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## Leadership in a weak-link game

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School of Economics Discussion Papers

**Leadership in a Weak-Link Game**

Joris Gillet, Edward Cartwright, Mark Van Vugt

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# Leadership in a Weak-Link Game

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## Abstract

We investigate, experimentally, the effects of leadership in a four player weak-link game. A weak-link game is a coordination game with multiple Pareto-ranked Nash equilibria. Because the more efficient equilibria involve a degree of strategic uncertainty groups typically find it difficult to coordinate on more efficient equilibria. Previous studies have shown that leadership by example - in the form of one player acting publicly before the rest of the group - can lead to increased cooperation in collective action problems and we are interested in finding out whether this result extends to weak-link games. Our results suggest that leadership does indeed increase coordination and efficiency. In particular, with leadership we typically observe efficiency rising over time while without it declines over time. There doesn't appear to be a difference between voluntary leaders and leaders that are (randomly) appointed.

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## 1. Introduction

The weak link game was first introduced by Hirshleifer (1983) as a stylized way to capture the private provision of many public goods. As an illustration Hirshleifer tells the story of Anarchia, a low lying island protected from flooding through a network of interconnected dikes. The crux is that each citizen makes a private decision about how strong a dike to build on their land, yet the island will be flooded if the weakest dike breaks. Most relevant, therefore, is not the average or total contributions to the public good but the minimum contribution. This applies to the production of any good, public or private, where output is determined by the weakest component of production. The weak link game is thus of much applied interest and can prove useful in understanding such things as the performance of organizations and nations (e.g. Knez and Camerer 1994 and Brandts and Cooper 2006b), for example, the high wage and productivity differentials between rich and poor countries (Kremer 1993).

Hirshleifer argued that production will be efficient in a weak link game. The basic reasoning is that a person cannot free-ride in a weak link game and so there is an incentive to contribute an efficient amount to the public good. This hypothesis was confirmed in two player games (Harrison and Hirshleifer 1989), but Isaac, Schmidt and Walker (1989), Van Huyck et. al. (1990) and subsequent studies provide little support for this hypothesis when there are more than two players. Basically, while it is a Nash equilibrium to contribute an efficient amount it requires coordination and trust, because the low contribution of one player will make any high contribution redundant and costly for that contributor (Yamagishi and Sato 1986). What we typically observe, therefore, in the weak-link game is considerable coordination failure with contributions rapidly falling to the minimum level (Camerer 2003).<sup>1</sup>

How can such coordination failure be avoided? Various solutions have been considered in the literature (Devetag and Ortmann 2007). For instance, coordination failure is less following a temporary increase in the gains of coordinating (Brandts and Holt 2006b), if there is pre-play communication (Blume and Ortmann 2007, Brandts and Cooper 2007 and Chadhuri et al. 2009), and if players opt in to play the game (Cachon and Camerer 1996). Generally speaking, however, these solutions may not always be practical. For example, pre-play communication may be unwieldy in large groups, and many of the solutions rely on the full distribution of contributions being known rather than just the minimum (a point taken up by Brandts and Cooper 2006a).<sup>2</sup>

The basic objective of this paper was to ask whether *leadership reduces coordination failure in the weak link game*. Leadership evolved to solve coordination problems between individuals and is common in all social species (Van Vugt, 2006; Van Vugt et al., 2008). Our main hypothesis is that leadership significantly reduces coordination failure compared to when all players contribute simultaneously. By

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<sup>1</sup> There are some notable exceptions including Bortolotti, Devetag & Ortmann (2009) who find higher effort levels in a real effort weak link game. See Devetag and Ortmann (2007) for a survey of the literature.

<sup>2</sup> To put these issues in some context: In the dike example, with which we began this paper, the full distribution of contributions would be observable (a person can just go around the island and look) but communication (e.g. each landowner saying how high a dike they plan to build) could be unwieldy. Next consider authors submitting articles to a special issue of a journal or contributed book. Here, only the minimum (i.e. slowest) contribution is likely to be observable and communication between authors may or may not be possible given anonymity.

leadership we shall mean that *one player can lead by publicly choosing a contribution before all other players*. Various experimental studies have already demonstrated the positive effect of this kind of leadership on cooperative behavior in public good and public bad games (Der Heijden & Moxnes, 2003, Güth et al. 2007 and Pogrebna et al. 2008 ). It remains to be seen whether leadership also works in public good games with weak-link features.

To test the benefits of leadership we ran a laboratory experiment with both exogenous and endogenous leadership in a repeated four-player weak link game. Overall we find that there is significantly less coordination failure in conditions with leadership than without. Interestingly, leadership has a delayed effect on the improvement of coordination because followers take their time in matching the leader's choice. It is as if leaders teach followers how to coordinate. The delayed benefit of leadership implies that leadership enables groups to overcome coordination failure rather than that it kick start coordination. Specifically, with or without leadership, contributions in the first round of play did not differ and were invariably low. However, with leadership some groups were able to overcome coordination failure and improve group efficiency. Leadership is not a panacea: In half of the groups the efforts of leaders did not pay off. Given, however, the difficulty in overcoming coordination failure in a weak link game (c.f. Crawford 2001 and Chadhuri et al. 2009), we suggest that leadership works.

We proceed as follows, in Section 2 we introduce the weak-link game and in Section 3 we discuss leadership, related literature, and state our hypotheses. Section 4 contains the results, Section 5 concludes and additional materials are provided in an appendix.

## 2. The Weak-Link Game

In a standard weak-link game participants simultaneously pick a number. The earnings of a particular player depend on the number they chose and on the lowest number chosen. The lower is the lowest number chosen then the lower are earnings. Earnings are also negatively correlated with the distance between own choice and the lowest choice. A weak-link game is a representation of any situation where the group output depends on the contribution (or effort) of the least contributing member and contributing is costly.

We adopt the standard payoff structure used by Van Hyuck et al. (1990). In this version of the game participants pick a *whole* number between 1 and 7 and their earnings depend on the choices made according to the following formula:

$$0.60 + 0.10 [\textit{minimum choice}] - 0.10 [\textit{own choice} - \textit{minimum choice}]$$

Table 1 describes the earnings for participants for every potential combination of their own choice and the lowest choice.

<b>Choice:</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>
<b>Min = 1</b>	0.7	0.6	0.5	0.4	0.3	0.2	0.1
<b>Min = 2</b>		0.8	0.7	0.6	0.5	0.4	0.3
<b>Min = 3</b>			0.9	0.8	0.7	0.6	0.5
<b>Min = 4</b>				1.0	0.9	0.8	0.7
<b>Min = 5</b>					1.1	1.0	0.9
<b>Min = 6</b>						1.2	1.1
<b>Min = 7</b>							1.3

**Table 1:** Payoff table

Every outcome where all participants choose the same number is a Nash equilibrium. Clearly Nash equilibria on higher numbers are preferred to those over lower numbers, so the Pareto optimum is for every player to choose 7. Note, however, that higher numbered Nash equilibria involve a degree of strategic uncertainty. Picking the highest number is the best strategy only if all other players also pick the highest number.

It is worth clarifying that there are two notions of coordination in a weak-link game. We can think of players as coordinating if they all choose the same number and so are coordinating on a Nash equilibrium. Alternatively we can think of players as coordinating if they all choose high numbers and so are coordinating on the most efficient Nash equilibria. Throughout the following, with the brief exception of Figure 3, we shall focus on the later notion of coordination. We, thus, say that there is increased coordination and efficiency if the minimum number increases, and there is coordination failure and inefficiency if the minimum number chosen is low.

### 3. Leadership

We contrast the *standard* weak link game in which all players choose simultaneously with a game in which one individual, the leader, makes a choice before the remaining players. In a standard weak link game we expect to see significant coordination failure. What difference will leadership make? Our main hypothesis is that it reduces coordination failure.

**Hypothesis 1:** There is less coordination failure in a weak link game with leadership than in a standard weak link game.

It is useful to decompose Hypothesis 1 into two parts: (a) leaders choose higher numbers than would players in a standard weak link game, and (b) followers respond by also choosing higher numbers. To show that leadership works we need to find evidence for both a and b. We suggest three reasons why both may hold – signaling, reciprocity and reduced strategic uncertainty.

In a weak link game with leadership a leader can, by choosing a high number, send a costly signal, or communicate to others, that it is good to choose a high number.<sup>3</sup> This is the overriding reason we suggest Hypothesis 1 and several studies have shown the benefits of both costless and costly communication in weak-link games (e.g. Cooper et al. 1992, Van Huyck et al. 1993, Cahon and Camerer 1995, Cooper 2006 and Blume &

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<sup>3</sup> The signal is costly because choice is non-reversible.

