhoods, as in our setup.

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Appendix

	T_l	T_m	T_a	T_h	Total
Mean	3.009	3.314	3.635	3.878	3.452
Std. Dev.	2.393	2.739	2.526	2.691	2.618
Freq.	1536	3072	3072	1280	8960
Share of (0,0)	16.99%	23.24%	12.92%	14.38%	22.05%

Table 11: Average contribution by treatment in periods 1 to 8.

	T_l	T_m	T_a	T_h	Total
Mean	2.033	2.596	3.177	3.859	2.769
Std. Dev.	2.111	2.739	2.491	3.053	2.646
Freq.	1152	2496	1600	576	5824
Share of (0,0)	32.99%	35.54%	18.63%	24.13%	29.26%

Table 12: Average contribution by treatment in periods 9 to 16.

	T_l	$T_{a,l}$	T_m	$T_{a,r}$	T_h
T_l		-0.659 (0.000)	-0.412 (0.000)	-1.123 (0.000)	-1.278 (0.000)
$T_{a,l}$			0.240 (0.000)	-0.464 (0.000)	-0.619 (0.000)
T_m				-0.704 (0.000)	-0.859 (0.000)
$T_{a,r}$					-0.155 (0.074)
T_h					

Table 13: Two sample t-test on individual average contribution except period 8 and 16.

	T_l	$T_{a,l}$	T_m	$T_{a,r}$	T_h
T_l		-0.551 (0.032)	-0.454 (0.072)	-0.999 (0.001)	-1.182 (0.001)
$T_{a,l}$			0.097 (0.643)	-0.448 (0.046)	-0.630 (0.035)
T_m				-0.546 (0.023)	-0.728 (0.022)
$T_{a,r}$					-0.182 (0.305)
T_h					

Table 14: Two sample t-test on average contribution across all periods except period 8 and 16.

Left contribution $c_i^L(t) - c_i^L(t-1)$					
VARIABLES	T_l	$T_{a,l}$	T_m	$T_{a,r}$	T_h
round	-0.015	0.003	-0.028		-0.026
	(0.050)	(0.043)	(0.035)		(0.067)
period	-0.022*	-0.022*	-0.021**		-0.022
	(0.013)	(0.011)	(0.010)		(0.020)
$c_{i-1}^L(t-2) - c_{i-1}^L(t-3)$	-0.034	-0.037*	-0.010		0.041
	(0.027)	(0.023)	(0.019)		(0.037)
$c_{i+1}^R(t-2) - c_{i+1}^R(t-3)$	-0.008	0.007	0.010		-0.071*
	(0.027)	(0.023)	(0.019)		(0.037)
Right contribution $c_i^R(t) - c_i^R(t-1)$					
round	-0.018		-0.028	0.013	-0.033
	(0.050)		(0.036)	(0.043)	(0.069)
period	-0.019		-0.029***	-0.025**	-0.030
	(0.013)		(0.010)	(0.012)	(0.020)
$c_{i-1}^L(t-2) - c_{i-1}^L(t-3)$	-0.053*		-0.013	-0.059***	0.030
	(0.027)		(0.019)	(0.023)	(0.038)
$c_{i+1}^R(t-2) - c_{i+1}^R(t-3)$	-0.139***		-0.025	-0.053**	-0.062
	(0.027)		(0.019)	(0.023)	(0.038)
Observations	2,112	3,520	4,416	3,520	1,376
Standard errors in parentheses					
$***p < 0.01, **p < 0.05, *p < 0.1$					

Table 15: Regression of individual contributions' difference on neighbors' difference in average contribution.

	Distance Difference 1		Distance Difference 2		Distance Difference 3		
Period	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Freq.
1	5.408	4.339	6.486	5.215	6.848	5.370	1024
2	6.131	4.953	7.365	5.904	7.969	6.312	1024
3	6.592	5.524	8.117	6.283	8.730	6.554	1024
4	7.145	5.822	8.688	6.751	9.457	6.879	1024
5	7.223	6.131	8.828	6.872	9.434	7.404	1024
6	7.189	6.163	8.875	6.881	9.594	7.354	1024
7	7.340	6.208	8.816	7.065	9.406	7.317	1024
8	7.098	6.118	8.494	6.790	8.879	7.259	1024
9	7.141	5.883	8.468	6.634	9.235	7.170	680
10	7.418	6.390	9.018	7.337	9.606	8.021	680
11	7.274	6.462	8.915	7.283	9.712	7.882	680
12	7.344	6.505	9.112	7.530	9.994	8.168	680
13	7.682	6.659	8.909	7.522	9.706	7.835	680
14	7.315	6.458	8.679	7.366	9.188	8.190	680
15	7.153	6.481	8.579	7.399	9.653	7.967	680
16	5.597	5.760	6.488	6.284	6.976	6.712	680
Total	6.905	5.988	8.333	6.824	8.977	7.274	13632

