Does Heterogeneity Spoil the Basket? The Role of Productivity and Feedback Information on Public Good Provision

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Abstract

In a circular neighborhood of eight, each member contributes repeatedly to two local public goods, one with the left and one with the right neighbor. All eight two-person games provide only local feedback information and are structurally independent in spite of their overlapping player sets. Heterogeneity is induced intra-personally by asymmetric productivity in left and right games and inter-personally by two randomly selected group members who are less privileged (LP) by being either less productive or excluded from end-of-period feedback information about their payoffs and neighbors' contributions. Although both LP-types let the neighborhood as a whole evolve less cooperatively, their spillover dynamics differ. While less productive LPs initiate "spoiling the basket" via their low contributions, LPs with no-end-of-round information are exploited by their neighbors. Furthermore, LP-positioning, closest versus most distant, affects how the neighborhood evolves.

Keywords: Public goods, Behavioral spillovers, Voluntary contribution mechanism, Heterogeneity, Experiment
JEL: C91, C72, H41

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1. Introduction

The existence and evolution of behavioral spillovers have been analyzed in different experimental settings (see e.g. Savikin and Shemereta, 2013, Bednar et al. 2012, Cason et al., 2012, Cason and Gangadharan, 2013 and Falk et al., 2013, for coordination and competitive games; Bernasconi et al., 2009 and Falk et al., 2013 for public good games).[1] Most studies assume symmetry and homogeneity, what may imply an implicit demand effect for correlating behavior across structurally independent games and question whether behavioral spillovers can also be robustly confirmed in situations with intra- and inter-personal heterogeneity.

Excluding asymmetry and heterogeneity simplifies the experimental setting at the cost of external validity since behavior in the field crucially depends on the heterogeneity of group members and on their relative positioning. So external validity of behavioral spillovers specifically requires robustness also in cases of heterogeneity which may not only be intra- but also inter-personal.

Circular neighborhoods with overlapping two-player sets involving bilateral linear public good games are convenient paradigms to explore local, e.g. bilateral interaction, embedded in a more global setup. Each group member confronts only one left and one right neighbor in two structural independence bilateral interactions. Such bilateral interaction is typical for neighborhoods in the field, even though local interaction can be more widespread. An example would be two neighbors who have to agree how to separate their gardens by a fence or wall. In a circular neighborhood each member has to agree independently with each neighbor how nicely and costly to divide their gardens. We capture this experimentally by letting both neighbors contribute voluntarily assuming that the sum of their contributions determine (linearly) the size or quality of their common fence or wall.

Asymmetry, i.e intra-personal heterogeneity, is captured by different productivities in one's left and right bilateral interaction, smaller in the former and larger in the latter. This feature is common to all treatments and in the Baseline treatment is the only type of heterogeneity which we allow for.[2]

We additionally allow for inter-personal heterogeneity by considering two (randomly selected) less privileged group members, referred to as LP-members (LPs). We focus on two very different types of heterogeneity: one in free-riding incentives and the other in feedback information.[3] Compared to the Baseline treatment, in the "low productivity" treatment

[1]Most of this literature focus on how an individual, successively facing multiple independent games, correlates behavior across them. Falk et al. (2013), instead, investigate social interaction effects when two identical public good games are played simultaneously with different sets of opponents.

[2]See Angelovski et al. (2018) where we allow only for intra-personal heterogeneity.

[3]The literature on public goods experiments partly considers other forms of heterogeneity, for example in

(hereafter PROD), LPs are less productive on both sides. In the "no information" treatment (hereafter INFO), LPs are excluded from end-of-period feedback information about their neighbors' contributions and their own payoff while maintaining the same productivities as in the Baseline treatment. Relative positioning of the two same-type LPs in the neighborhood is either close or maximally distant.

Structural independence of all two-person public good games is induced by local feedback information and separate individual endowments for both games.[4] Structural independence, in the sense that when both choice tasks are played once, renders free-riding strictly dominant.[5] Nevertheless, structural independence of local games does not guarantee their behavioral independence. Intra-personal spillovers can occur if agents link own left and right contributions. Furthermore, due to overlapping player sets, conditional cooperation may imply inter-personal spillovers and more or less co-evolving contributions. This interplay of intra- and inter-personal spillovers may trigger contribution dynamics to which we refer as (purely) behavioral spillovers. Based on the analysis and results of Angelovski et al. (2018),[6] we expect most group members to be discrimination averse (by not wanting to treat equals unequally) and reciprocators (in the sense of conditional cooperation) even when inducing inter-personal heterogeneity across group members.

Since LPs may weaken conditional cooperation, we predict inter-personal heterogeneity to moderate the dynamics of coevolving contributions in the neighborhood but not to question purely behavioral spillovers. Thus we predict and hope to confirm behavioral spillovers as robust to both, intra- as well as inter-personal heterogeneity.

Furthermore, we analyze how purely behavioral spillovers depend on LP-type. Specifically we expect less productive LPs to contribute less often and LPs excluded from end-of-period feedback information to inspire their neighbors' free-riding. Since participants are aware of LPs and their type but not of their positions in the neighborhood, regular members, suspecting a less productive LP neighbor, may contribute less when unwilling to excuse their neighbor's lower contribution by the higher free-riding incentive. Similarly, a regular member, suspecting an uninformed LP, may try to exploit his/her neighbor, hoping that

wealth and income (see Buckley and Croson, 2006; Chan et al., 1999), capabilities and valuation (see Kölle, 2015) and in group composition (see Burlando and Guala, 2005; Smith, 2011; Grund et al., 2018, consider partners-strangers group composition, whereas Bardsley and Sausgruber, 2005, Fischbacher and Gächter, 2010, and de Oliveira et al. 2015, consider composition of conditional cooperators and selfish players).

[4]For a study with overlapping player sets in a circular neighborhood without structurally independent local games, meaning that all group members are strategically interacting, see Boosey (2017).

[5]Due to a commonly known upper bound for the number of successive periods backward induction, in the sense of repeated elimination of dominated strategies, justifies free-riding even for finite horizon games.

[6]Our companion study shows that participants anchor intra-personally behavior on the higher marginal per capital return and that this enhances and stabilizes voluntary cooperation across the whole neighborhood.

this remains unnoticed. Finally, we investigate if close or distant positioning of LPs trigger different dynamics of voluntary cooperation.