Ortmann 2007). We note, however, that costless communication has proved less effective if only one player can communicate (Weber et al. 2001), primarily because signals are ignored.<sup>4</sup> Costly communication has also proved ineffective if players avoid the cost of signaling (Manzini, Sadrieh and Vriend 2009). Together, this casts doubt on both (a) and (b). Weber, Camerer and Knez (2004) seemingly confirm this by finding significant coordination failure in a sequential weak-link game. In this case choosing the highest number is the unique sub game perfect Nash equilibrium and so there should be no coordination failure. In fact, significant coordination failure was still observed, which the authors put down to an unwillingness of some leaders to bet on the levels of iterated rationality of others. That leadership will work is, therefore, an open empirical question.

The public good literature provides more reason to be optimistic about the effects of leadership. There leading by example has been shown to have a positive effect on contributions because high leader contributions are reciprocated by followers (Moxnes and Van der Heijden 2003; Güth et al. 2007). Extrapolating this finding to a weak link game means that if a leader chooses a high number (which is a relatively risky thing to do) then followers would reciprocate by also choosing a high number. In a linear public good game (and other settings where it is typical to talk of reciprocity) reciprocity is not consistent with Nash equilibrium and so leadership proves effective only because of followers social preferences (Fehr and Gächter 2000). In a weak link game reciprocation can be consistent with Nash equilibrium and should, therefore, reinforce signaling.<sup>5</sup> The public good literature has also highlighted, however, that a leader may not want to gamble on follower reciprocation (Cartwright and Patel 2010). For example, Fernanda Rivas & Sutter (2008) show a positive effect of leadership on cooperation but only for voluntary leaders.

The discussion so far suggests that while there are good, intuitive reasons that leadership could increase efficiency, because of signaling and/or reciprocity, there are also reasons it may not. This suggests comparing voluntary (endogenous) leadership versus imposed (exogenous) leadership. Our second hypothesis is that voluntary leadership is more effective than exogenous leadership.

**Hypothesis 2:** Coordination failure in a weak link game with endogenous leadership is less than in a weak link game with exogenous leadership.

This hypothesis is motivated by the idea that (a) voluntary leaders will be more willing to gamble by choosing a high number, and (b) followers may be more willing to reciprocate a voluntary leader. Support for this comes from the public good literature. For example, Van Vugt and De Cremer (1999) and Arbak and Villeval (2007) find that imposed

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<sup>4</sup> Costless communication has also proved less effective if there is not common knowledge what has been communicated (Chaudhuri et al. 2009).

<sup>5</sup> That does not mean that social preferences are not relevant. To illustrate, consider the Fehr-Schmidt model of inequality aversion (Fehr and Schmidt 1999) and, for simplicity, suppose that players must choose 1 or 7 and the leader has chosen 7. If a follower chooses 1 then the follower gets a payoff of 0.7 and the leader a payoff of 0.1. If the follower chooses 7 she must get the same payoff as the leader, either 0.1 or 1.3. Inequality aversion or not, there will be a Nash equilibrium where all followers choose 7 and one where they all choose 1. More relevant to us here is which equilibrium is more likely to occur, and intuitively inequality aversion could change this. To justify this, suppose there are  $n-1$  followers and one of these followers expects one other follower to choose 1 and the rest to choose 7. His payoff (using the Fehr-Schmidt notation) is  $0.1 - 0.6\alpha/(n-1)$  if he chooses 7 and  $0.7 - 0.6\beta(n-2)/(n-1)$  if he chooses 1. He may, therefore, get a higher payoff from choosing 7 if he is sufficiently inequality averse.

leaders contribute less to a group than voluntary leaders, while Gächter et. al. (2008) found that reciprocally oriented leaders contribute more.

A final important consideration is that outcomes in the weak-link game are sensitive to group size. The more people there are to coordinate the greater is coordination failure (Van Huyck et al. 1990 and Van Huyck et al. 2007). Given that the choice of the leader is known before followers make their choices, followers face less strategic uncertainty in a game with leadership than without. This means that leadership should improve coordination merely by reducing strategic uncertainty. Our final hypothesis is that leadership, because of signaling and reciprocity, does more than this. To test that we need to compare what happens in an  $n$  player game with leadership to an  $n - 1$  player game without leadership.

**Hypothesis 3:** Coordination failure in a weak link game with leadership and  $n$  players is less than in a standard weak link game with  $n - 1$  players.

Hypothesis 3 strengthens Hypothesis 1. In particular, for an  $n$  player game with leadership to really look like a standard  $n - 1$  player game *the leader must choose 7*. If the leader chooses anything less than 7 then there is no reason to expect choices to be as high in the game with leadership as the standard game. Clearly, therefore, we still need that (a), leaders choose high numbers, but have slightly raised the bar for how high a number they should choose. We have also raised the bar for our expectation of followers. Specifically, we now require that (b) a leader choosing a high number causes followers to choose a *higher* number than they would do in a standard weak link with as many players as there are followers. Only in this case can we really think of followers as having responded to the leader's example.

## 4. Method

To test our hypotheses we performed a laboratory experiment in which we compared four different versions of the weak link game, all sharing the payoff structure as given in Table 1:

**Simultaneous 3 player game (Sim3):** There are 3 players in the game who all simultaneously chose a number without knowing what the other players have chosen.

**Simultaneous 4 player game (Sim4):** There are 4 players in the game who all simultaneously chose a number without knowing what the other players have chosen.

**Exogenous leader (Exo):** There are 4 players in the game. One player is randomly selected to choose before the other three. When this player has made their decision, this decision is made public to the other 3. These remaining 3 players then all simultaneously chose a number.

**Endogenous leader (End):** There are 4 players in the game. Any one of the 4 players can choose to go first by simply being the first to choose a number. Once one player has chosen, their choice is made public to the other 3. These remaining 3 players then all simultaneously chose a number. In the event that no one chooses to go first (we imposed a cut-off of 30 seconds) the game is changed to one where all four players have to choose simultaneously as in Sim4.<sup>6</sup>

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<sup>6</sup> In the end, this never happened. During the game there was always someone who wanted to choose first.



Each experimental session consisted of 3 distinct parts. In each part participants were grouped into groups of 3 or 4, as appropriate, and played 10 rounds of either Sim3, Sim4, Exo or End. Note that within these 10 rounds the game and groups did not change. Between parts of the session the groups and possibly the game did change. Specifically, we ran seven sessions in all, each with four groups. In one session participants played Sim3 in all 3 parts of the experiment. In the other six sessions, participants played each of Sim4, Exo and End in varying order. That we had six sessions allowed us to consider all possible permutations of Sim4, Exo and End as detailed in Table 2.

Session	Participants	Part 1	Part 2	Part 3
1	16	Exo	End	Sim4
2	16	End	Sim4	Exo
3	16	Sim4	Exo	End
4	16	Exo	Sim4	End
5	16	Sim4	End	Exo
6	16	End	Exo	Sim4
7	12	Sim3	Sim3	Sim3

**Table 2:** Summary of sessions.

Participants were told at the start of the experiment that they would play ‘a number’ of games (of 10 rounds each). Participants were only given the instructions to a particular game before they played that game. It was also emphasized to participants that they would be playing in a totally new group in each part of the experiment. For example, session 4 participants were first given general instructions and then short specific instructions to Exo and played 10 rounds. They were then told the revised instructions for Sim4 and reminded that they would now be matched with new players before playing 10 rounds of Sim4. Finally, they were given the revised instructions for End and again reminded that they would now be matched with new players before playing 10 rounds of End. [The instructions are available in the Appendix.]

For the conditions with a leader we deliberately avoided terms like ‘leaders’ and ‘followers’ and instead used more neutral descriptions like ‘the person choosing first’ and ‘the other players’. Also, in each round once participants had made their decision the lowest - and only the lowest - number in the group, and the earnings were announced. Note that announcing the full distribution of choices, rather than just the minimum, has been shown to make it easier for subjects to coordinate, and so we provide a tougher test of leadership (Berninghaus and Ehrhart 2001 and Brandts and Cooper 2006a).<sup>7</sup>

The experiment was programmed and conducted with the software Z-tree (Fischbacher, 2007) and run at the University of Kent in March 2009. Afterwards participants were paid the earnings of one randomly selected game. Participants were recruited via the university-wide research participation scheme and were randomly

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<sup>7</sup> Basically, if the distribution of choices is observed then players can signal through repeated interaction that higher numbers could be chosen to mutual benefit. Observed coordination failure is, thus, typically less. A similar effect is seen by Blume and Ortmann (2007) in a setting where only the minimum choice is made public but in a pre-play communication stage *all* players can send a signal of what they intend to do.

assigned to the different conditions and to their respective groups. In total 108 subjects participated, who earned on average £8.82. The experiment took about 45 minutes.

