**Steady steps versus sudden shifts:**

**Cooperation in (a)symmetric continuous and step-level   
social dilemmas**

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# Abstract

Are groups of people better able to minimize a collective loss if there is a collective target that must be reached or if every small contribution helps? In this paper we investigate whether cooperation in social dilemmas can be increased by structuring the problem as a step-level social dilemma rather than a continuous social dilemma and by manipulating asymmetry between individuals. In an incentive compatible lab experiment, 120 participants played one of four versions of a repeated "public bad" game. We found that individuals defect less and are better able to minimize collective and personal costs in a step-level social dilemma than in a continuous social dilemma. Symmetry in endowments does not have an effect on defection levels at first, but over time asymmetry in endowments between individuals removes the positive effect of the step-level game. These results imply that presenting social dilemmas as step-level games and reducing (perceived) asymmetry can help solving environmental dilemmas in the long term.

**Keywords: (max. 6)** cooperation, social dilemma, behavioral economics, environmental behavior

# Introduction

Many efforts that aim to increase pro-social behaviors present social problems as continuous and symmetric social dilemmas (e.g., Balliet, Li, MacFarlan, & Van Vugt, 2011). When such a problem is framed as symmetric and continuous, this implies that each decision by every agent has a similar impact on the outcomes of the dilemma. For example, if a fish stock is threatened, each additional fish caught is considered equally harmful to the stock, and each person can equally harm or protect the stock. However, in actuality many social dilemmas resemble step-level social dilemmas rather than continuous social dilemmas, or can be presented as such (Abele, Stasser, & Chartier, 2010). Step-level problems involve sudden rather than gradual shifts. Once a certain threshold is reached, the burden on the environment is increased dramatically, but if the threshold is not reached, no change occurs. An example of a step-level environmental problem is overfishing: if a fish population is depleted below a critical threshold, the population does not have the capacity to reproduce itself anymore and even though not all fish of that population have been caught, the population will eventually be destroyed (Myers, Rosenberg, Mace, Barrowman, & Restrepo, 1994). This is not a gradual shift: before reaching that threshold, intensifying fishing is no real problem, because the fish population is capable of maintaining itself. However, after the threshold is reached the fish population is quickly depleted. Furthermore, the actors in real life social dilemma situations often have dissimilar impacts on the outcomes: the actions of certain large-scale fishers or retailers may have an outsized impact, whereas some minor players may hardly influence the stock.

In this paper we investigate how presenting a social dilemma as either a step-level or a continuous dilemma affects cooperation rates, depending on whether the participants' resources are symmetric or not. We argue that presenting environmental problems as step-level (rather than continuous) dilemmas increases cooperation rates, but that this improvement is only maintained over time if participants are symmetric.

Extensive research on both continuous and step-level social dilemmas has been done, for example in relation to social value orientation (Balliet, Parks, & Joireman, 2009), social identity (Simpson, 2006), the role of uncertainty (Biel & Gärling, 1995), membership fees (Bchir & Willinger, 2013) and the possibility to punish (Cooper & Stockman, 2002). However, we are not aware of any direct empirical comparisons between these two problem types.

Bornstein (1992) reports an experiment with two games that resemble a continuous and a step-level game and found that cooperation was higher in the step-level-like game. These results indicate that groups may be effective in reaching a collective goal if there is a risk involved with not reaching the goal. However, these games were not ‘pure’ continuous and step-level social dilemma games. They included competition between and within groups, and this extra element in the structure of the game may have affected the behavior of the participants. Therefore, the results may not be applicable to standard social dilemmas.

Abele et al. (2010) describe three important differences between the two types of social dilemmas, but have not empirically tested their hypotheses. The first difference has to do with the individual benefits of defecting, the second difference with Pareto efficiency and the third difference is a more intuitive one that is related to the perceived acceptable amount to donate. First, continuous social dilemmas have only one Nash equilibrium: regardless of the choice of the other players, defecting always yields superior outcomes for the self, because cooperation involves costs. Figure 1a shows the individual payoff functions of contributing players and defectors in a continuous social dilemma. The line for defectors always lies above the line of contributing players, defecting always gives a higher personal benefit than cooperating. In contrast to continuous social dilemmas, step-level social dilemmas have more than one Nash equilibrium. If none of the other actors cooperate, it is beneficial for the rational individual to defect as well, because the threshold will not be reached, no matter what action the individual takes. However, if the threshold is almost reached and the individual's contribution can be critical to reaching it, she should cooperate, because it will increase her private benefits. This is illustrated in figure 1 (right panel).