According to our data both LP types reduce voluntary cooperation compared to the Baseline. Nevertheless, while behavioral spillovers prevail in both treatments, voluntary cooperation differs across LP types. Less productive LPs contribute less what contaminates the whole neighborhood. LPs with no end-of-period information feedback, on the contrary, are on average the highest contributors but often, as expected, exploited by their neighbors. Furthermore, the relative distance of LPs can affect how the neighborhood evolves as whole.

Our approach to robustly assess effects of intra-personal asymmetry and inter-personal heterogeneity on purely behavioral spillovers seems novel and quite different from the existing literature. We, however, share some insights with studies examining within-group heterogeneity in free-riding incentives, ranging from Fisher et al. (1995) to contributions like Noussair and Tan (2011), Reuben and Riedl (2009, 2013), Fischbacher et al. (2014) and Kölle (2015). Specifically, we confirm results concerning the effects of different marginal per capita returns (MPCR hereafter). So far only de Oliveira et al. (2015) allow for heterogeneity in group composition via "selfish Bad Apples" (i.e. subjects identified as freeriders in a pretest) and analyse how their presence affects others and reduces group efficiency, while Grund et al. (2018) form heterogeneous groups in a public good game by varying the number of stranger versus partner participants in each group.

Our INFO treatment is related to studies varying feedback information in symmetric public good games (Marwell and Ames, 1981; Sell and Wilson, 1991; Chan et al., 1999; Neugebauer et al., 2009; Bigoni and Suetens, 2010; Grechenig et al., 2010 and de Oliveira et al., 2015). We confirm that participants without feedback information contribute significantly more than participants with feedback information.

Circular networks have been frequently compared to other networks (see for example Eckel et al., 2010; Suri and Watts, 2011; and Carpenter et al. 2012). However, our circular neighborhood is hardly comparable as it implements structurally independent bilateral games (Eckel et al., 2010, and Carpenter et al., 2012, provide local feedback but all participants contribute to and benefit from a single public good). Suri and Watts (2011) and Carpenter et al. (2012) also vary the network structure. Falk et al. (2013) let each participant confront two independent three-player public good games with homogeneous productivities.

Section 2 illustrates the experimental design and states our hypotheses. Section 3 presents and discusses the main results. We conclude in Section 4 with summary remarks and interpretations. The translated instructions are reported in the Appendix.

2. Experimental design and hypotheses

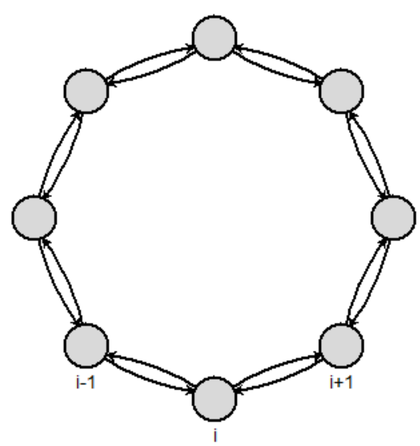
Participants form a circular neighborhood with eight members. Each member $i = 1, .., 8$ is involved in two linear public good games, one with the left neighbor $i-1$ (where $i-1 = 8$ for $i = 1$) and one with the right neighbor $i+1$ (where $i+1 = 1$ for $i = 8$). Figure 1 locates participant i at the bottom of the circular neighborhood.

For $i = 1, ..., 8$, let c_i^L and c_i^R denote i's left, respectively right, contribution. We restrict c_i^L and c_i^R to integers $(0, 1, ..., 9)$ to strengthen structural independence of one's left and right game via independent choice sets as well as by game specific endowments. Individual payoffs are:

$$2E - c_i^L - c_i^R + \alpha(c_i^L + c_{i-1}^R) + \beta(c_i^R + c_{i+1}^L) \qquad for \quad i = 1, ..., 8, \tag{1}$$

where $E = 9$ is the periodic initial endowment per public good game (on either side). MPCR α applies to i's left game, whose total public good contribution is $c_i^L + c_{i-1}^R$, and β to i's right game with total public good contribution $c_i^R + c_{i+1}^L$.

Figure 1: Circular neighborhood with the representative member i at the bottom



The asymmetric treatment of Angelovski et al. (2018) with $\alpha = 0.6$ and $\beta = 0.8$ is the Baseline treatment. In addition to its intra-personal heterogeneity, we add inter-personal heterogeneity via two LP-members, both of the same type, PROD and INFO.

For the PROD type we assume $\alpha = 0.4$ and $\beta = 0.6$ letting a less privileged member i earn:

$$2E - c_i^L - c_i^R + 0.4(c_i^L + c_{i-1}^R) + 0.6(c_i^R + c_{i+1}^L), \tag{2}$$

while the payoff of a regular member i is:

$$2E - c_i^L - c_i^R + 0.6(c_i^L + c_{i-1}^R) + 0.8(c_i^R + c_{i+1}^L) \tag{3}$$

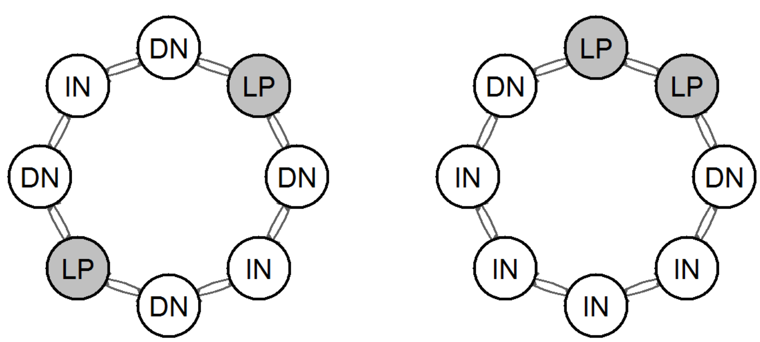
INFO LP-members have the same productivities as in the Baseline treatment, hence their payoff is as in (3) with $\alpha = 0.6$ and $\beta = 0.8$. But INFO-LPs are excluded from end-of-period feedback information about their neighbors' contributions and their own payoffs, while all others, including PROD-LPs, receive information on their neighbors' contributions and their own payoff before a new period begins.

