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 asymmetric (i.e. with different freeriding incentives) local public goods, one with the left and one with the right neighbor. All two-person public good games provide only local feedback information and are structurally independent in spite of their overlapping player sets. Here heterogeneity across neighbors is induced by two randomly selected members, named "Bad" Apples, who are either less productive or excluded from periodic information feedback about their payoffs and neighbors' contributions. Although the presence of both "Bad" Apple types leads to the neighborhood, as a whole, evolving less cooperatively, the way in which it spreads is quite different. While less productive "Bad" Apples directly initiate the spoiling of the basket due to their low contributions, "Bad" Apples excluded from periodic information are exploited by their neighbors. Furthermore, we find evidence that "Bad" Apples' positioning affects contributions in the neighborhood.

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1. Introduction

In the present paper, we allow for both, asymmetry and heterogeneity in a eight two-person public good game with overlapping player sets located in a circular neighborhood in order to study their effects on behavioral spillovers.

The existence and the evolution of purely 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] However most of the existing studies assume symmetry and homogeneity. This simplifies the experimental setting but hardly resembles behavior and performance in the field where social interactions crucially depend on the heterogeneity of group members and on their relative position. Therefore, excluding asymmetry and heterogeneity neglects important aspects of behavioral spillovers, for example, how one reacts to them and to what extent such heterogeneity affects the society as a whole.

Circular neighborhoods are a convenient vehicle to explore local interaction embedded in a more global setup, since they allow each group member confront only one left and one right neighbor. The interactive decision making of such group members is typical for neighborhoods in the field[2], even though local interaction in a more global setup can be more or less widespread. The most common example is, however, the interaction of two neighbors who may have to agree how to separate their gardens by a fence or wall. In a circular neighborhood this can mean, for instance, that each has to agree independently with each neighbor how to separate their gardens. This is captured experimentally by letting both neighbors contribute voluntary so that the sum of both contributions determines (linearly) the size or quality of their common dividing structure.

In a companion study (Angelovski et al., 2017) we have shown that independent local games are played in a correlated way even in the presence of asymmetry, namely that one confronts different (freeriding) incentives in one's left and right bilateral interactions, which is a likely feature in most field situations and a potential obstacle of behavioral spillovers. However, it has done so by maintaining the homogeneity of all group members, a frequent assumption in experimental research but one questioning the external validity of many findings

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[1]Most of this literature focus on how individual facing multiple independent games in sequence develop and apply common behavior across them instead of applying distinct strategies in each game. Falk et al. (2013), instead, investigate social interaction effects when two identical public good games are played simultaneously with different opponents.

[2]Although they may not always be represented circularly due to border cases, where one has only a left or right neighbor, which we exclude for the sake of simplicity.

given that field situations are mostly heterogeneous. In this paper, rather than considering only one type of heterogeneity which would render our results rather situation-specific, we focus on two very different, yet common, types of heterogeneity across individuals: one in freeriding incentives and the other in feedback information. In the following parts of the paper, we refer to those who differ, by being either productively- or informationally-handicapped, as "Bad" Apples in order to better link our study to related literature.

Since embedding only one "Bad" Apple in an otherwise homogeneous circular neighborhood would mean that its location does not matter, we set the number of "Bad" Apples to two per neighborhood, with both being the same type. This allows to vary their mutual distance from no distance between them to maximally distant.

Such experimentally-induced heterogeneity can question behavioral spillovers as group members may not be sure with whom they are interacting bilaterally on the left, respectively right side. Furthermore, as behavioral spillovers rely on feedback information one wonders whether excluding it for two group members, questions global behavioral spillovers altogether. All this illustrates that we do not only explore behavioral spillovers but also systematically check their robustness.

The present setup confronts each member with asymmetric freeriding incentives, larger on the left side and smaller on the other. Structural independence of the two-person public good games is induced by local feedback information and separate individual endowments for both games which are all strategically independent.[3] However structural independence of local games may 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.

The interplay of intra- and inter-personal spillovers to which we refer as (purely) behavioral spillovers, may let the neighborhood evolve as a whole in spite of structural independence. In our companion study we find evidence of behavioral spillovers even in the presence of asymmetric freeriding incentives. In particular, participants anchor intra-personally their behavior on the lower freeriding incentive, i.e. high marginal per capital return, and this in turn enhances and stabilizes voluntary cooperation across the whole neighborhood when compared to the three control treatments with symmetric freeriding incentives, based on the larger, the smaller, and the mean freeriding incentive of the asymmetric treatment.[4]

But does heterogeneity across group members still allow for purely behavioral spillovers?

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[3]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).

[4]The asymmetric treatment allows to avoid confounding intra-personal spillovers with symmetry heuristics like treating equally equals what may occur if one's left and right freeriding incentives coincide.

To answer this question, here we test the effect of having two types of "Bad" Apples using the same asymmetric structure. In separate treatments, "Bad" Apples are distinguished by randomly selecting two participants who are either less productive ("productivity handicap") or excluded from periodic feedback information ("information handicap"). Compared to the baseline asymmetric treatment, the "productivity handicap" (hereafter PROD) reduces "Bad"Apples' productivity on both sides. The "information handicap" (hereafter INFO) maintains the same productivities as in the baseline asymmetric treatment, but excludes "Bad"Apples from feedback information about their neighbors' contributions and their own payoff.[5] Further, we question whether the two "Bad"Apple types imply, through behavioral spillovers, different dynamics of contributions in the circular neighborhood. We conjecture that less productive "Bad"Apples are more likely to freeride while "Bad"Apples excluded from periodic feedback information possibly inspire their neighbors to freeride and thereby both may question conditional cooperation.