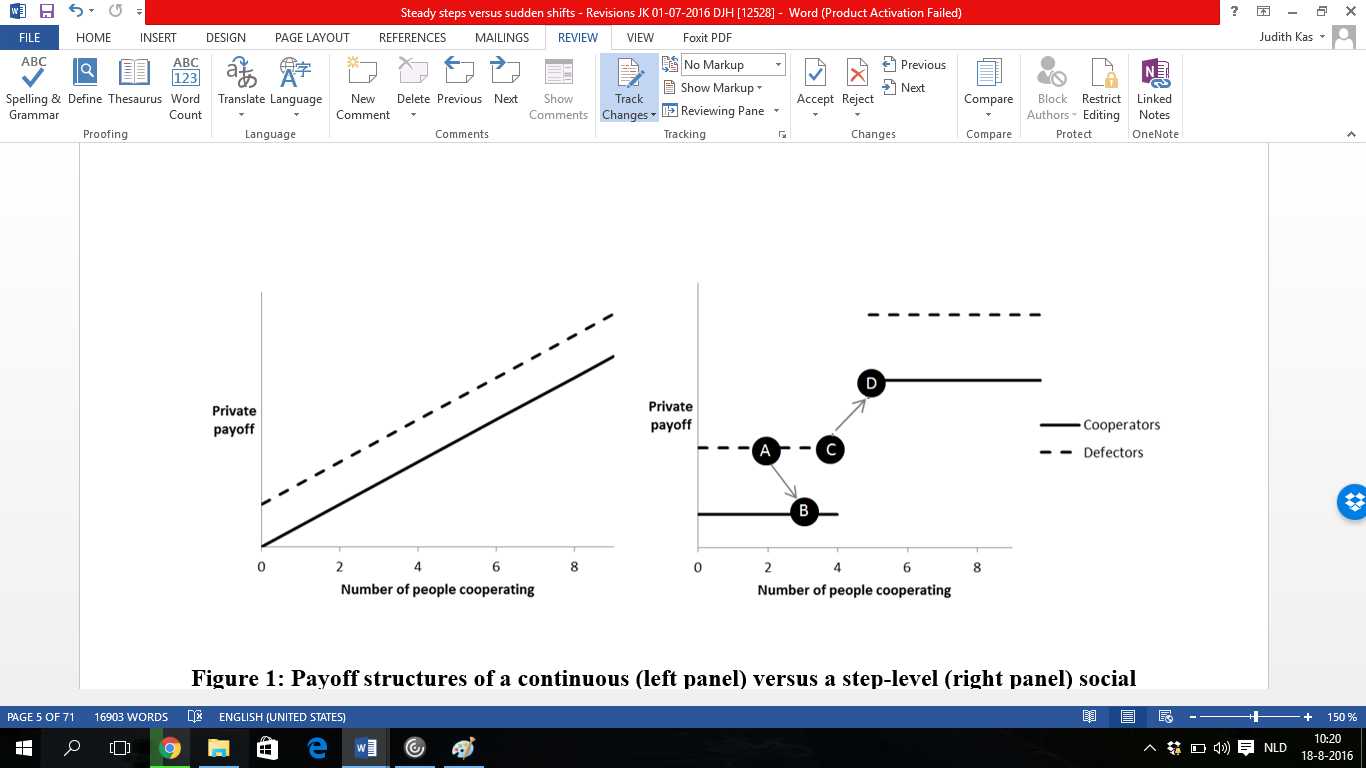


Figure 1: Payoff structures of a continuous (left panel) versus a step-level (right panel) social dilemma  
*In the left panel, the incentives for cooperation and defection are always the same. In the right panel, the public good only is provided if more than four individuals cooperate. Therefore, if an individual knows that two other individuals are cooperating, she should defect (point A), because cooperation is costly and the group is not going to reach the threshold even if she cooperates (point B). However, if she knows that four other individuals are cooperating, she should cooperate as well, because then her cooperation is critical for reaching the threshold. If they reach the threshold her personal payoff is higher (point D) than when she would defect and the threshold would not be reached (point C).*