## 5. Results

To give a first snapshot of the overall results, Table 3 summarizes the average choice, the average minimum choice and average total earnings per group over all 10 rounds for the four games. To put the average total earnings into context, if players coordinate on 7 in each round then average total earnings would be 13, and if they coordinate on 1 they would be 7. Note that we have pooled the results across the sessions thereby ignoring the order in which subjects play a particular game (this is justified in the appendix).

	Average choice	Average minimum choice	Average player earnings
Sim4	3.00 (1.33)	1.93 (1.14)	6.85 (1.31)
Exo	3.78 (1.49)	2.61 (1.63)	7.44 (1.97)
End	4.01 (1.71)	3.00 (1.78)	7.99 (2.09)
Exo + End	3.90 (1.59)	2.81 (1.78)	7.71 (2.04)
Sim3	4.23 (1.72)	3.45 (1.99)	8.67 (2.35)

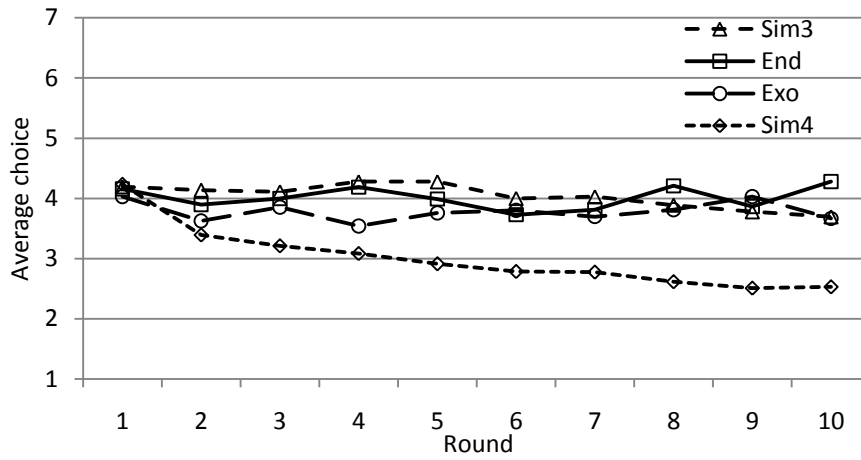
**Table 3:** Average choice, minimum choice and total earnings, standard errors in brackets.

There is evidence of leadership improving efficiency as expected (Hypotheses 1 and 2) given that efficiency was higher in the End condition than the in the Exo condition than in the Sim4 condition for all three criteria in Table 3. There is no statistically significant difference between the Exo and End leadership conditions ( $p > 0.232$ ). [All tests, unless otherwise stated, are two-sided Mann Whitney.] Pooling the averages from both leadership conditions over the 10 rounds the difference between the Sim4 condition and the combined leadership conditions are statistically significant for the average choice ( $p = .024$ ) and the average minimum choice ( $p = .040$ ) and marginally so for the average earnings ( $p = .082$ ).

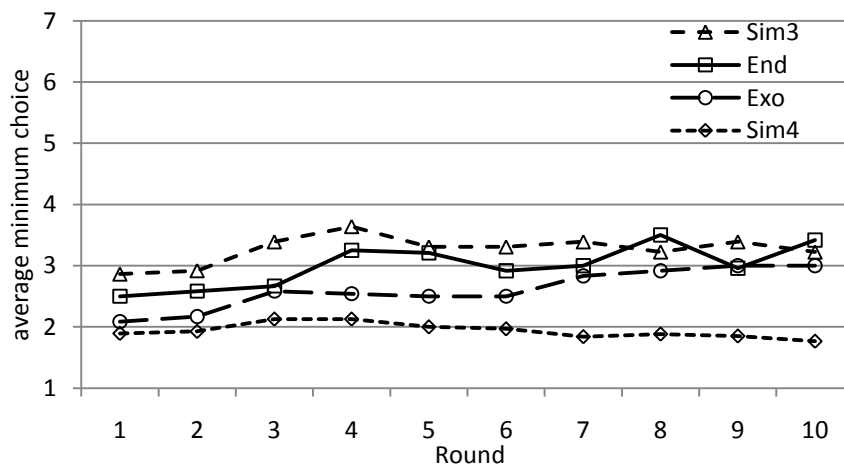
To get a more dynamic picture of behavior, Figures 1, 2 and 3 plot the development of, respectively, the average choice, minimum choice and average difference between choice and minimum over the course of the 10 rounds. Here we see a positive dynamic benefit of leadership. Specifically, in the Sim4 condition the average choice and minimum choice *fall* through the rounds (with coefficient (standard error) of  $-.151 (.022)$  and  $-0.23 (0.14)$ ). In the leadership conditions, by contrast, the minimum choice *increases* through the rounds ( $.101 (.021)$  for Exo and  $.085 (.023)$  for End).<sup>8</sup> The average choice remains relatively constant. We see in Figure 3 that in all four conditions there is a steady convergence of choices. Thus, players do learn to coordinate on a Nash equilibrium.

<sup>8</sup> In the Sim3 condition the average choice falls through the rounds while the minimum remains relatively constant ( $-.051 (.038)$  and  $.034 (.037)$ ).

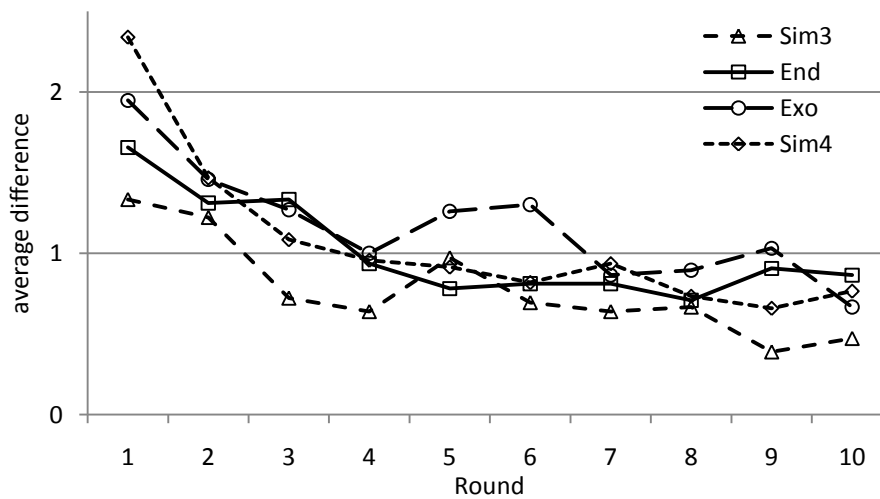
**Figure 1:** Average choice per round.



**Figure 2:** Average minimum choice per round.



**Figure 3:** Average difference between choice and minimum choice per round.



To look further at the dynamic effects Table 4 details the proportion of groups where the minimum choice was low (1 or 2), intermediate (3, 4 or 5) or high (6 or 7) in the 1<sup>st</sup> and 10<sup>th</sup> round.<sup>9,10</sup> Consistent with Figure 2, we see low and declining efficiency in the Sim4 condition. In the leadership conditions we observe initially low efficiency but increased efficiency by round 10. Indeed, in round 1 we find little difference in choices (i.e. all choices and not just the minimum) between the leadership conditions and Sim4 ( $p = 0.773$  and  $0.989$  comparing End and Exo respectively with Sim4, using the Kolmogorov-Smirnov test, and  $p = 0.400$  and  $0.100$  comparing to Sim3). By round 10 we find a significant difference in choices between the leadership conditions and Sim4 ( $p = 0.007$  and  $0.001$  comparing End and Exo respectively with Sim4 and  $p = 0.229$  and  $0.240$  comparing to Sim3).

Choice	Round 1			Round 10		
	1 or 2	3, 4 or 5	6 or 7	1 or 2	3, 4 or 5	6 or 7
Sim4	71	29	0	83	17	0
Sim3	42	59	0	42	33	25
Exo	58	34	8	46	25	29
End	67	25	8	50	29	21

**Table 4:** Minimum choice frequencies in rounds 1 and 10.

At this point we can begin to summarize our findings.