Additionally, we test whether the effects of "Bad" Apples differ depending on their relative positioning via comparing neighborhoods in which "Bad" Apples are next to each other or most distant. Neighboring "Bad" Apples interact among themselves and can be interpreted as one big "Bad"Apple, while distant "Bad" Apples may separate the whole neighborhood in two sub-neighborhoods. In particular, distant "Bad"Apples excluded from feedback information, like an "Iron Curtain", could split up the neighborhood in two isolated sub-neighborhoods. Participants are aware of "Bad" Apples and of their type but not of their position in the neighborhood. Therefore regular members, suspecting a less productive "Bad"Apple neighbor, may contribute less if they do not excuse their neighbor's freeriding because of the higher freeriding incentive. Similarly, a regular member, suspecting an uninformed "Bad"Apple neighbor may try to exploit this neighbor, hoping that this remains unnoticed. In summary, both types of "Bad"Apples may adversely affect purely behavioral spillovers.

The between-subject treatments we implemented experimentally vary in two conditions: the "Bad" Apple type and the sequence of their relative distance from each other (increasing - first close and then distant, vs. decreasing - first distant and then close) in the neighborhood. This hopefully helps to answer questions like:

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[5]We are aware that in the literature on public goods experiments other forms of heterogeneity are considered, for example in 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., 2016, who consider partners-strangers composition of the group, whereas Barsdley and Sausgruber, 2005, Fischbacher and Gächter, 2010 and de Oliveira et al. 2015, who consider conditional cooperators-(Nash) selfish composition).

1. Will "Bad" Apples weaken voluntary cooperation within and across overlapping neighbor pairs?

2. Will purely behavioral spillovers persist in the presence of "Bad" Apples and for both "Bad" Apples' types?

3. Will the "Bad" Apple types and their positioning trigger different behavioral spillovers and evolutionary dynamics of voluntary cooperation?

We find that both "Bad" Apple types reduce voluntary cooperation in the whole neighborhood compared to the baseline treatment with no "Bad" Apples. Nevertheless, behavioral spillovers generally prevail, although deterioration of voluntary cooperation differs across "Bad" Apple types. Less productive "Bad" Apples contribute less what, via purely behavioral spillovers, contaminates the whole neighborhood. "Bad" Apples with no information feedback, on the contrary, are the highest average contributors in their neighborhoods, with the basket being spoiled by their neighbors. Furthermore, the relative distance of "Bad" Apples plays a role in how the neighborhood evolves as whole.

To the best of our knowledge our approach to investigate effects of asymmetry and heterogeneity on purely behavioral spillovers is novel and quite different from the existing literature on this topic. We, however, share some insights with existing studies examining within-group heterogeneity in freeriding incentives, from the seminal contribution of Fisher et al. (1995) to the more recent contributions of Noussair and Tan (2011), Reuben and Riedl (2009, 2013), Fischbacher et al. (2014) and Kölle (2015) and confirm some of their results, e.g. concerning the effects of marginal per capita return (MPCR hereafter). Only de Oliveira et al. (2015) so far allow for heterogeneity in group composition via introducing "selfish Bad Apples" (i.e. subjects previously identified through a pretest as contributing zero in a two-person public good game) and analyse how their presence affects others and reduces the overall efficiency of the group.

Our INFO treatment can be related to studies varying feedback information in symmatric 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). Their general conclusion is that information given to all participants has a significant effect on their behavior and that participants without feedback information contribute significantly more than theoretically predicted and than participants with feedback information. We will confirm the result even in case of within-group heterogeneity in feedback information.

The circular network has been extensively 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 we allow only for structurally independent bilateral

games. While Carpenter et al. (2012) and Eckel et al., (2010) only provide local feedback, all their participants contribute to and benefit from a single public good. Suri and Watts (2011) and Carpenter et al. (2012) also vary the network structure. Similarly to Falk et al. (2013), our participants play only two local public good games with two neighbors yielding behavioral spillovers due to overlapping two-player sets.

The paper is organized as follows: Section 2 illustrates the experimental design and 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

Participants form a circular neighborhood with eight members. Each member $i = 1, .., 8$ is assigned to 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.[6]

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 $(0, 1, ..., 9)$. Individual payoffs are:

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

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 $c_i^R + c_{i+1}^L$.

In the baseline asymmetric treatment, we assume $\alpha = 0.6$ and $\beta = 0.8$. Regarding "Bad" Apple types, in the PROD treatment we assume that α is 0.4 and β is 0.6. Thus "Bad" Apple i earn:

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

while the payoff of regular members i is:

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

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[6] Our neighborhood with eight members, each playing two independent two-person public good games with her direct neighbors, is admittedly stylized and appeals to a circular road. It has the advantage of being easily understood by participants who confront the (compared to Angelovski et al., 2017) additional complexity of two "Bad" Apples. Note that although it employs an easily understood neighborhood structure, the focus of our experimental design is not on network formation but on whether and how behavior evolves within and across neighbors' pairs.