The second difference between continuous social dilemmas and step-level social dilemmas has to do with Pareto efficiency. A solution is Pareto efficient if no other solutions exist that improve the outcome of at least one player, without negatively affecting the outcome of any other person. In continuous social dilemmas, the Nash equilibrium in which everyone defects is clearly not Pareto efficient: if everyone would have cooperated, everyone would have had a better outcome. 100% cooperation is a Pareto efficient solution, but this situation is not a Nash equilibrium, because defecting is always payoff maximizing in continuous social dilemmas (as per figure 1, left panel). As a consequence, the Pareto efficient solution in which everybody cooperates is unstable (Abele et al., 2010): it is always tempting for individuals to move towards defecting and thus move away from the optimal solution. In step-level social dilemmas self-interest does not necessarily lead to defection. When the threshold is exactly reached there is a Nash equilibrium that is also Pareto efficient. No one can move from cooperating to defecting without harming the others *and* themselves, because that would mean that the threshold is no longer reached and both the personal and societal benefits are smaller than if that person would have cooperated.

The third difference is a more intuitive one that only applies to social dilemmas in which cooperation and defection are gradual (someone can e.g. cooperate for 75% and defect for 25%) rather than a dichotomous cooperate or defect choice. Different individuals have different perceptions of what an acceptable amount to contribute is (e.g. Buchan, Croson, & Johnson, 2004; Van Dijk & Wilke, 1993). In continuous social dilemmas those individual differences will translate into different cooperation rates by different persons, but step-level social dilemmas have an anchor of what an acceptable amount to contribute is and variety in perceived acceptable amounts may therefore be relatively limited (Van Dijk, de Kwaadsteniet, & De Cremer, 2009). The threshold indicates what the right amount to contribute is. If the threshold is 45 and there are three persons in a group, the fair amount to contribute is 15 for every player, so in step-level social dilemmas it is easier for individuals to decide how much they should contribute than in a continuous social dilemmas that lack this reference point. If the threshold is higher than the average cooperation rate in continuous social dilemmas and if individuals try to reach that threshold, cooperation will be higher in step-level social dilemmas (Croson & Marks, 2000; Suleiman & Rapoport, 1992).

Based on these three differences, we hypothesize that there is a main effect of game type on cooperation in social dilemmas:

H1: Individuals cooperate more in step-level social dilemmas than in continuous social dilemmas.

## 1.1 (A)symmetry between actors

In the context of solving environmental problems it is important to consider that not all actors involved have the same amount of resources, time, power, or ability to combat these problems (Van Lange, Joireman, Parks, & Van Dijk, 2013). Furthermore, not everyone has an equal influence on the environment: some individuals, businesses or countries pollute more than others and not everyone has the same interest in reduction. There have been a few studies that looked at asymmetry between actors in resources in social dilemma games and varying interest in the outcome. Total cooperation has been found to be lower with asymmetric endowments in both step-level games and continuous social dilemmas (Rapoport, 1988; Tavoni, Dannenberg, Kallis, & Löschel, 2011). However, no previous research that we are aware of has directly investigated whether the impact of asymmetry may vary between continuous vs. step-level dilemmas. In other words, there have been no tests of the interaction. Van Dijk & Wilke (1993, 1995) distinguish three rules that individuals may use to decide how much they will contribute when the amount of resources is not equal between actors (cf. Equity theory, Adams 1965; Messick & Cook, 1983). The first rule is the equal contribution rule: all actors should contribute the same amount, regardless of their possessions. The second one is the proportional contribution rule: all actors contribute the same proportion of what they have. The third and final rule is the minimize differences in final outcomes rule: actors with more resources contribute a larger proportion of their endowments than actors with fewer resources in order to minimize the difference between them. Individuals tend to use different rules in different situations. The equal contribution rule is applicable when all actors are equal (Van Dijk & Wilke, 1995). In public goods games, where individuals choose to contribute to a public good or not, individuals mostly use the proportional contribution rule when there is inequality. In resource dilemmas, in which individuals choose how much to take from a shared pool, individuals tried to minimize the differences in outcomes between them in case of inequality (Van Dijk & Wilke, 1995; Van Lange et al., 2013). In a step-level public goods game, players consider it to be fair that players with higher endowments should contribute more, but in reality this does not happen (Van Dijk & Grodzka, 1992). Because asymmetry between individuals can have an effect on how they act in social dilemmas, the second question in this research focuses on the influence of asymmetry between actors in social dilemmas.