**Result 1:** Leadership does lead to increased efficiency. It does not have any apparent effect on initial choices but does lead to increased efficiency after repeated interaction.

Despite the positive effects of leadership it is clear that leadership has not completely removed inefficiency. We need, therefore, to look in more detail at whether leaders chose high numbers and whether followers reacted to the leader's choice.

## 5.1 Leader and follower choices

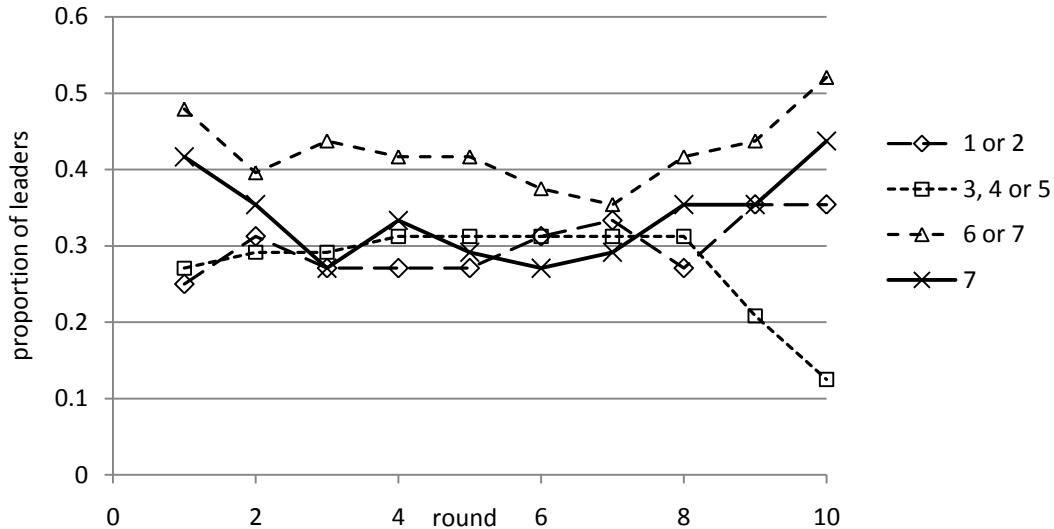
We begin by looking at the choices of leaders. Figure 4 plots the proportion of leaders, both exogenous and endogenous, choosing a low, intermediate or high number in each round. We see that in each round a high proportion of leaders do choose high numbers. The only dynamic effect is a slight polarization of leader choices towards the extremes by round 10. Figure 4 leaves open the question of whether leaders choosing high numbers are evenly distributed over groups. Figure 5 shows per group how many times the leader chooses 6 or 7. We can clearly see that there is a lot of diversity in groups. In most groups there are relatively few occasions where leaders choose high numbers. Put another way, however, in 93% of groups there is at least one round where a leader does choose a

<sup>9</sup> The complete data for minimum and overall choice frequencies, as well as choices for each game, is available in the Appendix.

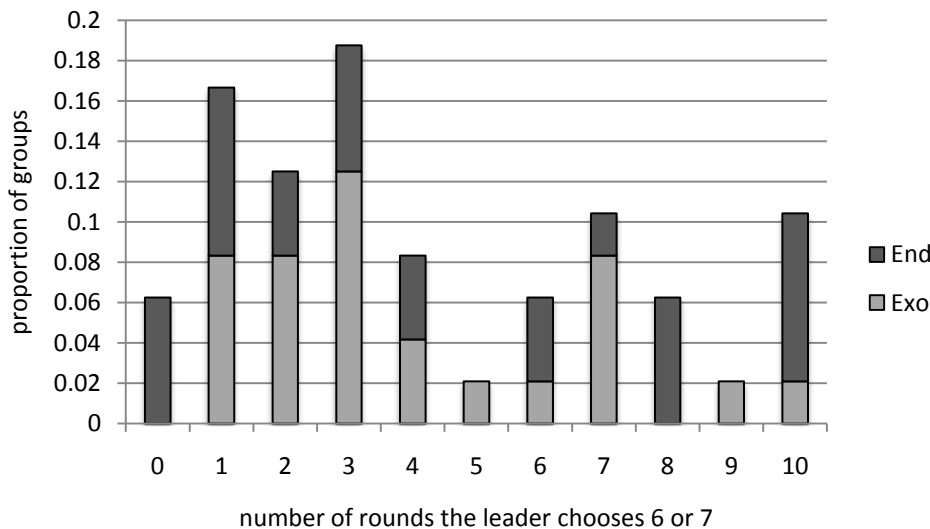
<sup>10</sup> The distinction into, low, intermediate and high is clearly somewhat arbitrary but hopefully intuitive. Given that our main focus will be on leaders choosing high numbers we note that a leader choice of 6 or 7 appears to result in relatively similar outcomes (as we shall see) while a leader choice of 5 appears to result in qualitatively different outcomes.

high number. Many leaders were willing to gamble by choosing a high number, but clearly not all.

**Figure 4:** The proportion of leaders choosing 1 and 2 or 3, 4 and 5 or 6 and 7.



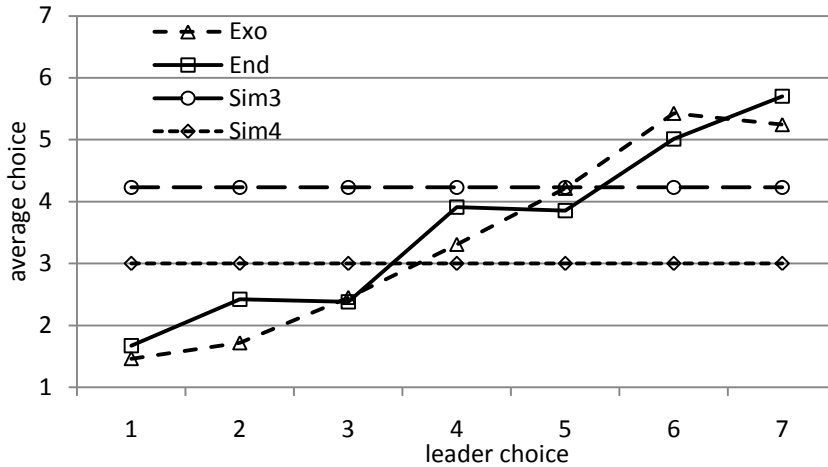
**Figure 5:** The number of rounds (out of 10) the leader chooses 6 or 7 per group.



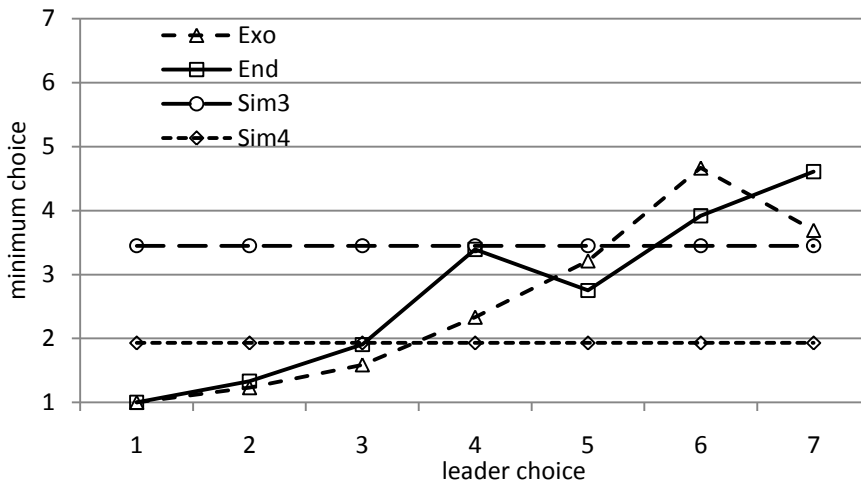
Turning to follower behavior, figures 6 and 7 plot the average and minimum choice of followers as a function of leader choice for all 10 rounds. Clearly, we do see evidence that follower choice is positively correlated to leader choice. The correlation between the number chosen by the leader and (the average) number chosen by followers is high. The Pearson correlation is .873 in the exogenous condition and .822 in the endogenous condition. Both correlations are significant ( $p < .001$ ). While follower choice does correlate it is noticeable that followers pick a significantly lower number than the leader. The average difference between leader choice and (average) follower choice is .54

for exogenous leaders and .38 for endogenous leaders. Both differ significantly from zero ( $p < .001$  and  $p = .001$  respectively) but not from each other ( $p = .149$ ).