2.1. Protocols

In each treatment subjects play repeatedly four supergames. Each supergame has a random but commonly known finite horizon of either eight (with probability 1/3) or sixteen periods (with probability 2/3). The actual horizon of each supergame is randomly determined by the computer after the eighth period. In each supergame subjects interact repeatedly with the same neighbors. Across successive supergames subjects' positions in the neighborhood are randomly reshuffled such that each member has at least one new neighbor.[7]

At the beginning of every supergame the computer randomly selects two members as LPs, who are either next to each other or maximally distant (see Figure 2). All group members are informed about the LP-type, PROD or INFO, but not about their relative positioning. LP distance is held constant for two successive supergames and then changed for the remaining two. We distinguish an increasing sequence (LPs are neighbors in the first two supergames and distant in the last two) and a decreasing one (LPs are distant first and neighbors later).

Figure 2: Distance variation of LPs distinguishing group members' types: Less Privileged (LP), their neighbors (DN) and indirect neighbors (IN)



[7]Participants are assigned positions randomly at the beginning of every supergame through zTree's random number generator, then the software makes a check of whether both neighbors are the same as in the previous supergame and, if they are, repositions them again until they have at least a new neighbor.

Summing up, the four between-subject treatments vary two dimensions: LP-type (PROD and INFO) and distance sequence (Increasing and Decreasing distance, see Table 1).

Table 1: $2 \times 2-$factorial treatment design and the Baseline

		LP-type	
		Lower productivity (PROD)	No feedback information (INFO)
LP-distance sequence	Increasing	8 Neighborhoods (64 Subjects)	9 Neighborhoods (72 Subjects)
	Decreasing	9 Neighborhoods (72 Subjects)	8 Neighborhoods (64 Subjects)
Baseline treatment[a] (without LPs)		12 Neighborhoods (96 Subjects)	

[a] For this treatment, we use the data of Angelovski et al. (2018).

The experiment was run at CESARE lab of LUISS Guido Carli (Rome, IT) with 272 subjects participating in the four additional treatments with LPs, divided into 34 groups of 8 participants each. The Baseline treatment (without LPs) employed 96 participants, i.e. 12 groups of 8. An experimental session included two or three such groups and no subject participated in more than one session. Each session lasted, on average, 100 minutes. At the end of the last supergame the computer randomly selected one supergame for final payment, the average payoffs in that supergame. The average earning of participants was 20€. The experiment was programmed with Z-Tree (Fischbacher, 2007) and used Orsee (Greiner, 2015) for recruitment.

2.2. Hypotheses

The mechanism of purely behavioral spillovers assumes that group member i (the group member at the bottom in Figure 1) determines the left c_i^L and right c_i^R contribution in a correlated way. If, additionally, contributions of pairs in which i is involved, i.e. $\{i-1, i\}$ and $\{i, i+1\}$, are also correlated, this obviously links the behavior of $i-1$ and $i+1$ although they are not directly interacting. In this way, across time, all group members i can affect the entire neighborhood via behavioral spillovers. Our main hypothesis is that

(M) The correlated evolution of contributions, referred to as purely behavioral spillovers, is still observed in the presence of two LP-members of the same LP-type in both treatments, PROD or INFO.

Hypothesis M, in our view, is justifiable by a mechanism postulating intra-personal correlation of left and right individual contributions due to individual discrimination aversion and inter-personal correlation due to conditional cooperation of overlapping neighbor pairs.[8] In the Baseline treatment all eight members are homogeneous in spite of their different left and right free-riding incentives. So in the Baseline one would avoid discrimination when wanting to treat equals equally.[9] However, two LPs may question such a desire, what demonstrates that the additional inter-personal heterogeneity due to two LPs is a serious challenge for purely behavioral spillovers.

When comparing treatments with LPs and the Baseline treatment without them, we expect to confirm that

(C) Neighborhoods with two LPs, of either type, contribute less than those of the Baseline treatment.

Hypothesis C is based on the intuition that lower productivity (MPCR) has a direct negative impact on contributions. Furthermore, since participants with no end-of-period feedback information are unable to conditionally cooperate, they are either likely to decrease own contributions when fearing exploitation or may be exploited by their neighbors.

We abstain from speculating which LP-type triggers more voluntary cooperation than the other and just test whether there is a significant difference against the null hypothesis:

(N) Voluntary cooperation does not significantly depend on the LP-type.

Regarding how LPs are positioned in the neighborhood, i.e. whether they are next to each other or far apart, we predict that

(P) Voluntary cooperation significantly depends on LP-positioning.

Hypothesis P is based on the fact that distant LPs have a larger number of direct non-LP neighbors, what can affect the dynamics of behavioral spillovers.

Beyond these hypotheses we are interested in restart, end-game effects and the path dependence via learning about neighbors past contributions.

3. Results

To answer whether purely behavioral spillovers survive inter-personal heterogeneity, we first assess the effects of including LPs, of either type, on average group contributions in subsection 3.1.

[8] Conditional cooperation of repeatedly interacting parties has been widely confirmed (see Selten and Stoecker, 1986, Axelrod, 1986, Fischbacher and Gächter, 2001 and Kocher et al., 2008 for a review).

[9] See Homans (1961).

Subsequently, subsection 3.2 is devoted to questions like:

(i) Do differences (if any) in average contribution behavior, compared to Baseline, originate in LP-behavior, or do they result from behavioral differences of non-LP members?

(ii) Do the contribution dynamics of the neighborhood differ between LP-types?

Subsection 3.3 explores the effects of LP-positioning for both LP-types what may provides policy suggestions on how to best mitigate the adverse (or boost the positive) effects of LPs on neighborhood.

3.1. Differences from Baseline behavior

Table 2 reports average group contributions in the INFO and PROD treatments as well as in the Baseline, pooled across left and right public good and across all periods, and also separately for the first and second eight periods of supergames to illustrate possibly endogenous restart effects.

To rely on as conservative statistical analysis as possible, we apply two-independent sample t-tests on average group contribution by supergame (aggregating across periods): with LP-members, average contributions are significantly lower than the Baseline. While there is a significant difference (which is weak for PROD) already in the first eight periods, the differences to Baseline further increase for both LP-types in the second half of the supergame (after an endogenous restart).