In asymmetric social dilemmas, it could be considered to be fair to minimize the difference in the final outcomes. That would mean that people with higher endowments should contribute more and people with low endowments could contribute less. Following this ‘fairness rule’ is in the self-interest of ‘poor’ people but not in the self-interest of ‘rich’ people, because contributing is costly. Beliefs about fairness influence individuals’ decisions, but more so if it is in their own self-interest (Buchan et al., 2004; Tavoni et al., 2011; Wade-Benzoni, Tenbrunsel, & Bazerman, 1996). This implies that only people with low endowments will use the ‘minimize differences in final outcomes rule’, because it is in their self-interest. Rich people will stick to the equal contribution rule, because that is in their self-interest. Thus, we expect that low endowed people will contribute less, because they consider it to be fair to do that, whereas high endowed people do not contribute more. This leads to lower total cooperation in asymmetric social dilemmas.

H2: Asymmetry between actors leads to lower total cooperation.

## 1.2 Interaction between game structure and (a)symmetry of actors

How might the impact of (a)symmetry be different for continuous vs. step-level games? Two opposing predictions are plausible. We might expect the effect of asymmetry to be stronger in continuous social dilemmas than in step-level social dilemmas. Whereas defection is always better for the individual in the continuous dilemma, it is ambiguous in the step-level dilemma (as seen in Figure 1). If a person’s contribution is critical for reaching the threshold in the step-level situation, he or she should cooperate to maximize both his or her own benefit and the collective benefit. In this case, cooperating overlaps with self-interest and therefore individuals who possess higher endowments in step-level social dilemmas may be likely to cooperate regardless of fairness considerations. Therefore, individuals who possess higher endowments will cooperate more in the step-level game than in the continuous game. This leads to the following hypothesis:

H3a: There will be an interaction between (a)symmetry and game type, such that the negative effects of asymmetry will be stronger in continuous dilemmas than in step-level dilemmas.

An alternative prediction comes from the logic of appropriateness (Weber, Kopelman, & Messick, 2004). When deciding how much to cooperate or defect, participants ask themselves "what does a person like me do in a situation like this?" From this perspective, cues on the "appropriate" amount to contribute are critical. In the symmetric, step-level game, the threshold (equally divided among participants) provides a natural reference point for the appropriate amount to contribute. In the other three conditions, the asymmetry in endowments or lack of a threshold mean that the "appropriate" amount to contribute is less obvious, and people may (selfishly) cooperate less as a result.

H3b: There will be an interaction between (a)symmetry and game type, such that the negative effects of asymmetry will be stronger in step-level dilemmas than in continuous dilemmas. In other words, the cooperation will be highest in the step-level, symmetric game, and lower in the other conditions.

## 1.3 The current research

Social dilemma problems have extensively been studied using decision making games: in experiments that resemble simplified social dilemma situations individuals are asked to make a choice between their self-interest and the group’s interest. The main paradigm that is used to study social dilemmas are public goods games (in which players can cooperate by contributing to a public good) and resource dilemma games (in which players cooperate by not taking from a common resource pool; Van Dijk & Wilke, 2000). However, many environmental problems do not resemble public goods games or resource dilemmas, but ‘public bad’-games: the more CO2 is emitted, the worse it is for the climate; the more people litter, the worse for the environment etc. The defecting behavior is here to litter or to emit CO2 and the cooperative behavior is to *not* perform those harmful behaviors. Presenting a social dilemma experiment as a public good game or a public bad game influences cooperation rates. Cooperation has been found to be higher in a public good game than in a public bad game (Sonnemans, Schram, & Offerman, 1998). Because many environmental problems entail public bad rather than public goods or common resources, the current study explores the research questions in a public bad scenario.