**Figure 6:** The average choice of followers per leader choice.



**Figure 7:** The minimum choice of followers per leader choice.

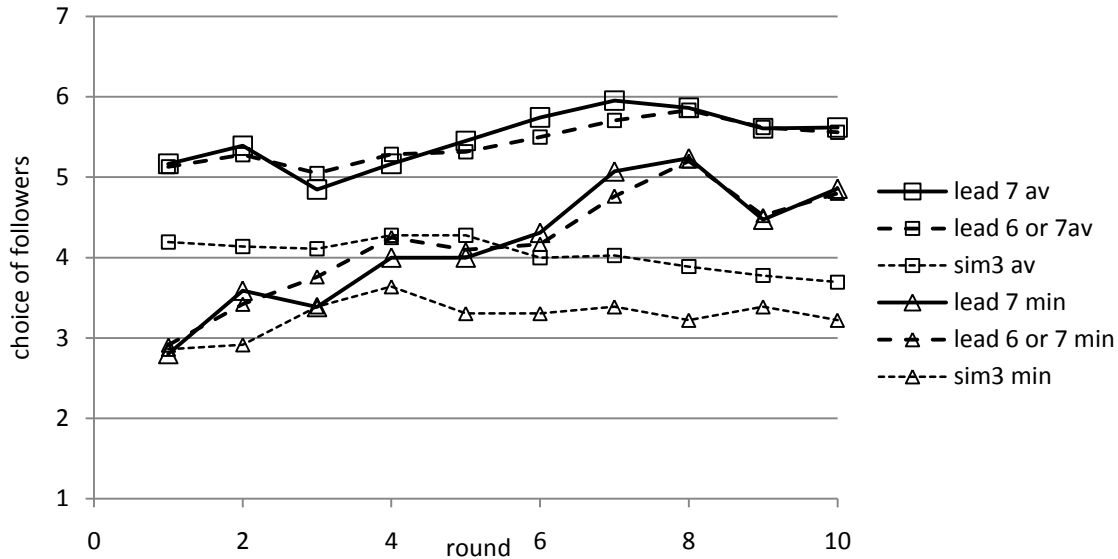


Of most relevance to us is whether a *high* leader choice causes followers to choose high numbers, and higher than those chosen in Sim3. Figures 6 and 7 suggest that it does. Figure 8 further supports this by detailing the average and minimum choice of followers if the follower chooses 6 or 7. We see in Figure 8 that the minimum choice of followers, conditional on a leader choosing a high number, is increasing over the 10 rounds (with coefficient (standard error) of 0.203 (0.036)).<sup>12</sup> Furthermore, followers of a leader who has chosen a high number choose significantly higher numbers than do subjects in Sim3 ( $p < 0.01$  using Kolmogorov Smirnov test for both exogenous or endogenous leaders choosing 6 or 7 or choosing 7). It would seem, therefore, that a

<sup>12</sup> For clarity we have pooled the leadership data but the data for Exo and End follow a very similar pattern.

leader's choice sets a good example for followers and this signal becomes stronger with repeated interaction.<sup>13</sup>

**Figure 8:** The average and minimum choice of followers if leaders choose 6 or 7.



We summarize these findings with our second result.

**Result 2:** Leaders do choose a high number a large proportion of the time (over 40%) but there is considerable variation in leader choices across groups. Followers do respond to a high leader choice with a higher choice than can be expected solely due to reduced strategic uncertainty. Also, the minimum choice following a higher leader choice is increasing with repeated interaction.

## 5.2 Overcoming coordination failure

Result 2 suggests that we do see the two components for leadership to work, namely leaders choosing high numbers and followers reacting to this. We also, however, see that some persistence by leaders may be necessary before followers respond. This leads to the interesting notion that leadership may help overcome coordination failure. In a standard weak link game it typically proves impossible to escape from a low choice equilibrium (e.g. Weber et al. 2001, Brandts and Cooper 2006a, 2007 and Chaudhuri et al. 2009). To explore whether leadership can avoid this we look individually at each of the 48 groups from the leadership conditions and characterize what happens in each group. Clearly any characterization is somewhat subjective and arbitrary, because all groups are different, but we think that there are some consistent trends are observable (and our characterization can be easily checked using the information in the Appendix). We distinguish groups according to the following categories:

<sup>13</sup> We do have to be careful that there is not a self selection issue here but Figure 4 has already clarified that the number of leaders choosing a high number is relatively constant, so this should not be a concern.

*Successful reversal of coordination failure (SR)*: If there was a minimum of 3 or less in round 1 and of 5 or more in round 10 then we say that there was a successful reversal of coordination failure. Table 5 shows two examples. In the first example leaders persistently choose 7 and this eventually leads to efficiency. In the second example leader choice fluctuates but the minimum consistently rises.

*Persistent coordination failure (CF)*: If there was a minimum of 3 or less in at least 9 rounds then we say that there was persistent coordination failure. Again, Table 5 shows two examples. In both examples the minimum stays at 1 despite the efforts of leaders to increase efficiency.

*Efficient (E)*: If the minimum choice was 4 or above in all rounds then we say the group was efficient. Note that this category is mutually exclusive from all others, i.e. in every group that does not fit this category there is at least one round with a minimum below 4.

*Reversal of coordination failure to 4, 5, 6 or 7 (Rx)*: If there was a round with a minimum of 3 or less and then a *later* round with a minimum of  $x = 4, 5, 6$  or 7 or more then we say that there was a reversal of coordination failure to  $x$ . This category allows a fairly mixed selection of dynamics as illustrated by the two examples in Table 5.<sup>14</sup>

We note that every group fits into one of the four categories above and some of them into one than one. (The categorization is detailed in the Appendix.) Table 6 details how many groups fit into each category.

Category	Group	Round									
		1	2	3	4	5	6	7	8	9	10
SR	10 End	7 3	7 2	7 4	7 6	7 6	7 6	7 6	7 6	7 6	7 7
	21 Exo	4 2	2 1	7 2	2 1	4 2	7 4	7 4	5 4	7 4	7 5
CF	7 End	4 3	3 2	2 1	1 1	5 1	1 1	6 1	1 1	1 1	1 1
	11 Exo	7 1	1 1	4 1	1 1	7 1	7 1	4 1	5 1	5 1	2 1
E	19 Exo	7 6	7 6	6 6	7 6	6 5	6 5	6 5	5 4	7 6	7 6
R4	23 End	4 3	1 1	1 1	5 4	5 4	1 1	6 4	1 1	5 4	1 1
R7	2 End	2 1	1 1	6 5	7 6	7 7	7 7	7 7	7 7	7 1	7 2

**Table 5:** Examples of group dynamics, showing the leader and minimum choice by round for example groups.

	E	SR	R7	R6	R5	R4	CF
Exogenous (n = 24)	2	5	1	4	11	12	11
Endogenous (n = 24)	3	4	4	6	7	12	11
Sim4 (n = 24)	0	0	0	1	2	6	19
Sim3 (n = 12)	4	0	0	0	0	3	8

**Table 6:** Characterizing group dynamics by leadership condition. The number of groups that fit into each category.

<sup>14</sup> By definition any group in the SR category must be in the R5 category. A group in the CF category could also be in the Rx category.



As we would expect in the Sim3 and Sim4 conditions there is little evidence that groups can overcome coordination failure. In the leadership conditions we do see evidence that groups could overcome coordination failure. For example, in only 2 out of 32 groups without leadership did we see a minimum of 5 or more after there had been a round with a minimum of 3 or less; in groups with leadership that proportion rises to 18 out of 43. Similarly, in 0 out of 29 candidate groups (i.e. groups with a minimum of 3 or less in round 1) without leadership we do see a successful reversal of coordination failure; in groups with leadership this proportion rises to 9 out of 38. That leadership is not a complete answer to coordination failure is clear. In particular, there were numerous groups in which leaders repeatedly chose high numbers only to see at least one follower choose 1. This, however, merely serves to reiterate how difficult it can be to overcome coordination failure in the weak link game. That between 42% and 24% of groups, depending on how one counts, were able to overcome coordination failure seems a relatively high proportion and leads to our next result.

**Result 3:** In games Sim3 and Sim4 one instance of coordination failure typically leads to persistent coordination failure. In games with leadership we see that coordination failure need not be persistent. In a significant number of groups the high choice of a leader did mean coordination failure could be overcome.