Table 2: Average contribution by treatment with tested treatment differences (two-independent sample t-test)

	Baseline	PROD	INFO
All Periods			
Avg.	3.478	2.861	2.748
Diff. from Baseline		-0.617**	-0.730**
Periods 1-8			
Avg.	3.635	3.197	3.015
Diff. from Baseline		-0.438*	-0.620**
Periods 9-16			
Avg.	3.177	2.329	2.295
Diff. from Baseline		-0.848***	-0.882***

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Finding 1: Irrespective of their type, (two) LP-members significantly lower average contributions compared to the Baseline.

To better understand this finding, we compare average contributions in the first period of firstly played supergames in PROD and INFO treatments with those in the Baseline. Initial average contributions do not differ from Baseline when LPs' contributions are included (p-value=0.569 when comparing PROD with Baseline, and p-value=0.505 when comparing INFO with Baseline, using two-independent sample t-test). Also when excluding LPs' contributions, differences from Baseline remain not significant (p-value=0.599 when comparing PROD with Baseline, and p-value=0.478 when comparing INFO with Baseline, using two-independent sample t-test). This suggests that differences in contributions from Baseline emerge via repeated interaction of overlapping neighbor pairs and are not immediately triggered by the common awareness of the presence of LPs.

3.2. Behavioral spillovers in spite of inter-personal heterogeneity

Since common awareness of LPs' presence is not what initiates the decline in contributions, we investigate whether lower contributions result directly from LPs and only affect other members over time or from other neighborhood members.

Figure 3 illustrates the dynamics of contributions in PROD, INFO and Baseline treatments. There is a distinct difference in contribution dynamics: in PROD the decay of contributions is strongest for LPs whereas in INFO the decrease appears to be triggered by their direct neighbors (DN), who seem to detect and exploit their LP-neighbors. This, in turn, often spills over to indirect neighbors (IN) and affects the whole neighborhood. Direct (DN) and indirect (IN) neighbors contributions differ more (less) in PROD (INFO) treatments, in spite of their decline across periods, except for common restarts. Figure 3 also reveals higher (lower) variability in contributions across group member types in PROD (INFO) treatments.

Figure 3: Contribution dynamics of PROD (left panel) and INFO (right panel) treatments by subject types and of Baseline

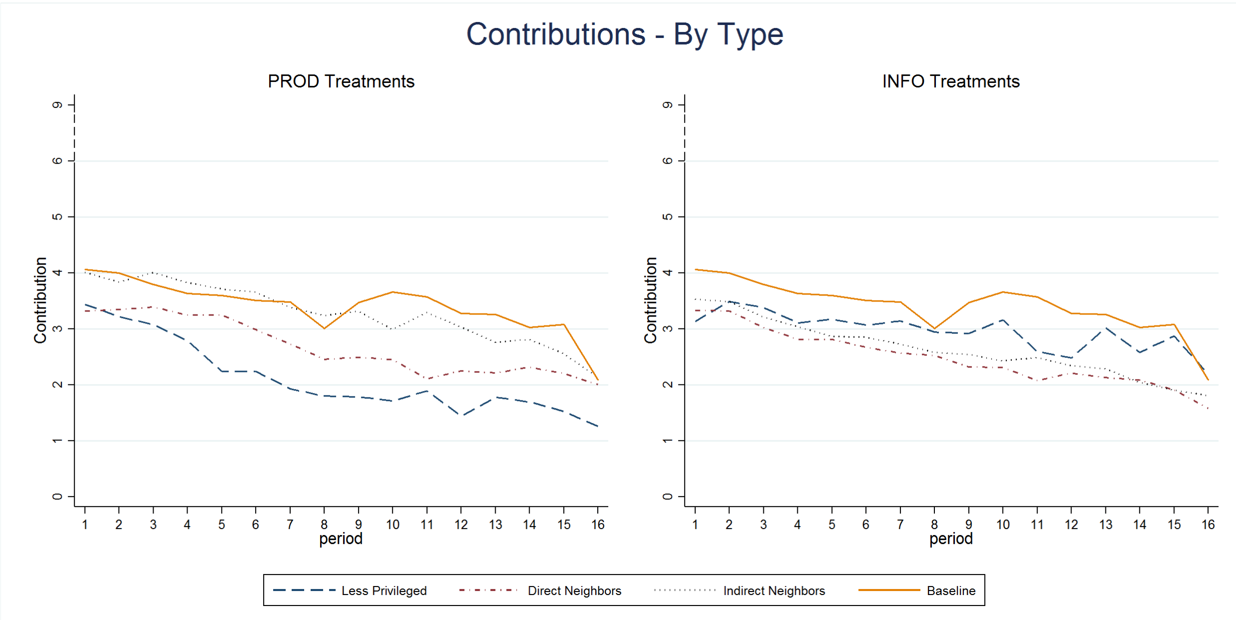


Table 3 compares contributions in PROD and INFO treatments by LPs, their direct (DN) and indirect (IN) neighbors. The unit of observation is average (across periods of the same supergame) group contribution by type what allows for conservative two sample t-tests. Indirect neighbors contribute more in PROD than in INFO treatments (3.379 vs. 2.744, p-value < 0.001), while there is no significant difference between direct neighbors in both treatments. PROD-LPs contribute significantly less in INFO-LPs (p-value < 0.001).

Table 3: Average contribution by player type with tested treatment differences (two-independent sample t-test)

	LP	DN	IN
PROD	2.221	2.767	3.379
INFO	3.012	2.578	2.744
Difference	0.791***	-0.189	-0.635***

Significance levels: *** p<0.01, ** p<0.05, * p<0.1

Comparing average contribution by type within treatments, we find that LPs contribute less than all other types in PROD and more than any other type in INFO. In particular, in PROD LPs contribute on average 2.221, their DNs 2.767, and INs 3.379. In INFO, LPs contribute on average 3.012, their DNs 2.578, what qualifies them as the lowest contributors, and INs 2.744.[10]

Finding 2: LPs with lower productivity differ in contributions from those without feedback information: PROD-LPs are lowest and INFO-LPs are highest contributors.