## In particular, we look at behavior in a public bad game that is framed as an environmental scenario. In addition to testing our hypotheses by manipulating the symmetry of the players and structure of the game, we also explore changes over repeated plays of the game. Furthermore, we explore what the effect of the manipulation, demographics and individual differences are on several other outcome variables, such as the size of the personal costs, the size of the contributions and the number of contributing players.

## 2. Methods

## 2.1 Participants and design

A laboratory experiment with a 2 (game type: continuous vs. step-level) x 2 (symmetry: symmetric vs. asymmetric actors) between-subjects design was conducted at a large North-American university. 120 individuals (70% female; *Mage* = 24.3, *SDage* = 7.8) participated in one of 16 experimental sessions, each lasting 50 minutes. The participants were recruited via posters in university buildings, messages on Facebook and emails to subscribers of the email list and most of them were students. Participants' compensation for participating in the study was incentive compatible – they were informed in the recruitment message that they would receive between $8 and $15, with an average of $11.45.

## 2.2 Materials

In this lab experiment, a public bad game is used (e.g. Moxnes & Van der Heijden, 2003; Sonnemans et al., 1998). In this game the participants were asked to imagine that they were the owner of a company that was located at the shore of a lake, along with two other businesses. The three businesses together are responsible for the maintenance of the lake. Groups of two to six individuals are commonly used in social dilemma games (Balliet, 2010; Sally, 1995; Zelmer, 2003) and three-person groups are practical while still allowing for group dynamics that characterize real-world problems. In the game, each company produces a certain amount of waste in each round. As the owner of the company, the participants have to make a decision on what to do with the waste. They can either transport it to a waste treatment plant or dump it in the lake. Dumping the waste is harmful for the environment and the other businesses that are located at the shore of the lake, but bringing the waste to the treatment plant costs the company money: $1 million per unit of waste. If the waste is dumped in the lake, all business that are located at the shore at the lake have to clean the lake together at high cost (see below). These costs are shared equally among all three players. The participants played between twenty and forty rounds of the game, depending on the amount of time available.

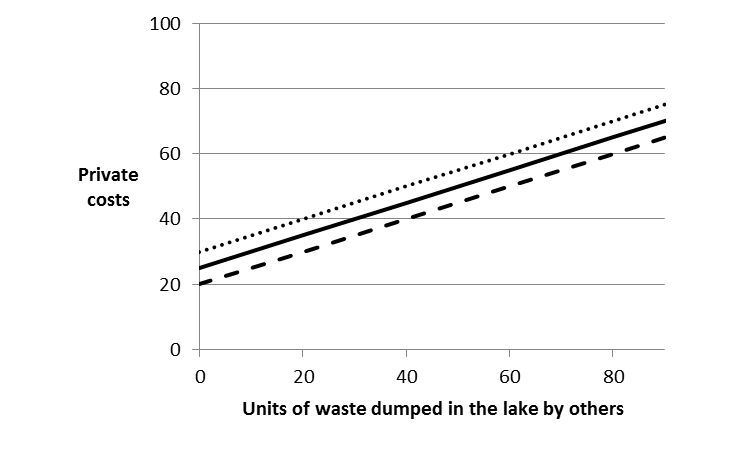
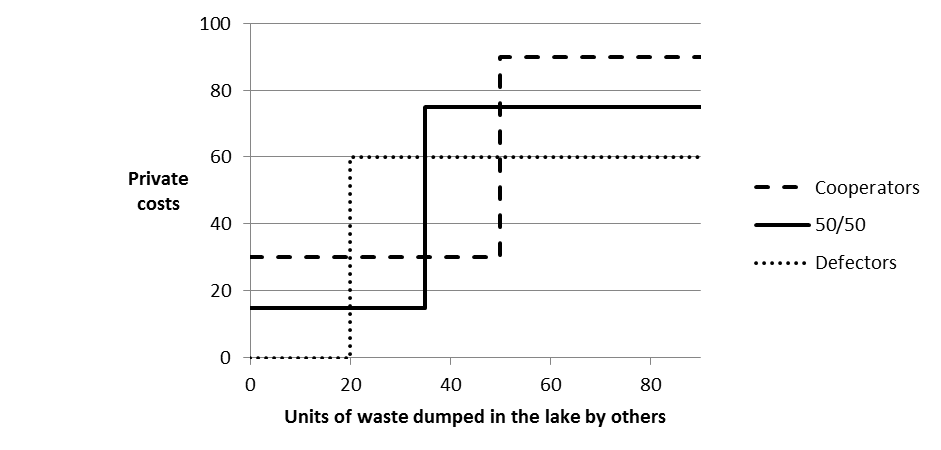
The rules of the game were explained to the participants in written instructions (Appendix B). The instructions were phrased in neutral language with no mention of cooperation, defection, or competition. At the end of the instructions the participants were provided with an example of three companies and their decisions and they were asked to calculate the costs for one of these companies to ensure comprehension. We used the software Z-tree for playing the social dilemma game (Fischbacher, 2007). A screenshot of the participants’ interface can be found in Appendix C.