Figure 1: Circular neighborhood with the representative member i at the bottom
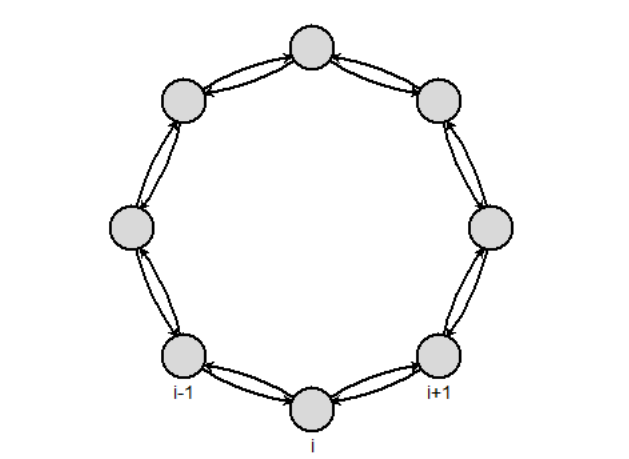
In the INFO treatment, "Bad" Apples have the same productivities as in the baseline treatment ($\alpha = 0.6$ and $\beta = 0.8$) but are excluded from periodic feedback information regarding their neighbors' contributions and their own payoffs.

In every period subjects contribute to both, left side and right side public goods. Before a new period begins, they receive information on both neighbors' contribution choices and own payoff (except "Bad" Apples in INFO 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 eight period. In each supergame, subject play with the same neighbors. Subjects' position in the neighborhood is randomly reshuffled in every supergame such that at least one neighbor is new.

At the beginning of every supergame the computer randomly selects two members as "Bad" Apples, who are located either next to each other or at maximal distance (see Figure 2) and are informed about their type, depending on the treatment PROD or INFO, but not about their relative distance. The other members of the neighborhood are informed about two "Bad" Apples being present and their type, but not about their position nor relative distance. "Bad" Apples' distance is held constant for two successive supergames and then changed for the remaining two. We distinguish (within-subjects) an increasing sequence ("Bad" Apples are neighbors in the first two supergames and distant in the last two) and a decreasing one ("Bad" Apples are distant in the first two supergames and neighbors in the last two).

Summing up, the four between-subject treatments vary in two dimensions: the "Bad" Apple type (PROD and INFO) and distance sequence ($+$ for increasing distance and $-$ for decreasing distance, see Table 1). We compare these treatments to the baseline treatment without

Figure 2: Distance variation of "Bad" Apples distinguishing group members' types: "Bad" Apples (BA), their neighbors (DN) and indirect neighbors (IN)
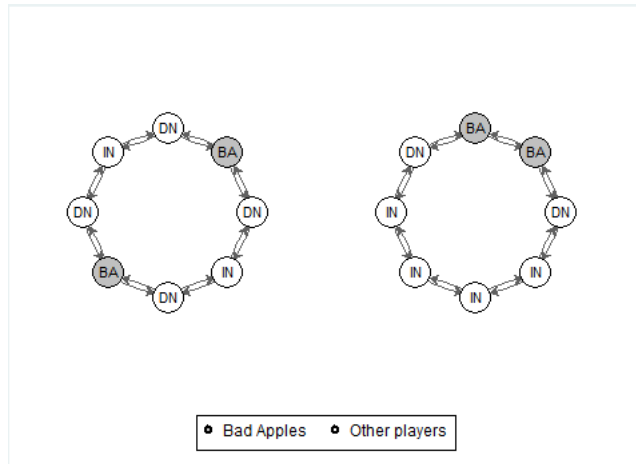
"Bad" Apples that stems from the dataset of the previous experiment reported in Angelovski et al. (2017).

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

		"Bad" Apples' handicap	
		Productivity	Information
Distance	Increasing	PROD +	INFO +
	Decreasing	PROD -	INFO -
Baseline treatment		no "Bad" Apples	

The experiment was run at CESARE lab at LUISS Guido Carli (Rome, IT) with 272 subjects participating in the four (new) treatments, divided into 34 groups of 8 participants each. The baseline treatment employed 96 subjects, i.e. 12 groups of 8. An experimental session included two or three such groups and no subject participated in more than one session. At the end of the last supergame the computer randomly selected one supergame for the final payment, consisting of the average payoff for that supergame. The average earning was 20€. The experiment was programmed with Z-Tree (Fischbacher, 2007) and we used Orsee (Greiner, 2015) for recruitment.

Before presenting our results, let us illustrate, via Figure 1, the mechanism on which purely behavioral spillovers rely which may soon or later affect the whole neighborhood: assume 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 player pairs in which i

is involved, i.e. $\{i-1,i\}$ and $\{i,i+1\}$, are conditionally cooperating, this obviously links the behavior of $i-1$ and $i+1$ although they are not directly interacting. Since what applies to i also applies to $i-1$ and $i+1$, the entire neighborhood might be affected by behavioral spillovers. The postulated mechanism letting the neighborhood possibly evolve has a whole assumes intra-personal correlation of left and right contribution by each group member and inter-personal conditional cooperation within overlapping pairs.

3. Results

In order to assess whether purely behavioral spillovers exist in case of "Bad" Apples, we first assess the effects of "Bad" Apples on voluntary contributions, and in particular we try to answer the following research questions:

(i) Do "Bad" Apples have a negative impact on voluntary contributions, i.e. do they "spoil the basket"?

(ii) Is this due to "Bad" Apples's behavior or to the reaction of other members to the presence of "Bad" Apples in the neighborhood?

Table 2: Average group contribution by treatment and difference from baseline treatment (left panel) and by distance sequence (right panel). P-values from two-independent sample t-tests in parentheses.