Figure 3 and Table 3 provide also a first indication that behavioral spillovers may occur even in neighborhoods with intra-personal heterogeneity. To confirm behavioral spillovers for both types of LPs, we report in Table 4 the estimates of a two-limit random-effects tobit model with group dummies[11] for left and right contributions at period t.[12] The set of regressors includes own lagged left (Left contribution $(t-1)$), respectively right (Right contribution $(t-1)$) contribution, one-period lagged contributions of left (L neighbor $(t-1)$) and right (R neighbor $(t-1)$) neighbors, period and supergame dummies. For LP-treatments it also includes dummies for the three member types: LP, DN and IN.[13]

Results show that in PROD and INFO treatments the effect of lagged left (right) neighbor contribution on current own right (left) contributions is statistically significant. Thus participants correlate how they behave in their two structurally independent games what confirm intra-personal behavioral spillovers and thereby purely behavioral spillovers also in case inter-personal heterogeneity.

Finding 3: In LP-neighborhoods, intra-personal spillovers exist both in PROD and INFO treatments.

Table 4 also reveals decay of voluntary cooperation across supergames and periods (in line with the usual decline in repeated public goods experiments) as well as path dependence of left and right contributions. Since current contributions are positively affected by one-period lagged own contributions on the same side, there is also own path dependence in behavior. Table 5 reports the results of a two-limit random-effects tobit model with group dummies for the effects of own and neighbors' type on (left or right) contributions in period t (for example the dummy variable LP to LP compares the contribution of a LP to another neighboring LP with the reference category IN to DN, i.e. the contribution of indirect neighobors to direct

[10] Almost all differences between member types of the same treatment are statistically significant (conservative two-independent sample t-test average contributions across periods of the same supergame). PROD treatment: LP vs. DN p-value = 0.000, LP vs. IN p-value = 0.000, DN vs. IN p-value = 0.000; INFO treatment: LP vs. DN p-value = 0.004, LP vs. IN p-value = 0.085, DN vs IN. p-value = 0.222.

[11] Results are consistent with a two-nested level (mixed effects) regression.

[12] The difference in observations is due to the random horizon rule (subjects in INFO treatments happened to play less often till sixteen periods compared to PROD treatments).

[13] Note that when LPs are next to each other, there exist two direct and four indirect neighbors; when LPs are far apart, there are four direct and two indirect neighbors (see Figure 2).

Table 4: Panel tobit regression of left-hand side and right-hand side contributions

	Left contributions at time t			Right contributions at time t		
	Baseline	PROD	INFO	Baseline	PROD	INFO
Left contribution $(t-1)$	0.506***	0.527***	0.514***			
	(0.021)	(0.017)	(0.017)			
Right contribution $(t-1)$				0.544***	0.575***	0.571***
				(0.020)	(0.017)	(0.016)
L neighbor $(t-1)$	0.299***	0.281***	0.176***	0.039**	0.066***	0.047***
	(0.018)	(0.015)	(0.014)	(0.018)	(0.015)	(0.014)
R neighbor $(t-1)$	0.067***	0.033**	0.039***	0.367***	0.334***	0.182***
	(0.018)	(0.016)	(0.015)	(0.019)	(0.016)	(0.015)
Period	-0.078***	-0.080***	-0.050***	-0.083***	-0.073***	-0.059***
	(0.012)	(0.009)	(0.008)	(0.012)	(0.009)	(0.009)
Supergame 2	-0.003	-0.629***	-0.292***	-0.176	-0.200*	-0.439***
	(0.136)	(0.107)	(0.096)	(0.136)	(0.110)	(0.099)
Supergame 3	-0.258*	-0.703***	-0.768***	-0.315**	-0.596***	-0.870***
	(0.134)	(0.110)	(0.101)	(0.134)	(0.113)	(0.105)
Supergame 4	-0.170	-1.010***	-1.227***	-0.634***	-0.707***	-1.155***
	(0.142)	(0.113)	(0.102)	(0.143)	(0.116)	(0.105)
Ref. Category: indirect neighbors (IN)						
LP		-0.627***	0.380***		-0.613***	0.532***
		(0.114)	(0.096)		(0.118)	(0.099)
Direct neighbors of LPs (DN)		-0.083	-0.122		-0.237**	0.059
		(0.099)	(0.083)		(0.101)	(0.086)
Group dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,288	6,560	6,365	4,288	6,560	6,365
Number of i	96	136	136	96	136	136

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

neighbors). Using contributions from indirect neighbors to direct neighbors as the reference category, contributions of LPs to LPs are higher in INFO treatments on the right, i.e. more productive, side. The same pattern occurs when LPs contribute to direct neighbors: it seems that LPs in INFO treatments trust that their neighbors will not exploit them but reciprocate their cooperative behavior.

Table 5: Panel tobit regression of individual left and right contributions on type constellation, distinguishing own and neighbor's type (LP for less privileged, DN for direct neighbor and IN for indirect neighbor). Reference category are contributions of INs to DNs

	Left contributions at time t		Right contributions at time t	
	PROD	INFO	PROD	INFO
Ref. Category: IN to DN				
LP to LP	-1.219***	-0.052	-1.962***	0.404**
	(0.212)	(0.186)	(0.228)	(0.192)
LP to DN	-0.674***	0.417***	-1.277***	0.475***
	(0.154)	(0.132)	(0.156)	(0.138)
DN to LP	-0.265*	-0.437***	-0.987***	0.106
	(0.152)	(0.132)	(0.156)	(0.132)
DN to IN	0.475***	-0.168	-0.258*	-0.106
	(0.146)	(0.127)	(0.155)	(0.135)
IN to IN	0.762***	-0.297**	0.307**	-0.148
	(0.142)	(0.135)	(0.147)	(0.136)
Period	-0.166***	-0.100***	-0.180***	-0.120***
	(0.009)	(0.008)	(0.009)	(0.008)
Supergame 2	-1.421***	-0.776***	-1.011***	-1.006***
	(0.112)	(0.099)	(0.118)	(0.104)
Supergame 3	-1.750***	-1.566***	-1.806***	-1.818***
	(0.113)	(0.101)	(0.120)	(0.107)
Supergame 4	-2.246***	-2.414***	-2.119***	-2.546***
	(0.115)	(0.098)	(0.122)	(0.103)
Group dummies	Yes	Yes	Yes	Yes
Observations	7,104	6,908	7,104	6,908
Number of i	136	136	136	136

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

For PROD treatments, Table 5 reveals lower contributions of LPs to LPs on both sides and that more distance from an LP increases average contributions and that contributions of INs to INs in PROD are significantly higher than in the reference category (IN to DN) what once again confirms spillovers across structurally independent games.[14]