### 2.2.1 Continuous versus step-level and symmetry versus asymmetry.

*Game type.* The first independent variable is game type: we compare continuous and step-level social dilemmas. In the continuous condition the three businesses together have to pay $2 million per unit of waste that is dumped for cleaning the lake, regardless of who the dumper is. Remember that the dumper could have avoided this cost by paying $1 million. This means that each business has to pay $2/3 million, which saves the dumper $1/3 million, but costs the other two $2/3 million extra. A multiplier (or Marginal Per Capita Return) of two is commonly used in social dilemma experiments (Croson & Marks, 2000). The average expected costs per round of the continuous game is 47.3.

In the step-level condition the companies only pay the cleaning costs if 46 units of waste or more are dumped in total. A threshold of 50% of total possible cooperation/defection in step-level dilemmas is commonly used in social dilemma experiments (Croson & Marks, 2000). If that threshold is exceeded, the companies together pay $180 million for cleaning the lake, which is $60 million per company, which is equivalent to the multiplier of 2 in the continuous game. If the threshold is not reached, the companies pay nothing for cleaning the lake. The average expected costs per round of the step-level game is 46.7.

The expected costs per round are similar in the continuous game and the step-level game. This is necessary to be able to compare the results of the two games. Two pilot studies showed that the values we chose for the threshold and the multiplier lead to variance in cooperation rates (i.e., avoiding ceiling and floor effects).

Figure 2: Structures of the continuous and step-level social dilemma game in this study

*Asymmetry.* The second independent variable is endowment (a)symmetry. In the symmetric condition each company produces 30 units of waste per period. In the asymmetric condition one company produces 20 units of waste, one company produces 30 units of waste and one company produces 40 units of waste. A ratio of two -- which means that the individuals that possess the most have twice as many possessions as those with the least -- is commonly used (Rapoport & Suleiman, 1993; Van Dijk & Grodzka, 1992; Van Dijk & Wilke, 1995).

### 2.2.2 Dependent variables.

*Absolute defection.* The decisions in the repeated public bad game result in multiple dependent variables that are all related. First we looked at absolute defection: how many units of waste did a participant dump in the lake in a certain round?

*Percentage defection.* Second, we analyzed percentage defection: the amount of waste each participant dumped in the lake in a certain round as a percentage of a person’s endowments.

*Personal costs.* The next dependent variable is the size of the personal costs in a certain round. The personal costs are composed of the costs of bringing waste to the treatment plant ($1 per unit) and the costs of cleaning the lake that are shared with the group. This variable is a good indicator of a person’s and group’s ability to reach the optimal solution: the lower the personal costs are (on average); the better a group is at managing the public bad.