	Average	Difference	P-value[a]	P-value[b]
Baseline (B)	3.478			
PROD	2.861**	-0.617	(0.000)	(0.011)
INFO	2.748***	-0.730	(0.000)	(0.004)
Periods 1 to 4				
Baseline	3.871			
PROD	3.499*	-0.372	(0.004)	(0.069)
INFO	3.234***	-0.637	(0.000)	(0.001)
Periods 5 to 8				
Baseline	3.340			
PROD	2.895***	-0.505	(0.000)	(0.008)
INFO	2.796***	-0.603	(0.000)	(0.003)
Periods 9 to 12				
Baseline	3.492			
PROD	2.485***	-1.007	(0.000)	(0.000)
INFO	2.449***	-1.043	(0.000)	(0.001)
Periods 13 to 16				
Baseline	2.862			
PROD	2.174***	-0.688	(0.000)	(0.008)
INFO	2.141***	-0.720	(0.000)	(0.005)

	PROD	INFO
Incr. (+)	2.799	2.900
Decr. (−)	2.992	2.747
Difference	-0.193	0.154
P-value	(0.344)	(0.458)

(a) Unit of observation is average group contribution in every period.
(b) Unit of observation is average group contribution across periods.
Significance levels according to (b): *** p<0.01, ** p<0.05, * p<0.1

Table 2 reports average contributions to the public good (left and right side pooled) comparing INFO and PROD treatments to the baseline treatment. In order to assess treatment effects on independent observations, we perform two-independent sample t-tests on: (*a*) average group contributions to local public goods in every period, and (*b*) average group contributions across all periods. We report P-values for both tests and assess significance on the basis of the second, more conservative, level of aggregation. The data show that average contributions are significantly lower in PROD and INFO treatments than in the baseline treatment (2.861 in PROD and 2.748 in INFO versus 3.478 in baseline), and this effect persist also when we consider quarters of supergames (see Table 2, left panel).

Finding 1: Irrespective of handicap type, either productivity or information, average contribution in presence of "Bad" Apples is lower than in the baseline treatment (P-value< 5%), and this effect persists across (quarters of) periods.

On the other hand, we find that the order according to which "Bad"Apples' distance is varied (increasing vs. decreasing) does not affect average contributions (see Table 2, right panel), hence there is no distance sequence effect.

Finding 1, therefore, supports the idea that the presence of "Bad"Apples spoils the basket. To deepen the understanding of this finding, we assess the initial impact of common awareness of the presence of "Bad"Apples and compare average contribution in the first period of the first supergame in PROD and INFO treatments and in the baseline treatment (see Table 3). The data show that initial average contribution do not differ, both when "Bad"Apples' contributions are included (Table 3, upper part) and when they are excluded (Table 3, lower part). This results suggests that the difference in contributions from the baseline emerges over time through the interaction of the members of the neighborhood.

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Table 3: Average group contributions in the first period of the first supergame and difference from baseline treatment. P-values from two-independent sample t-tests in parentheses.

All contributions			
	Baseline	PROD	INFO
Averages:	4.208	4.390	3.989
Diff. with baseline:		0.181	-0.219
P-value:		(0.569)	(0.505)

All contributions except those from and to BA			
	Baseline	PROD	INFO
Averages:	4.208	4.372	3.929
Diff. with baseline:		0.164	-0.279
P-value:		(0.599)	(0.478)

To further investigate this point and make a preliminary assessment of whether only the evolution of "Bad"Apples' behavior or also of other neighborhood's members supports Finding 1, we compare average contributions in the games in which "Bad" Apples are not involved. Table 4 reports P-values from two-independent sample t-tests performed on the same levels of aggregation as in Table 2; here, however, we omit contributions from and to "Bad" Apples. Results for PROD and INFO treatments differ substantially: average contributions in PROD treatment are not statistically different from the baseline when we exclude games where "Bad"Apples are involved. This result changes when we consider later periods (third and fourth quarters), where contributions are substantially lower than in the baseline. This suggests that "Bad"Apples are indeed spoiling the basket because, via behavioral spillovers, they do eventually affect other group members, who end up reducing their contributions as well.

Table 4: Average group contribution without contributions from and to "Bad" Apples and difference from baseline treatment. P-values from two-independent sample t-tests in parentheses.

	Average	Difference	P-value[a]	P-value[b]
Baseline (B):	3.478			
PROD:	3.234	-0.244	(0.002)	(0.571)
INFO:	2.694***	-0.784	(0.000)	(0.002)
Periods 1 to 4				
Baseline:	3.871			
PROD:	3.753	-0.117	(0.390)	(0.435)
INFO:	3.257***	-0.613	(0.000)	(0.000)
Periods 5 to 8				
Baseline:	3.340			
PROD:	3.364	-0.036	(0.791)	(0.795)
INFO:	2.729***	-0.671	(0.000)	(0.000)
Periods 9 to 12				
Baseline:	3.492			
PROD:	2.946**	-0.546	(0.002)	(0.009)
INFO:	2.385***	-1.107	(0.000)	(0.000)
Periods 13 to 16				
Baseline:	2.862			
PROD:	2.494*	-0.368	(0.035)	(0.058)
INFO:	1.989***	-0.873	(0.000)	(0.000)

[a] Unit of observation is average group contribution by period

[b] Unit of observation is average group contribution across periods

Significance levels according to (b): *** $p<0.01$, ** $p<0.05$, * $p<0.1$

In INFO treatment however, average contributions are persistently and significantly lower than in the baseline treatment, even when we exclude contributions to and from "Bad" Apples. This suggests that the drop in group average contributions is not, or at least not exclusively, due to "Bad" Apples, but due to other group members and their awareness that two subjects receive no feedback information on neighbors' contributions. If this is the case, then INFO "Bad"Apples are not the ones that are spoiling the basket, but other group members are.