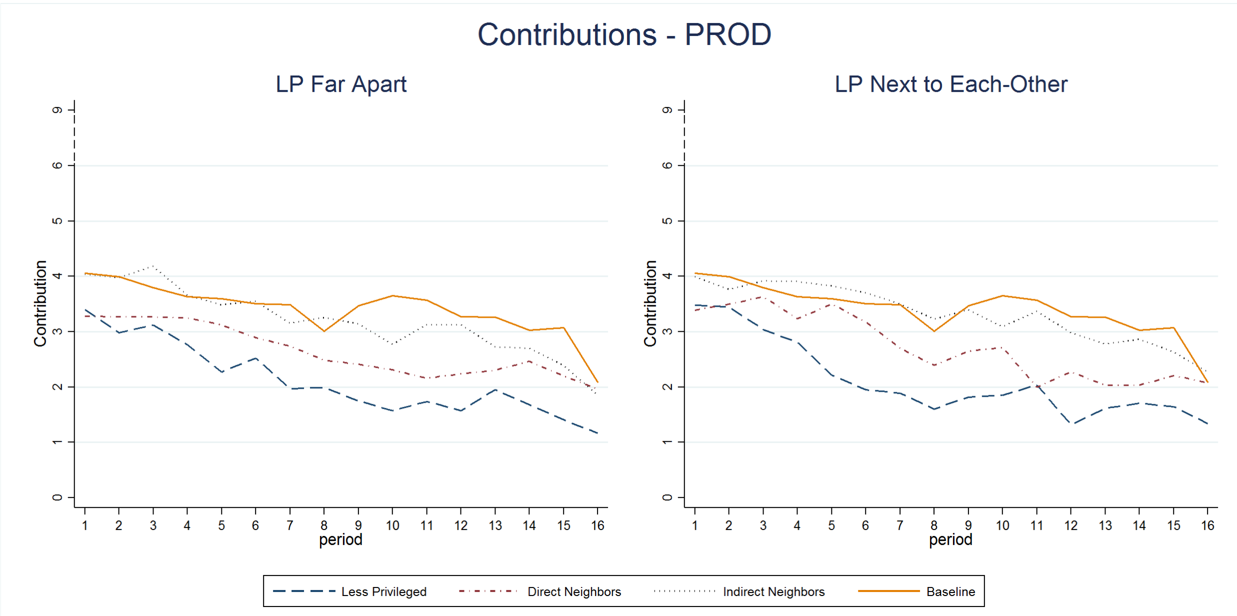
3.3. Effects of LP-positioning

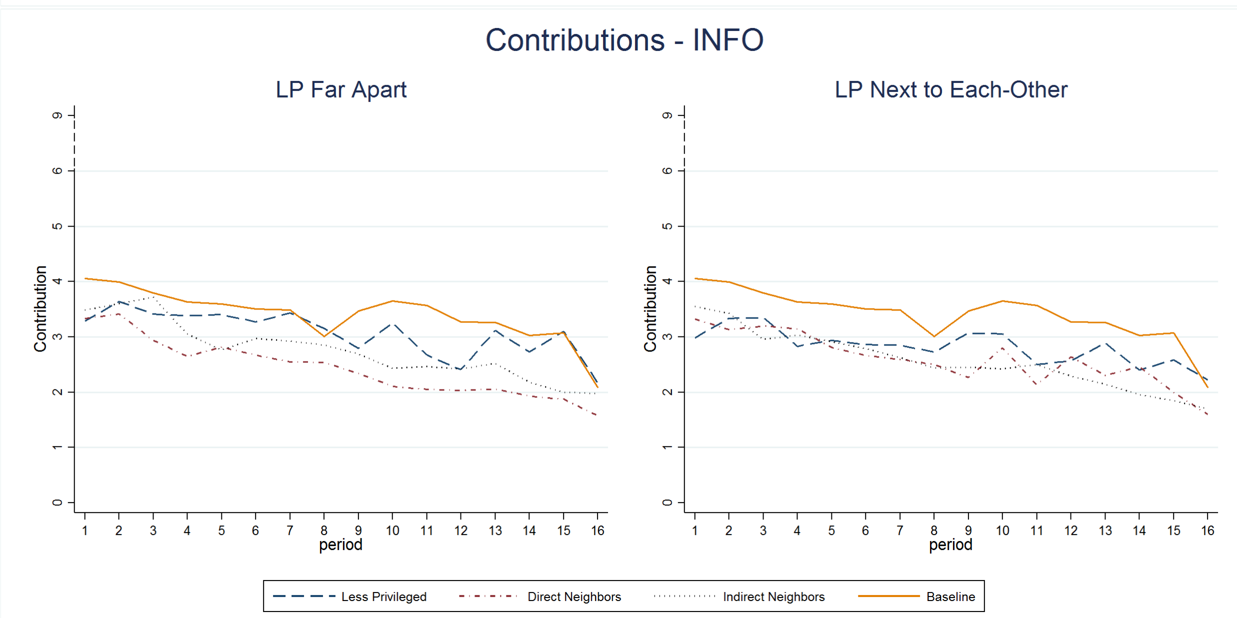
Finally, we check if the overall contribution of a group depends on the positioning of its heterogeneous members. Figure 4 illustrates how distance between LPs affects average contribution dynamics for all member types in PROD and INFO treatments, separately for close and distant LPs. The upper panels for PROD show that distance of LPs results in only minor differences in contributions of member types. While Table 5 shows that LPs contribute the least to other LPs (i.e. when they are next to each other) and mutually reinforce their

[14]Controlling for period and supergame confirms that contributions decrease over time in both treatments.

low contributions, the difference in LPs' aggregated average contributions is however small. For direct (DN) and indirect (IN) neighbors, graphs do not suggest an obvious effect of LP-distance.

Figure 4: Average contributions across periods when LPs are at the maximum (left panel) and minimum (right panel) distance in PROD (top panel) and INFO (bottom panel) treatments





INFO-LPs contribute about the same across distance and DN contributions are lowest irrespective of LP-distance. When LPs are close, average contributions of member types do not differ significantly, while for distant LPs average DN-contributions are lower than those of LPs.