### 5.3 Exogenous versus endogenous leadership

Finally, we compare endogenous versus exogenous leadership. The data is broadly consistent with Hypothesis 2: The average number chosen by endogenous leaders is higher than by exogenous leaders (4.39 versus 4.33); the minimum choice of followers in the endogenous condition is closer to leader choice than in the exogenous condition (0.38 versus 0.54); followers choose on average a higher number if an endogenous leader chooses 6 or 7 compared to an exogenous leader (5.55 versus 5.28); finally, as we saw in Table 3, average and minimum choice, and payoffs, are higher in the endogenous compared to exogenous leadership condition.<sup>15</sup> None of these differences are, however, large or statistically significant. This leads to our final result.

**Result 4:** We find no significant difference between games with an endogenous and exogenous leader.

To try and understand this lack of difference, we first note that if results 2 and 3 suggest high leader choices can ultimately lead to improved group efficiency they leave open the question of whether choosing high numbers pay off for leaders. Recall from Table 1 that a leader can guarantee a payoff of 0.7 by choosing 1. If he chooses 7 then he needs the minimum choice of followers to be at least 4 in order to get a payoff of 0.7 or above. It is clear from figure 8 that this may not be the case, particularly in the early rounds. In fact leaders do earn slightly less (but not significantly so) than followers in both conditions, as detailed in Table 7, and the average payoff of leaders is increasing over rounds (with coefficient (standard error) 0.02 (0.003)). Leaders do not earn

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<sup>15</sup> All participants in sessions 1 to 6 played games End, Exo and Sim4. The group a participant was with would change for each game so a direct comparison will be distorted by group effects. It still seems an interesting comparison, however, to see how a particular participant did across the three games. Choices and payoffs were higher in End than Exo for a statistically insignificant majority (50 and 53 out of 96).

significantly more or less than players in the Sim4 condition. In fact only followers in the endogenous condition do significantly different than they would have done in the simultaneous condition ( $p = .012$ ). For followers in the exogenous condition the difference is not significant ( $p = .187$ ).

	Leader	Followers
Exogenous	0.69 (.21)	0.76 (.18)
Endogenous	0.76 (.22)	0.81 (.20)
Sim4	0.69 (0.11)	

**Table 7:** Average earnings per round for leaders and followers per leadership condition.

Now consider a player who believes that the high choice of a leader might increase efficiency over time. In the End condition this player has the opportunity to lead and choose a high number. Whether he does so will likely depend on whether he is willing to gamble on followers responding and whether he expects some other player to do it. If he does expect some other player to do it then it is best to be a follower with its higher expected payoff.<sup>16</sup> In the Exo condition this last possibility is removed as no other player could possibly lead. This creates two countervailing forces: (i) In the End condition one or two players who decide it is worthwhile to lead and choose high numbers can do so in every period, but in the Exo condition they are constrained to wait their turn. (ii) In the End condition players willing to gamble on followers responding may wait for someone else to do so, and nobody does, but in the Exo condition their turn comes along and they take the gamble. The overall effect is ambiguous because (i) suggests greater efficiency in the End condition and (ii) in the Exo condition. Some support for this is seen in Figure 5 where see that there are more groups where leaders consistently choose high numbers or never choose higher numbers in the End than Exo condition.

## 6. Conclusions

The provision of many public and private goods hinges on the actions of the weakest link in the chain, that is the lowest contributor (Hirshleifer 1983 and Camerer 2003). The evidence suggests that in such cases the likely outcome is coordination failure. Various possible solutions have been considered in the literature and our objective in this paper was to consider a novel solution, leadership. By leadership we mean that one person, the leader, announces their contribution first thereby setting an example for the rest of the group. Our main hypothesis was that by choosing a high number the leader could improve efficiency.

As predicted, we find that leadership increases efficiency. More surprising was that it does so with a delayed effect. Specifically, leadership generally failed to *establish* efficiency in the early rounds but there was a *rise in efficiency* over time. That leadership produced increased efficiency over time is because individuals took time to follow the example of leaders. Our main conclusion is therefore that leadership works if individuals

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<sup>16</sup> More formally, a leader who chooses 7 is gambling on the choices of 3 followers. A follower choosing 7 after a leader has chosen 7 is gambling on the choices of only 2 other followers.

persistently set a good example and eventually pull up the efficiency of the group. We found no discernible difference between voluntary and imposed leaders.

We finish by relating our results to some related work. In concurrent and on-going work, Coelho et al. (2009), address a very similar question to that which motivated this paper. They consider a 10 player weak link game in which a leader, the person in the group with the highest CRT score, leads by example. The most significant differences with our approach are that the leader remains the same throughout the rounds and is selected on ability. They find that leadership leads to immediate and sustained efficiency if all players observe the minimum choice of previous rounds but immediate and declining efficiency if the minimum choice of previous rounds is not observed by followers. These results seem quite different to ours and suggest that more work on the consequences of leadership, and in particular the consequences of different types of leadership, would be desirable.

Blume and Ortmann (2007) show that when *all* players send a message of what they intend to do it helps to *establish* coordination. They also show that this kind of communication stops to be useful if efficiency starts to decline (this happened in 2 of 8 groups). Our setting differs in that only one player can communicate but this communication is not cheap talk. We observed much lower efficiency than Blume and Ortmann (2007) in the baseline treatment of a standard weak-link, so it is difficult to make any meaningful quantitative comparison of results. It seems, however, that leadership by example may be as, if not more, effective in tackling coordination failure and maintaining group efficiency because the leader's signal is not cheap talk.

Finally, Brandts and Cooper (2006a and 2006b) consider a setting where there is no communication but all contributions are observed and not just the minimum. They show that inefficiency can be reversed if enough, of what they call, strong leaders emerge who increase their contributions and persuade the laggards to do the same.<sup>17</sup> Our setting differs in that only one leader can send a public signal but this signal is possibly more salient. We find that one leader can be enough to turn around inefficiency, while it never was in the setting of Brandts and Cooper (2006b). The one leader in our setting has, however, a lower success rate than if there are three strong leaders in the setting of Brandts and Cooper (2006b). So, if it is a case of three people trying to increase the contributions of one, then making contributions public looks best, but if it is a case of one person trying to persuade three then maybe leadership may be more effective. Unfortunately, that's not possible to test with our data set.

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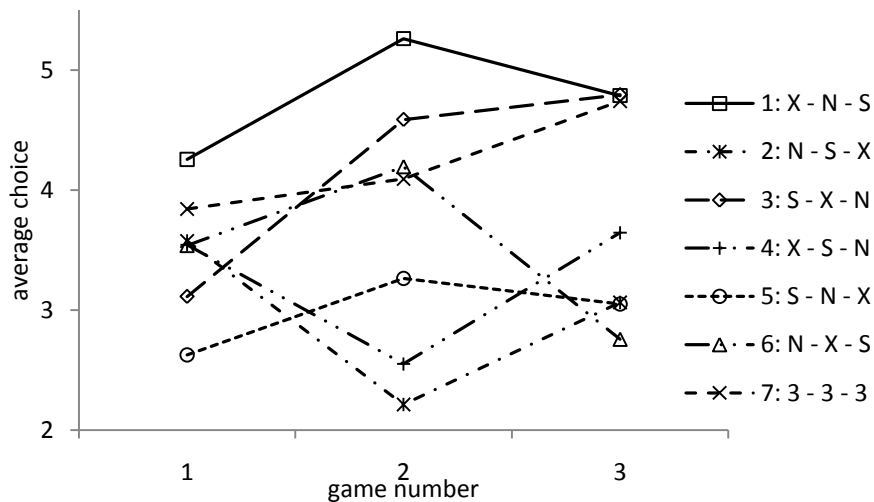
<sup>17</sup> One distinction should be noted. In the setting of Brandts and Cooper (2006a and b) players can signal, and only signal, over time from one round to the next. A strong leader is thus someone who signals from one round to the next. In our setting the leader can signal immediately to the other players. In the setting of Blume and Ortmann (2007) all players can signal immediately to all other players.

## Appendix A

One issue that we need to address is whether there were any order effects in playing the game. Recall that all participants in the four player conditions played each of the different versions once, as detailed in Table 2. The experiment was designed in a way so as to try and remove any order effects by, for example, completely changing groups for every game. Even in a perfect stranger set-up, however, we cannot simply rule out the possibility of the existence of some sort of learning effect caused by playing – a similar version of – the game three times in a row. In fact, we find no evidence of an order effect. For example, when we take the average choice over all three four-player conditions together participants chose in the first the game they played 3.44 (1.1), in the second game 3.68 (1.72) and in the third 3.68 (1.81). There is no significant difference (Kruskal-Wallis,  $p = .989$ ) in the average choice between these games. Participants do not, on average, pick higher numbers as they play related games in a row. The one exception is Session 7 where subjects played Sim3 three times in a row and improved efficiency each time. We are not, however, too concerned about this exception because its only consequence will be that we *overestimate* how well players coordinate in Sim3.