To confirm the presence of behavioral spillovers with both types of "Bad"Apples, we report in Table 5 the estimates of a two-limit random-effects tobit model with group dummies[7]

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

on left and right contributions at period t.[8] The set of regressors includes own lagged left (Left contribution $(t-1)$), respectively right (Right contribution $(t-1)$), contribution, one-period lagged contributions of both left neighbors (L neighbor $(t-1)$) and right neighbors (R neighbor $(t-1)$), period, and supergame dummies. For treatments with "Bad"Apples it also includes dummies for the three categories of subjects: BA for "Bad"Apples, DN for their direct neighbors and IN for their indirect neighbors.[9]

Table 5: 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)						
"Bad" Apples (BA)		-0.627***	0.380***		-0.613***	0.532***
		(0.114)	(0.096)		(0.118)	(0.099)
Neighbors of BA (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

Results show that in both PROD and INFO treatments, as well as in the baseline, left and right individual contributions are affected not only by past contributions of the neighbor

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[8]The difference in observations is due to the random horizon rule, which implied that subjects happened to play less often till sixteen periods in INFO treatment than in PROD treatment.

[9]Recall that, when "Bad"Apples are next to each other, there exist two direct and four indirect neighbors, whereas, when "Bad"Apples are far apart, there are four direct and two indirect neighbors (see Figure 2)

on the same side but also by past contributions of the neighbor on the opposite side: the effect of lagged left neighbor contribution and of one-period lagged right neighbor contribution on the current own right, respectively left, contribution is statistically significant. This shows that participants correlate how they play their two, structurally independent, games and, therefore, that the two games are behaviorally linked due to intra-personal behavioral spillovers. This evidence confirms that behavioral spillovers found in the baseline, homogeneous, treatment implemented in Angelovski et al. (2017) exist also in a more heterogeneous setting.

Finding 2: In a neighborhood with "Bad"Apples intra-personal spillovers exist both in PROD treatment and INFO treatment.

Table 5 also reveals decay across supergames and periods (in line with the standard decay pattern of repeated public goods experiments) as well as path dependence of both, left and right side contributions (current contributions are positively affected by one-period lagged own contributions on the same side).

To better understand the relation between Finding 1 and Finding 2, we analyze the contribution choices of the different member types of the neighborhood, "Bad"Apples, their direct neighbors and indirect neighbors, in Table 6. We find that "Bad"Apples are significantly less cooperative than other members in PROD treatment whereas they are most cooperative in INFO treatment. This difference in the behavior of "Bad"Apple types can be better understood when comparing their contribution behavior with that of their (in)direct neighbors.

Table 6 also compares contribution of "Bad" Apples, their neighbors and indirect neighbors (IN) separately for PROD and INFO treatments. The unit of observation is average (across period and at the group level) contribution, thus allowing for a two sample t-test on independent observations. In PROD treatment "Bad" Apples contribute on average less than in INFO treatment (2.221 vs. 3.012, p-value < 0.001), while indirect neighbors contribute more in PROD treatment than in INFO treatment (3.379 vs. 2.744, p-value < 0.001).

Table 6: Summary statistics of contributions by treatment type and member type with two-sample t-test on mean differences (on independent average group contributions)

| | PROD | | | INFO | | | T-test |
	Mean	Median	Std. dev	Mean	Median	Std. dev	(p-value)
"Bad" Apples (BA)	2.221	1.5	2.309	3.012	3	2.474	(0.000)
Direct Neighbors (DN)	2.767	2.5	2.377	2.578	2	2.234	(0.246)
Indirect Neighbors (IN)	3.379	3.5	2.534	2.744	2.5	2.422	(0.000)

When comparing average contribution within treatments, we find that "Bad" Apples contribute less than any other type of participant in PROD treatment and more than any other type of participant in INFO treatment. In particular, in PROD treatment "Bad" Apples contribute on average 2.221, their direct neighbors 2.767, and the indirect neighbor 3.379; in INFO treatment, "Bad" Apples contribute on average 3.012, while their direct neighbors are the lowest contributors (2.578), and the indirect neighbor contribute 2.744.[10]

Finding 3: "Bad" Apples with lower productivity differ in contribution from those without feedback information: In PROD treatment "Bad" Apples are the lowest contributors whereas they are the highest contributors in INFO treatment.