Figure 5: Average individual contributions by position in the neighborhood across all groups of the respective treatment: PROD treatments with distant LPs (a), or next to each other (b); INFO treatments with distant LPs (c), and next to each other (d)

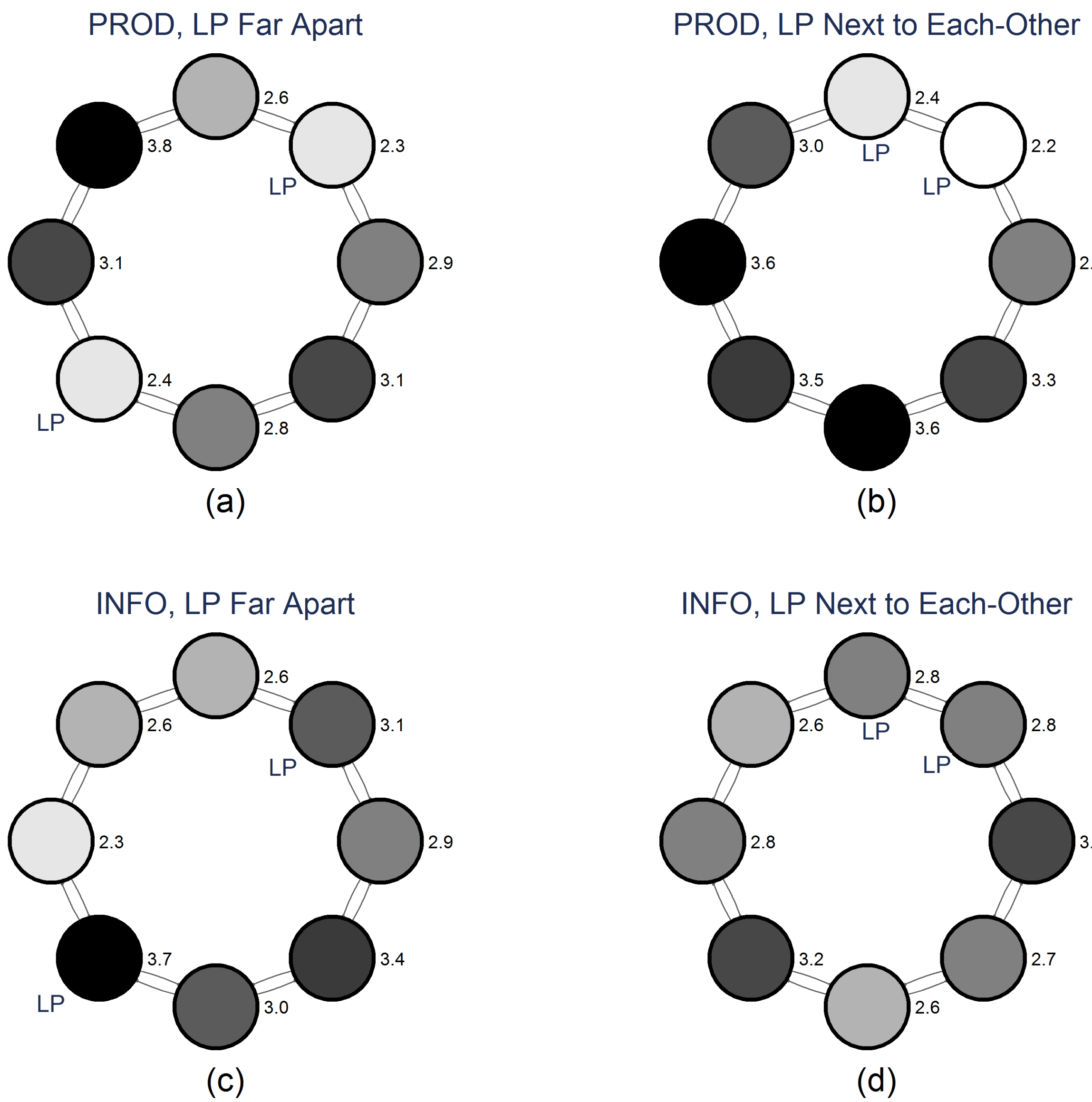


Figure 5 further illustrates these findings.[15] The subgraphs condition LP-type (upper versus lower panels) and their mutual distance (left and right panels). Neighborhood (a)

[15] A darker (lighter) shade represents higher (lower) average contribution (actual average contribution shown next to each position).

clearly reveals that distant LPs contribute least whereas indirect neighbors contribute most (3.8, respectively 3.1). In neighborhood (b) close LPs are the lowest contributors and indirect neighbors, again, are the highest ones. Here LPs with a non-LP neighbor on their (more productive) right side contribute more (3.0) than the other LP (2.7).

The INFO-neighborhood (c) illustrates the two sub-neighborhoods which differ in cooperativeness (one with at most 2.6 and one with at least 2.3) due to distant LPs which prevent behavioral spillovers to spread across sub-neighborhoods. Neighborhood (d) displays more variance in average contributions for DN and IN than for close INFO-LPs. Figure 5 further shows that group performance strongly depends on the type of non-privileged LPs, i.e. they evolve very differently.

The sequence in which LPs' distance is varied (Increasing vs. Decreasing) has no effect on neighborhood cooperation. According to two-independent sample t-test (using the same rationale as in Table 2), there is not a significant difference in average contributions due to the sequence in PROD (p-value=0.344) and in INFO (p-value=0.458).

We finally check if LPs' distance affects the neighborhood's contributions, controlling for supergame, period and sequence effect. For distance and sequence effects we use two dummy variables, equal to 1 if LPs are next to each-other, respectively when the sequence is decreasing, and 0 otherwise. Table 6 presents a two-limit random-effects tobit model of average group contributions. PROD groups do better when LPs are next to each other while PROD-LPs contribute slightly less when next to each-other. There is no difference for other member types (see Figure 4) but groups as a whole contribute more when PROD-LPs are close what is at least partly due to differences in neighborhood composition. When LPs are next to each-other, there are two DN and four IN whereas there exist four DN and two IN when LPs are distant. Given that PROD-DNs contribute significantly less than their INs (see Table 3), this at least partly explains why neighborhoods with more DNs contribute significantly less.