Figure 9 plots the average choice for each of the seven sessions and suggests that session effects outweighed any group effects. In Session 1, for example, choices are relatively high and in session 5 they are relatively low. We might conjecture that this is because in session 1 game Exo was played first and in session 7 Sim4 was played first. A look at session 3 (which started with game Sim4 but saw relatively high choices), and session 4 (which started with game Exo but saw relatively low choices) shows, however, that this conjecture does not get much support. It might be interesting to note that in all sessions bar one payoffs are higher in End than Exo than Sim4. In this remaining session they are higher in Exo than End than Sim4.

**Figure 9:** The average choice by session and game number, X = Exo, N = End, S = Sim4 and 3 = Sim3.





**Table A2:** Overall choice frequencies by condition and round, column = round, row = choice and cell = frequency.

Sim4 (n=96):

	1	2	3	4	5	6	7	8	9	10
1	16.67	22.92	31.25	32.29	38.54	41.67	40.63	41.67	46.88	45.83
2	7.29	15.63	10.42	13.54	13.54	12.50	13.54	11.46	15.63	16.67
3	13.54	14.58	19.79	12.50	10.42	10.42	12.50	13.54	7.29	6.25
4	15.63	19.79	10.42	18.75	14.58	13.54	14.58	14.58	13.54	14.58
5	15.63	8.33	12.50	8.33	9.38	10.42	6.25	13.54	8.33	5.21
6	8.33	9.38	6.25	8.33	7.29	5.21	5.21	3.13	3.13	6.25
7	22.92	9.38	9.38	6.25	6.25	6.25	7.29	2.08	5.21	5.21

Endogenous (n=96):

	1	2	3	4	5	6	7	8	9	10
1	26.04	29.17	23.96	31.25	29.17	29.17	28.13	23.96	33.33	35.42
2	4.17	13.54	13.54	9.38	7.29	7.29	9.38	9.38	3.13	9.38
3	15.63	11.46	6.25	12.50	7.29	9.38	11.46	10.42	4.17	6.25
4	12.50	10.42	16.67	9.38	16.67	8.33	11.46	15.63	7.29	7.29
5	7.29	6.25	7.29	14.58	12.50	16.67	14.58	17.71	14.58	8.33
6	5.21	5.21	13.54	4.17	8.33	12.50	5.21	4.17	13.54	10.42
7	29.17	23.96	18.75	18.75	18.75	16.67	19.79	18.75	23.96	22.92

Exogenous (n=96):

	1	2	3	4	5	6	7	8	9	10
1	19.79	25.00	21.88	19.79	17.71	27.08	29.17	28.13	34.38	29.17
2	7.29	12.50	7.29	7.29	16.67	10.42	9.38	7.29	9.38	4.17
3	14.58	11.46	14.58	11.46	8.33	8.33	13.54	6.25	1.04	7.29
4	11.46	8.33	11.46	14.58	17.71	19.79	5.21	7.29	13.54	10.42
5	13.54	10.42	14.58	9.38	5.21	5.21	10.42	5.21	5.21	4.17
6	9.38	6.25	10.42	17.71	14.58	9.38	6.25	16.67	5.21	7.29
7	23.96	26.04	19.79	19.79	19.79	19.79	26.04	29.17	31.25	37.50

Sim3 (n=36):

	1	2	3	4	5	6	7	8	9	10
1	2.78	8.33	5.56	5.56	8.33	13.89	13.89	13.89	13.89	16.67
2	11.11	11.11	16.67	11.11	11.11	8.33	11.11	13.89	16.67	13.89
3	25.00	19.44	16.67	19.44	22.22	27.78	25.00	16.67	25.00	25.00
4	19.44	11.11	19.44	16.67	8.33	5.56	5.56	11.11	5.56	5.56
5	13.89	19.44	8.33	13.89	8.33	8.33	5.56	16.67	5.56	5.56
6	8.33	13.89	11.11	8.33	16.67	11.11	11.11	5.56	8.33	13.89
7	19.44	16.67	22.22	25.00	25.00	25.00	27.78	22.22	25.00	19.44

Next we detail the minimum choice, in Sim4 and Sim3, and the leader choice and minimum choice, in Exo and End, by round for all groups. Recall that participants in groups are randomized after each game, so the participants in group 1 of the Sim4 condition will definitely not be the same as those in group 1 of the Exo condition etc. It may be worth note, however, in looking through the data that each session had 4 groups and the groups are provided in order. This means that the participants in groups 1-4 of the

Sim4 are the same as in groups 1-4 of the Exo and End conditions etc. There was only one session of the Sim3 condition.

**Table A3:** The minimum choice by round and group in the Sim4 condition.

Group	Round										Category
	1	2	3	4	5	6	7	8	9	10	
1	4	3	4	2	3	4	4	4	4	2	R4
2	3	4	5	6	6	6	6	4	5	4	R6
3	3	5	2	4	4	4	3	4	4	4	R5
4	4	1	3	3	2	3	3	2	2	2	CF
5	1	1	1	1	1	1	1	1	1	1	CF
6	2	2	2	2	2	2	2	2	2	2	CF
7	1	1	1	1	1	1	1	1	1	1	CF
8	1	1	1	1	1	1	1	1	1	1	CF
9	1	3	3	2	2	1	1	2	1	2	CF
10	1	3	3	2	2	1	1	2	1	2	CF
11	1	2	3	4	4	4	4	4	4	4	R4
12	1	1	1	1	1	1	1	1	1	1	CF
13	2	2	1	2	1	1	1	1	1	1	CF
14	1	1	1	1	1	1	1	1	1	1	CF
15	1	1	1	1	1	1	1	1	1	1	CF
16	1	2	3	4	1	1	1	2	1	2	R4 + CF
17	2	1	1	1	1	1	1	1	1	1	CF
18	1	1	1	1	1	1	1	1	1	1	CF
19	1	1	1	1	1	1	1	1	1	1	CF
20	4	3	4	2	3	4	2	2	3	2	R4
21	1	1	1	1	1	1	1	1	1	1	CF
22	1	1	1	1	1	1	1	1	1	1	CF
23	1	1	1	1	1	1	1	1	1	1	CF
24	1	2	3	3	3	2	2	2	1	1	CF

**Table A4:** The leader choice and minimum choice by round and group in the Exo condition.

Group	Round										Category
	1	2	3	4	5	6	7	8	9	10	
1	5 3	7 1	4 1	3 1	7 4	1 1	2 2	5 4	6 6	6 6	SR + R6
2	3 2	3 2	2 1	2 1	2 1	6 4	3 3	4 3	6 4	7 5	SR + R5
3	7 4	4 2	7 6	7 5	7 4	7 4	4 3	7 5	6 5	5 4	R6
4	4 3	5 5	4 4	5 2	4 3	7 1	1 1	4 3	3 3	5 3	R5
5	1 1	7 3	5 3	7 5	3 1	7 5	7 5	7 4	6 4	7 3	R5
6	7 1	1 1	7 1	1 1	1 1	1 1	5 1	1 1	1 1	1 1	CF
7	4 2	3 2	2 1	1 1	5 1	1 1	6 1	1 1	1 1	1 1	CF
8	1 1	7 3	4 1	7 3	6 3	3 1	1 1	3 1	1 1	1 1	CF
9	7 1	7 6	7 7	5 5	5 5	5 5	7 7	7 7	7 7	7 7	SR + R7
10	7 6	7 6	6 6	7 5	7 5	7 6	7 7	7 7	7 7	7 7	E
11	7 1	1 1	4 1	1 1	7 1	7 1	4 1	5 1	5 1	2 1	CF
12	7 1	4 1	3 1	7 1	1 1	5 1	3 1	1 1	1 1	1 1	CF
13	7 1	2 1	6 5	1 1	4 1	5 1	7 1	4 1	7 1	1 1	CF + R5
14	7 1	7 1	4 4	7 4	7 4	5 5	5 5	7 6	5 5	6 6	SR + R6
15	7 3	4 1	2 1	1 1	7 1	1 1	2 2	2 2	7 1	2 1	CF
16	3 2	3 1	6 1	7 2	1 1	3 2	4 3	4 2	3 1	5 1	CF
17	1 1	7 1	4 1	1 1	1 1	1 1	1 1	3 1	1 1	1 1	CF
18	1 1	1 1	1 1	1 1	7 1	7 1	1 1	5 1	7 1	1 1	CF
19	7 6	7 6	6 6	7 6	6 5	6 5	6 5	5 4	7 6	7 6	E
20	7 1	3 1	1 1	4 1	1 1	1 1	1 1	1 1	1 1	1 1	CF
21	4 2	2 1	7 2	2 1	4 2	7 4	7 4	5 4	7 4	7 5	SR + R5
22	1 1	4 4	7 5	6 5	7 5	4 3	7 5	7 4	7 1	7 4	R5
23	4 3	1 1	1 1	5 4	5 4	1 1	6 4	1 1	5 4	1 1	R4
24	7 2	1 1	1 1	3 3	4 4	6 4	5 3	7 5	5 5	4 4	R5