Figure 3: Contribution dynamics in PROD (left panel) and INFO (right panel) treatments by subject types vs. the baseline treatment
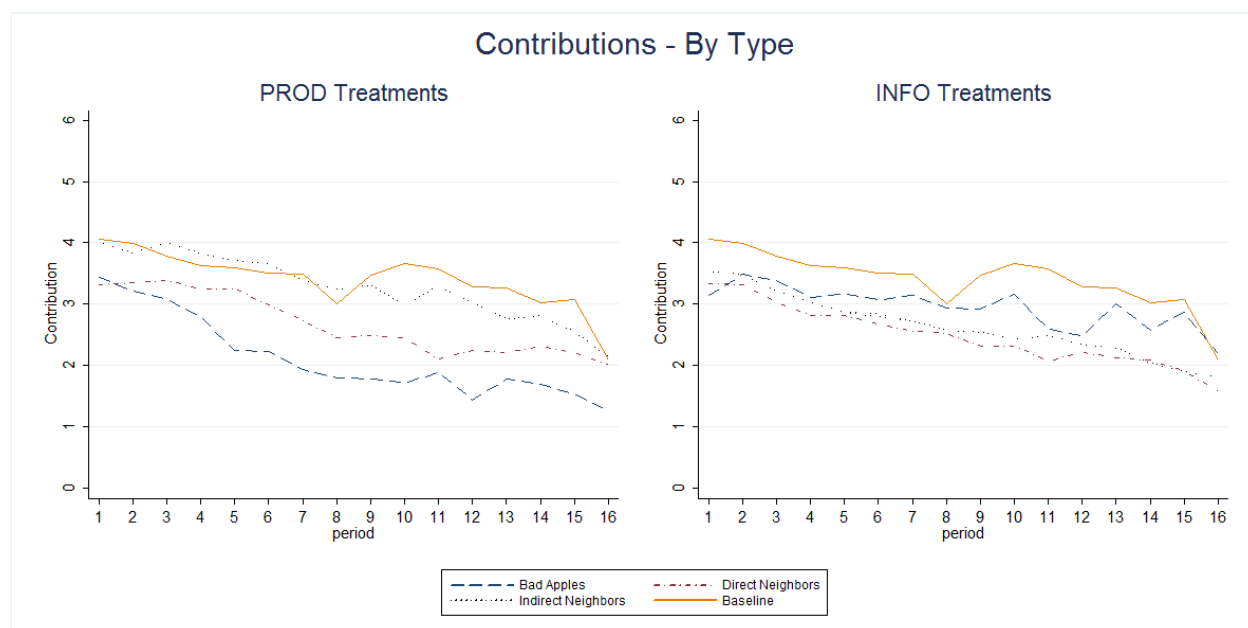

Figure 3 compares the dynamics of average contributions in PROD, INFO and baseline treatments. It illustrates that direct and indirect neighbors contribution dynamics differ more (less) in PROD (INFO) treatments in spite of declining contributions of all member types. There is a distinct difference in contribution dynamics of PROD and INFO neighborhoods:

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[10]Almost all mean differences between member types of the same treatment are statistically significant (two-independent sample t-test on supergame-level average contributions by type of member, in order to avoid dependence between members belonging to the same group). PROD treatment: BA vs. DN p-value = 0.000, BA vs. IN p-value = 0.000, DN vs. IN p-value = 0.000; INFO treatment: BA vs. DN p-value = 0.004, BA vs. IN p-value = 0.085, DN vs IN. p-value = 0.222.

in PROD the decay of contributions is initiated by "Bad"Apples whereas in INFO "spoiling the basket"seems to be triggered by their direct neighbors trying to detect and exploit a "Bad"Apple; this in turn spills over to the indirect neighbors, thus affecting the whole neighborhood. Figure 3 also reveals higher (lower) variability in contributions across group member types in PROD (INFO) treatments.

Table 7 reports the results of a two-limit random-effects tobit model with group dummies on the effects of own and neighbors' type on contributions (either left or right) in period t. Using contributions from indirect neighbors to direct neighbors as the reference category, the contributions of "Bad"Apples to "Bad"Apples is lower in PROD treatments on both sides and higher in INFO treatments on the right side, the one with higher MPCR. The same pattern occurs when "Bad"Apples contribute to direct neighbors: it seems that "Bad"Apples in INFO treatments trust blindly that their direct neighbors will not exploit them and reciprocate. For PROD treatments, on the other hand, Table 7 indicates that the further away a member is from a "Bad"Apple, the higher her average contribution.[11]

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

Table 7: Panel tobit regression on individual contributions at period t

| | Left contributions at time t | | Right contributions at time t | |
	PROD	INFO	PROD	INFO
Ref. Category: IN to DN				
BA to BA	-1.219***	-0.052	-1.962***	0.404**
	(0.212)	(0.186)	(0.228)	(0.192)
BA to DN	-0.674***	0.417***	-1.277***	0.475***
	(0.154)	(0.132)	(0.156)	(0.138)
DN to BA	-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: *** $p<0.01$, ** $p<0.05$, * $p<0.1$