Table 6: Panel tobit regression of group average contributions at period t

Average group contributions at time t		
	PROD	INFO
LPs next to each-other	0.133***	-0.037
	(0.045)	(0.046)
Sequence (Decreasing)	0.213	-0.208
	(0.380)	(0.406)
Period	-0.103***	-0.070***
	(0.005)	(0.005)
Supergame 2	-0.837***	-0.653***
	(0.065)	(0.066)
Supergame 3	-1.168***	-1.169***
	(0.065)	(0.067)
Supergame 4	-1.355***	-1.663***
	(0.065)	(0.063)
Constant	4.357***	4.366***
	(0.267)	(0.301)
Observations	888	864
Number of groups	17	17

Standard errors in parentheses: *** p<0.01, ** p<0.05, * p<0.1

INFO-neighborhoods react differently to LP-positioning. Indirect neighbors contribute less when LPs are far apart, due to many DN-neighbors, who contribute lowest in INFO, what does not question group efficiency. Experience, measured by supergame as well as periods reduce group performance irrespective of sequence in distance (Increasing or Decreasing) but does not significantly affect group performance.

Finding 4: Group performance is enhanced when by LPs are close in PROD treatments but not in INFO treatments.

4. Conclusions

Our analysis confirms purely behavioral spillovers in bilateral linear public good games even when left and right free-riding incentives differ (intra-personal heterogeneity) and when inter-personal heterogeneity is added by two LPs of two LP-types who are either close or distant. The presence of LP-members lowers average contribution in the neighborhood compared to the benchmark without them, however intra-personal spillovers survive in both, PROD and INFO treatments. This robustness to intra- and inter-personal heterogeneity convincingly proves that purely behavioral spillovers will likely be observed even in worst-case scenarios. While both LP-types let the neighborhood as a whole evolve less cooperatively, their spillover dynamics differ: less productive LPs initiate “spoiling the basket” via their low contributions, LPs with no-end-of-round information are exploited by their neighbors.

Since PROD-LPs are lowest and the INFO-LPs are highest contributors, their effect on group performance depends on their positioning. While close LPs allow for globally evolving spillovers, distant INFO-LPs could separate the whole neighborhood in two sub-neighborhoods which can evolve differently. The LP-type dependency of distance effects, in our view, justifies our new treatments which vary both, LP-type and distance from close to maximally distant.

Different contribution results and dynamics depending on LP-type should be taken into consideration when policy can and wants to position heterogeneous members in a neighborhood group. When wanting to avoid different evolutionary trends in sub-neighborhoods (see neighborhood (c) in Figure 5), one may favor close positioning of PROD-LPs over distant ones. Actually, neighborhoods (c) and (d) in Figure 5 seem to display similar heterogeneity in individual average contributions but in case of (c) mainly across sub-neighborhoods, and policy may want to avoid this possibility. Of course, sub-neighborhoods are themselves responsible for their dynamics of voluntary cooperation, but policy may have an effect on their evolution.

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Appendix - Instructions

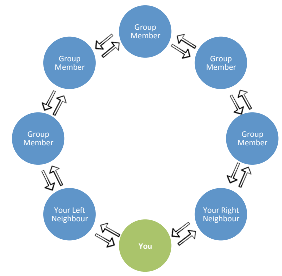
Welcome. You are participating in an experiment about economic decision-making. During the experiment, you can earn money. Your earnings will depend on your decisions and the decisions of others. These instructions describe the decisions you and other participants should take and how your earnings are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

During the experiment, all interactions between the participants will take place through computers. It is forbidden to communicate with other participants by any other 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 earnings will be calculated in points. At the end of the experiment, the points will be converted to euros at the following exchange rate:

1 point = 1€ .

In the experiment, you will be a member of a group containing a total of eight 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 neighbor to the left and a neighbor to the right.



During the experiment, each of you will interact with your two neighbors. These two neighbors will be the same two individuals for one supergame. In the experiment, there will be a total of four supergames. One supergame lasts either eight or sixteen periods (as will be explained later). Therefore, you will have to make either eight or sixteen decisions before the supergame ends. At the end of each supergame, your group consisting of eight members will be reshuffled randomly. For every member, at least one neighbor will be different from the previous supergame. *Keep in mind that you do not 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 supergame lasts depends on chance. A supergame 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 number 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 nine points you are endowed with you will 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 nine points you are endowed with you will 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 nine points to Project R and a maximum of nine point to Project L; moreover, you cannot invest your points for Project R into Project L, and vice versa.

You will retain for yourself the points that 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 eight points in project R, and keep $9 - 8 = 1$ for yourself, or invest three 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 supergame will depend only on your own choices and on those of your two neighbors.

Six out of the eight members of your group will be informed, at the end of every period, about their own payoff and their neoghbors' contributions; the remaining two members will not receive any feedback (as will be explained later.)

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

For Project R: ($9 -$Your contribution) $+0.8*$ (Your contribution + Your right neighbor's contribution)

For Project L: ($9 -$Your contribution) $+0.6*$ (Your contribution + Your left neighbor's contribution)

EXAMPLE: Let's try to compute your payoff in the following case. For the purpose of the example we imagine that both your right and left side neighbors contribute 8 points. If you contribute 8 points into Project R, your payoff will be $(9-8)+0.8*(8+8) = 1+0.8*16 = 1 + 12.8 = 13.8$. Similarly, if you contribute 3 points into Project L, your payoff will be $(9-3)+0.6*(3+8) = 6+0.6*11 = 6+6.6 = 12.6$.

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 will play multiple periods with the same participants and that you will choose how much to contribute before knowing the contributions of your neighbors, if you are one of the members receiving feedback information.*

At the end of each period, six group members will be informed about own payoffs from Project L and from Project R, contributions by both left and right neighbors, and accumulated earnings from both projects. The remaining two members will not receive any information and the following period will start directly.

What you will actually earn is:

At the end of the experiment the computer will randomly select the average payoff you obtained in one of the four supergames as a final payment. Thus your payment will be equal to the average payoff of supergame 1, or to the average payoff of supergame 2, or to the average payoff of supergame 3, or to the average payoff of supergame 4. Such a payoff will be converted to euros at the exchange rate of 1 point = 1 €.

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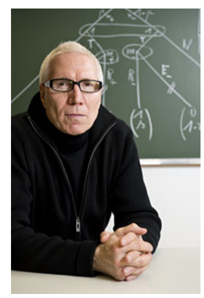

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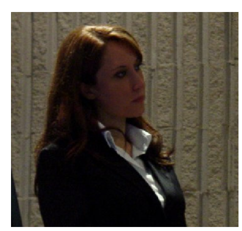

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