**Table A5:** The leader choice and minimum choice by round and group in the End condition.

Group	Round										Category
	1	2	3	4	5	6	7	8	9	10	
1	3 2	4 3	2 1	3 1	4 3	4 2	3 2	7 5	7 5	7 5	SR + R5
2	2 1	1 1	6 5	7 6	7 7	7 7	7 7	7 7	7 1	7 2	R7
3	7 5	5 5	4 4	6 6	7 5	7 6	7 6	7 6	7 7	7 7	E
4	6 6	7 4	7 3	5 5	6 6	4 4	5 5	7 7	4 4	7 7	R7
5	7 6	7 6	6 4	6 4	6 4	4 1	7 2	7 4	5 2	7 3	R4
6	7 1	6 1	7 1	7 1	1 1	1 1	7 1	7 1	1 1	7 1	CF
7	4 3	3 2	2 1	1 1	5 1	1 1	6 1	1 1	1 1	1 1	CF
8	3 2	1 1	7 1	7 3	6 2	6 2	1 1	7 1	2 1	6 3	CF
9	7 1	1 1	3 3	3 3	4 4	4 4	5 5	6 6	7 7	7 7	SR + R7
10	7 3	7 2	7 4	7 6	7 6	7 6	7 6	7 6	7 6	7 7	SR + R7
11	1 1	7 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	7 1	CF
12	7 4	7 5	6 5	6 6	6 6	7 6	7 7	7 7	7 7	7 7	E
13	6 1	3 3	5 3	7 4	2 2	5 2	3 1	1 1	1 1	1 1	CF + R4
14	7 4	7 5	7 6	7 6	7 7	7 7	7 7	7 7	7 7	7 7	E
15	2 1	7 2	2 1	1 1	3 1	1 1	1 1	1 1	1 1	1 1	CF
16	5 3	5 2	6 3	3 2	2 1	1 1	1 1	3 2	2 1	3 1	CF
17	7 4	7 5	7 4	7 3	7 5	7 2	7 6	6 4	7 4	7 4	R6
18	1 1	1 1	1 1	1 1	4 1	2 1	1 1	1 1	1 1	1 1	CF
19	1 1	1 1	1 1	4 4	4 4	4 4	4 4	4 4	7 4	4 4	R4
20	5 1	1 1	1 1	5 1	1 1	1 1	1 1	1 1	1 1	1 1	CF
21	5 3	3 2	5 3	7 4	2 2	6 4	3 3	6 5	4 4	7 6	SR + R6
22	1 1	7 4	7 3	4 3	7 1	3 1	1 1	1 1	1 1	1 1	CF + R4
23	2 2	1 1	5 1	3 2	3 2	2 2	2 1	5 2	3 1	1 1	CF
24	6 4	6 3	4 4	4 4	4 4	4 3	3 1	3 3	2 2	6 3	R4

**Table A6:** The minimum choice by round and group in the Sim3 condition.

Group	Round										Comments
	1	2	3	4	5	6	7	8	9	10	
1	3	1	2	4	3	3	3	3	3	3	CF + R4
2	1	2	3	4	3	3	3	3	3	3	CF + R4
3	2	3	4	3	2	3	3	3	3	3	CF + R4
4	2	1	2	3	1	2	2	1	2	1	CF
5	4	5	5	5	5	5	5	5	5	5	E
6	2	1	1	1	1	1	1	1	1	1	CF
7	4	5	6	7	7	7	7	7	7	7	E
8	2	2	2	2	2	2	2	2	2	2	CF
9	3	3	2	3	3	2	3	2	3	2	CF
10	5	6	7	7	7	7	7	7	7	7	E
11	5	6	6	6	6	6	6	6	6	6	E
12	3	2	3	1	2	1	1	1	1	1	CF

## Appendix C

*All participants received the following general instructions:*

In this experiment you are going to play a number of, slightly similar, games.

You will play these games in groups of four. Each game lasts for ten rounds and during these ten rounds you will be playing with the same people. When we start a new game we also change the group you are playing with. All groups are formed randomly. You will **never** play a game with the same player twice.

In each round of this game you will have to pick a number. Your earnings depend on the number you pick and the numbers picked by the other players in your group.

You can pick any *whole* number between 1 and 7.

Your earnings are determined by your choice and the **lowest number** chosen by the players in your group. Mathematically your earnings (in pounds) are determined by the following formula:

$$0.60 + 0.10 \times [\text{minimum choice}] - 0.10 \times [\text{your choice} - \text{minimum choice}]$$

To keep it simple the table below describes your earnings for each combination of your choice (columns) and the minimum choice in your group (rows). This table will also be on your screen during the experiment.

Choice:	1	2	3	4	5	6	7
min = 1	0.7	0.6	0.5	0.4	0.3	0.2	0.1
min = 2		0.8	0.7	0.6	0.5	0.4	0.3
min = 3			0.9	0.8	0.7	0.6	0.5
min = 4				1	0.9	0.8	0.7
min = 5					1.1	1	0.9
min = 6						1.2	1.1
min = 7							1.3

An example (and the numbers used in this example are picked for clarification purposes only):

- You pick 5 and the other players in your group pick 7, 6 and 3. The minimum choice in your group is 3. Since you have picked 5 your earnings are 0.7 (and the player picking 7 earns 0.5, the player choosing 6 0.8 and the player choosing 3 0.9)

It doesn't matter who picks the lowest number or how many players pick the lowest number. The earnings for **all players** are calculated as in the table.

In general, you won't learn what player picked what number (nor will the other players know what number you have picked). In each round we will just tell you the **lowest number** and how much you have earned.

As said, you will play a number of different versions of this game; each time with different people. All your earnings of the ten rounds in a particular game will be summed together. Afterwards we will randomly select **one of the games** you have played and pay you your earnings of that game.

*Before playing game Sim4 participants received the following instructions:*

In this version of the game everybody picks their numbers **simultaneously**.

In every round players choose their numbers without knowing the number the other three pick. When everybody has chosen their number (and clicked 'ok') the computer announces the lowest choice in the group and your earnings. We then proceed to the next round.

*Before playing game Exo participants received the following instructions:*

In this version of the game one player is selected to pick his/her number **before the rest**. Who goes first is determined randomly for each round.

After the first player has chosen his/her number, the other players learn what number was picked and then pick their own numbers **simultaneously**. The three remaining players pick their numbers without knowing what number the other two pick. When everybody has chosen their number (and clicked 'ok') the computer announces the lowest choice in the group and your earnings. We then proceed to the next round.

Being the first to pick a number does **not affect** your earnings in any way. The earnings for all players are calculated as in the table regardless of order.

*Before playing game End participants received the following instructions:*

In this version of the game one player can decide to pick his/her number **before the rest**.

A player can become the one to choose before the rest by being the first to pick a number (and to click 'ok').

After the first player has chosen his/her number, the other players learn what number was picked and then pick their own numbers **simultaneously**. The three remaining players pick their numbers without knowing what number the other two pick.

In each round there are 30 seconds for players to pick a number before the rest. If none of the players do so in this time the **whole group** will choose their number simultaneously. Then all four players pick their number without knowing what number the other three pick.

When everybody has chosen their number (and clicked 'ok') the computer announces the lowest choice in the group and your earnings. We then proceed to the next round.

Being the first to pick a number does not affect your earnings in any way. The earnings for all players are calculated as in the table regardless of order.

*Before each new game participants were also told:*

Remember, by starting a new version of the game we also change the group of players you're playing with. Which player plays in which group is determined randomly. The only thing that is certain is that you will **never** play a game with the same participants twice.

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