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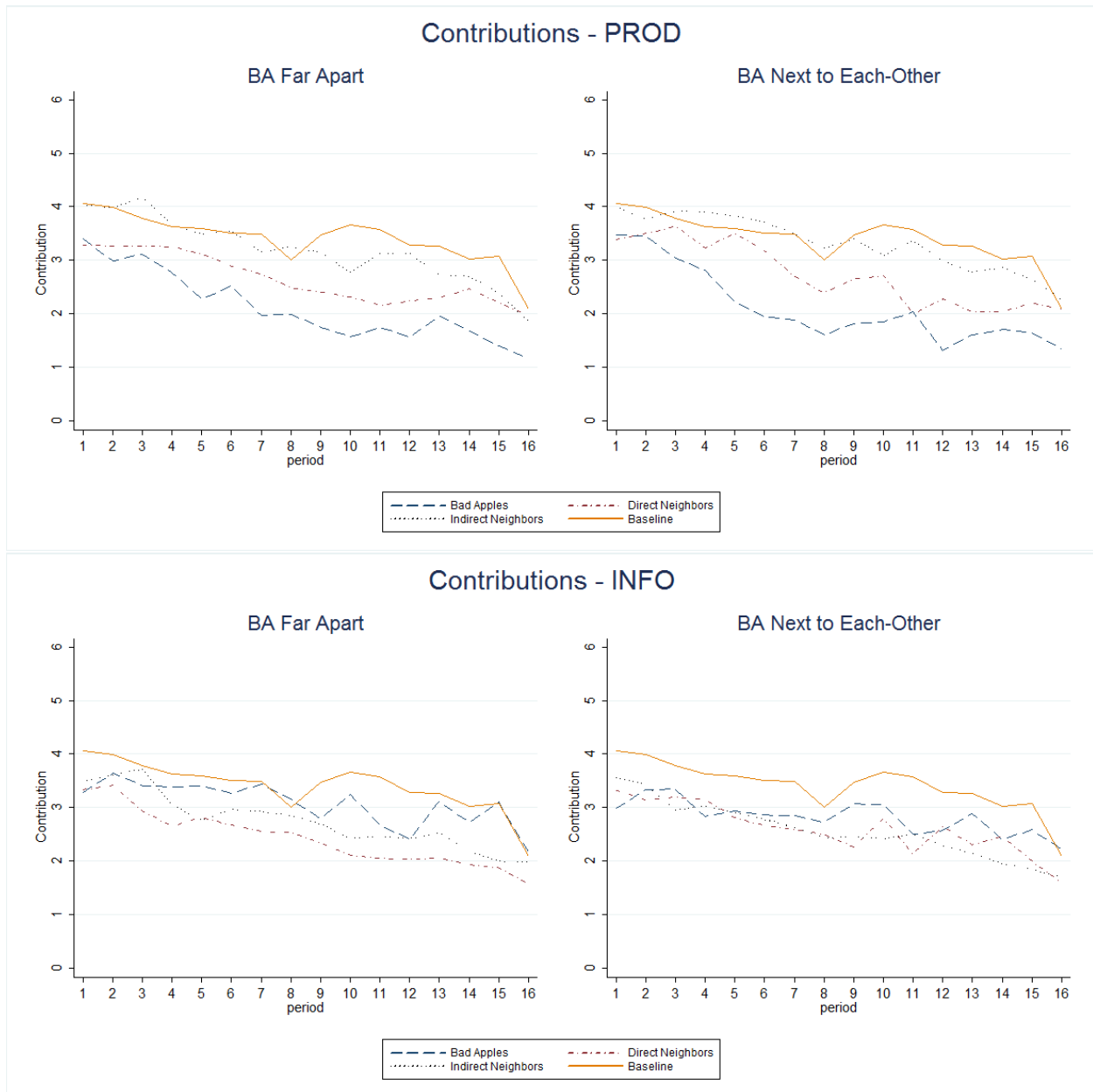

Figure 4 illustrates the distance effect of "Bad"Apples on the average contribution dynamics for all group members types in PROD and INFO treatments separately for near and distant "Bad"Apples. It illustrates that in PROD treatments "Bad"Apples perform worse when they are next to each other, i.e. they mutually reinforce freeriding and low contributions. This result is also supported by regression results in Table 7: when comparing "Bad"Apples' contributions to other "Bad"Apples (i.e. when they are close) and to direct

neighbors, the first are consistently lower than the latter in both left and right contributions (Wald test on equality of coefficients: p= 0.012 for left and p= 0.002 for right). On the other hand, direct neighbors and indirect neighbors do not seem to be affected by the distance between "Bad" Apples.

In INFO treatment "Bad" Apples' contributions are unaffected by their distance, which is due to their inability to reciprocate and to infer their neighbor's type. Contributions of direct neighbors is the lowest irrespective of "Bad" Apples' distance even though when "Bad" Apples are close, member types' average contributions do not differ significantly, while when "Bad" Apples are distant direct neighbor average contribution is significantly lower than that of "Bad" Apples, according to a one-tailed two-sample t-test (0.000), and of indirect neighbors (0.058).

Figure 5: Average individual contributions by position in the neighborhood across all groups of the respective constellation: PROD treatments when Bad Apples are far, subgraph *(a)*, and next to each other, subgraph *(b)*; INFO treatments when Bad Apples are far, subgraph *(c)*, and next to each other, subgraph *(d)*
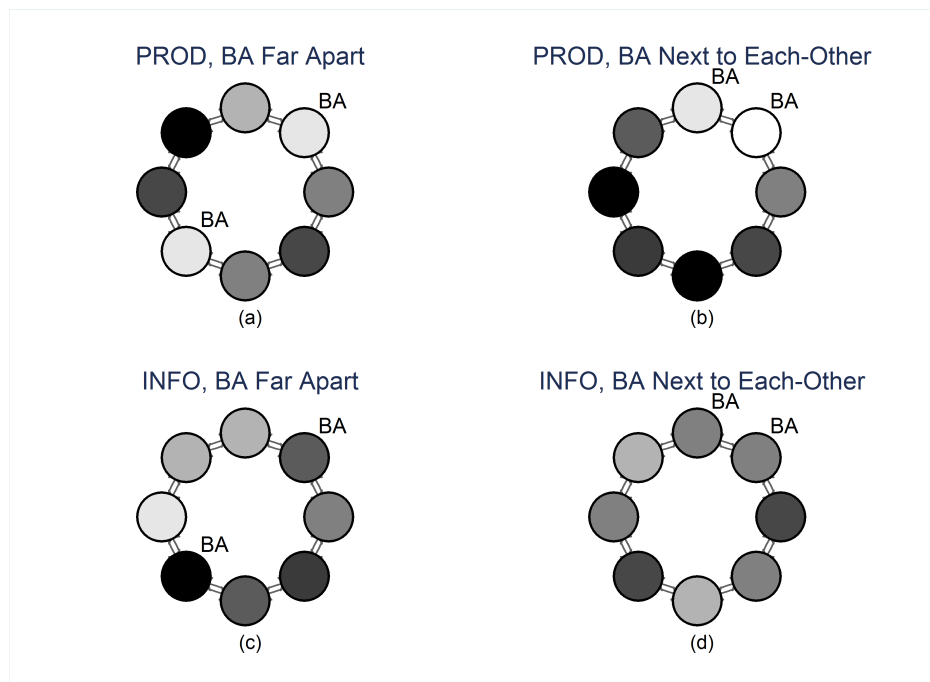