Table 16: Difference in $n-$link away contributions by period

INSTRUCTIONS

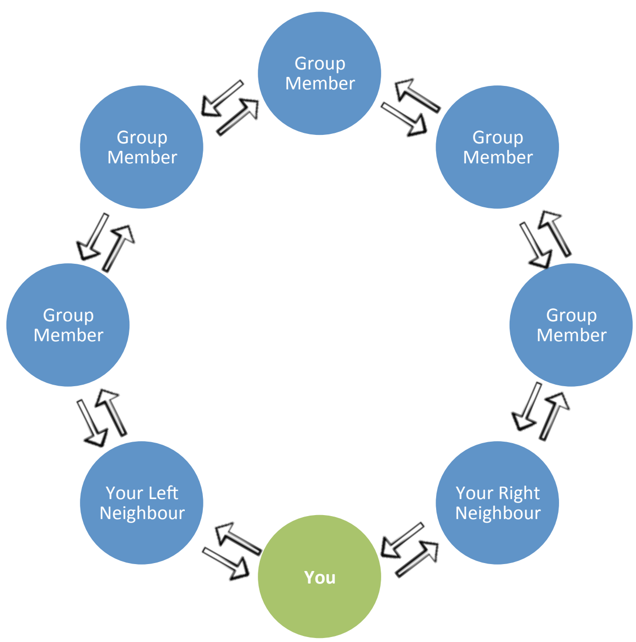
You are participating in an experiment about economic decision-making. During the experiment, you can earn money. Your earnings will depend on your decisions and the decisions of others. These instructions describe the decisions you and other participants should take and how your earnings are calculated. Therefore, it is important to read them carefully.

During the experiment, all the interaction between the participants will take place through computers. It is forbidden to communicate with other participants by any means. If you have any questions, please raise your hand and one of us will come to answer it. Keep in mind that the experiment is anonymous, i.e., your identity will not be disclosed.

During the experiment, your winnings will be calculated in points. At the end of the experiment the points will be converted to euro at the following exchange rate:

2 points = 0.5 €

In the experiment you will be a member of a group containing a total of 8 members, including you. For the purpose of this experiment you and the rest of the members in the group are positioned in a circular manner. This means that each member has a neighbour to the left and a neighbour to the right.



During the experiment, each of you will interact with **your two neighbors**, and these two neighbors are going to be the same two individuals for 1 round. In the experiment, there will be a total of 4 rounds. One round lasts either 8 or 16 periods (as it will be explained later). Therefore you will have to make either 8 or 16 decisions before the round ends. At the end of each round, your group consisting of eight members will be reshuffled randomly. For every member, at least one neighbor will be different from the previous round. *Keep in mind that you don't know the identity of your neighbors so you will not know if both of your neighbors are new, or just one of them.*

How many periods a round lasts depends on chance. A round will last for 8 periods with a probability of 1/3, and 16 periods with probability of 2/3.

In each period, you and your two neighbors will be endowed with points. More specifically, nine (9) points will be assigned to you for the interaction with your left neighbor, and nine (9) points will be assigned to you for the interaction with your right neighbor. The same amount of points will be assigned to both of your neighbors, and all other members in your group.

In each period, you will have to decide, individually and independently, how many of the 9 points you are endowed with you want to contribute to a project with your left neighbor; in what follows, this is referred to as Project L. Similarly, in each period you will have to decide, individually and independently, how many of the 9 points you are endowed with you want to contribute to a project with your right neighbor; in what follows, this is referred to as Project R.

Keep in mind that you can invest a maximum of 9 points to Project R and a maximum of 9 point to Project L; moreover, you cannot invest your points for Project R into Project L, and vise-versa.

You will keep for yourself the points you decide not to invest in either project. Therefore, you will keep for yourself 9-your contribution to Project L; similarly you will keep for yourself 9-your contribution to Project R. For example, you can invest 8 points in project R, and keep 9-8=1 for yourself, or invest 3 points in Project L and keep 9-3=6 to yourself.

Every member is going to make the decisions simultaneously.

PAYOFFS

Your payoff in each round will depend only on your own choices and on those of your two neighbours.

At the end of each period, your payoff is computed in the following manner:

For Project R: (9 - Your contribution) + 0.7 * (Your contribution + Your right neighbour's contribution)

For Project L: (9 - Your contribution) + 0.7 * (Your contribution + Your left neighbour's contribution)

EXAMPLE: Let's try to compute your payoff with the example given above. For the purpose of the example we imagine that both your right and left sided neighbors contribute 8 points. If you contribute 8 points into Project R, your payoff will be 0.7*(8+8)+1= 0.7*16 + 1= 11.2 + 1= 12.2. Similarly, if you contribute 3 points into Project L, your payoff will be 0.7*(3+8)+6= 7.7+6= 13.3.

In each of the successive periods, all group members will simultaneously choose their contributions to Project R and to Project L. *Keep in mind that you play multiple periods with the same participants and that you decide about your contribution without knowing the contributions of your neighbors.*

At the end of each period, each group member will be informed about own payoffs from Project L and from Project R, contributions by both left and right neighbours, and accumulated earnings from both projects.

What actually will earn is:

At the end of the experiment the program will automatically calculate your actual payoff given by the sum of the average payoffs in a round (Your average payoff of round 1 + Your average payoff of round 2 + Your average payoff of round 3 + Your average payoff of round 4) and will convert it at the given exchange rate (2 points = 0.5 €).