Figure 5 further illustrates these findings.[12] The subgraphs differ in "Bad" Apple type and their distance. In neighborhood (a) one clearly sees that "Bad" Apples contribute least whereas their indirect neighbors contribute most. In neighborhood (b) close "Bad" Apples have the lowest contributions and their indirect neighbors, again, the highest. Here "Bad" Apples with a non-"Bad" Apple neighbor on their (more productive) right side contribute more than

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[12]A darker shade represents higher average contribution and a lighter shade lower one.

the other "Bad"Apple. Neighborhood (c) indicates that behavior can evolve differently in the two sub-neighborhoods that are formed between the two "Bad"Apples. Given that "Bad"Apples receive no feedback information, they do not allow for behavioral spillovers to occur between the two sub-neighborhoods. i.e. they act like "Iron Curtains". Type (d) neighborhood, however, seems to display no systematic regularity.

Table 8: Panel tobit regression on group average contributions at period t

	Average group contributions at time t	
	PROD	INFO
BA are neighbors	0.133***	-0.037
	(0.045)	(0.046)
Distance 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

Finally, we check if "Bad"Apples' distance affects contribution within the neighborhood, controlling for supergame, period and sequence effect. Table 8 presents of a two-limit random-effects tobit model of average group contributions showing that PROD groups do better when "Bad"Apples are next to each other. While "Bad"Apples in PROD contribute very little, the group as a whole contributes more. Apparently other non-"Bad"Apple participants, overcompensate the decrease of BA contributions. Distance of "Bad"Apples in INFO has no effect on group efficiency. Experience, measured by supergame as well as periods, reduces group performance; sequence of distance (increasing or decreasing) has no significant effects on group performance.

Finding 4: Group performance is enhanced by "Bad"Apples distance in PROD treatment but not in INFO treatment.

4. Conclusions

The present analysis shows that purely behavioral spillovers exist in local two-sided structurally independent public good games and that they survive when accounting for asymmetry in freeriding incentives and for participants' heterogeneity implemented by introducing in the neighborhood two heterogeneous members, named "Bad" Apples.

We study purely behavioral spillovers and test their robustness by inducing experimental heterogeneity of group members in the asymmetric treatment considered by Angelovski et al. (2017). Two "Bad" Apples differ from the six other group members either by larger (asymmetric) freeriding incentives or by not receiving information feedback. Furthermore, "Bad" Apples are either neighbors or most distantly located. The results confirm that both "Bad" Apple types and their distance, affect the evolution of voluntary cooperation across the circular neighborhood while still, under some conditions, allowing for sub-neighborhoods to evolve differently. This shows that systematic heterogeneity variations shape but do not question purely behavioral spillovers, even under stress conditions.

We confirm that across the two types and the two relative distances "Bad" Apples spoil the basket by lowering average voluntary cooperation of the whole neighborhood. But the active spoiling of the basket only applies to "Bad" Apples with stronger freeriding incentives who fail to conditionally cooperate with their neighbors, which then spreads to a varying degree across the neighborhood. "Bad" Apples excluded from feedback information are not actively spoiling the basket; they are exploited by their neighbors when the latter are convinced that this will remain unnoticed. In our view, this indicates that the metaphor of "Bad" Apples is not always appropriate: from the basket being spoiled one cannot infer that this is due to the behavior of those group members who are different, but only - at least for the conditions explored in our study - that player heterogeneity across neighbors can endanger voluntary cooperation by possibly weakening both spillovers due to strategic exploitation attempts of "Bad" Apples themselves or of those interacting with them.

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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.
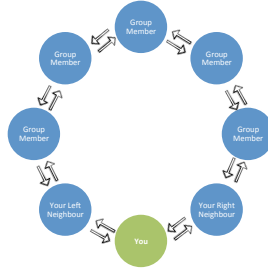
During the experiment, all interactions between the participants will take place through computers. It is forbidden to communicate with other participants by any other means. If you have any questions, please raise your hand and one of us will come to answer it. Keep in mind that the experiment is anonymous, 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:

$$1 \text{ point} = 1 \text{€}.$$

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.

<u>PAYOFFS</u>

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: $(9 - \text{Your contribution}) + 0.8 * (\text{Your contribution} + \text{Your right neighbor's contribution})$

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

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.

<u>What you will actually earn is:</u>

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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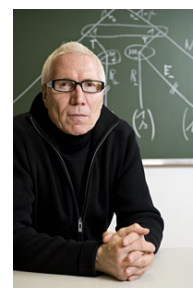
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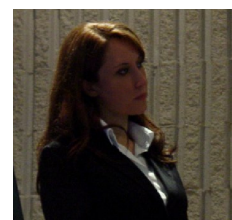
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