### 2.2.3 Demographics and individual differences.

After playing the game, the participants answered five demographic questions (gender, age, level and field of education and nationality) and a number of questions on numeracy, environmental attitude, social value orientation, consideration of future consequences and temporal discounting. The whole questionnaire can be found in Appendix D. At the end of the questionnaire the participants were asked to guess the purpose of the experiment. None of them guessed the true hypotheses of the study.

## 2.3 Procedure

Each 50-minute session consisted of 6 or 9 participants. If the number of participants that showed up was not a multiple of three, the remaining participants were assigned to another, unrelated task. Each session was randomly assigned to one of the four conditions. The participants were seated in a private cubicle with a computer, from where they could not see the other participants. The participants could see the experimenter, which was always the same person, at the start of the experiment and at the start and end of the social dilemma game. During the experiment, the participants were seated with their back to the experimenter. At the start of the experiment the experimenter read instructions out loud that informed the participants about the duration and procedure of the study (Appendix B). The participants were told that communication and the use of mobile phones were not permitted during the study and they were encouraged to read the instructions for the study carefully, because their payment depended on the decisions they were making in the study.

After reading the instructions for the game, the participants answered two questions to test their comprehension of the game rules and payouts. They were asked to calculate the resulting outcomes of two hypothetical games. When they gave a wrong answer to a question, they were instructed to read the instructions again and try answering the question again. If they failed to give the right answer the second time, the experimenter verbally explained the steps to calculate the answers. All participants were able to correctly answer the questions after getting the verbal explanation. The participants were informed that the decisions they were making were private and that for each $50 million in costs in the game, their actual payment for the experiment would be reduced by $0.10. This means their payment for participating in the study varied between $8 and $15, depending on the decisions they and the others made.

Next, the experimenter showed an example of the interface of Z-tree on the big screen in front of the room, and all the participants were directed to the starting screen of Z-tree on their individual computer terminals. A main server randomly assigned the participants to three-person groups. These group compositions were kept constant during the ten rounds of one block, but after every block of ten rounds the participants were assigned to a new group. The participants were not informed about this in advance, but they did know that they were assigned to a new group when it happened. The experimental condition remained the same over all blocks and the participants did not know who was in their group.

The participants then played two to four blocks of ten rounds of the public bad game, depending on the amount of time available. In some groups reading the instructions and answering the comprehension questions took longer than in other groups, and as the session time was limited to 50 minutes, not every group played the same number of blocks. The number of participants per condition in each block can be found in Appendix A. The participants did not know how many blocks they were going to play or how many rounds one block consisted of (although they could guess after the first block that the subsequent blocks would also have 10 rounds). On average fewer rounds (*M* = 38.57, *SD* = 3.53) were played in the asymmetric than the symmetric conditions (*M* = 30.26, *SD =* 8.26; *F*(1, 118) = 53.08, *p* < .001). The reason for this is that participants in that conditions took more time for reading the instructions and answering the comprehension questions, probably because the asymmetric games are more complex. One group played only half of the third block due to a lack of time.

At the beginning of a round, each participant was informed how much waste he or she had produced. This number was constant during all rounds within a block. In the asymmetric conditions the three players in one group had a different endowment level. They were told that not all companies were producing the same amount of waste, but that one company produced 20 units per round, one produced 30 per round and one company produced 40 units per round. At the beginning of a round, the waste their company produced was displayed. This distribution of endowments was the same throughout the block, but after each block the allocation was done again (randomly). The participants then made a decision about how much waste they wanted to dump and they entered the desired amount in Z-tree. Once all the participants had made their decisions, the main server pooled all the decisions and provided each participant with feedback: The participants saw how much each of the players in their group had dumped and how high the costs were for each of them. In the results screen, they always viewed themselves as ‘You’ and the other players as ‘player 2’ and ‘player 3’. The participants could view the results as long as they wanted and as soon as they were all done with viewing the results, they proceeded to the next round.

After completing the game, the participants proceeded to the questionnaire and if there was still time remaining they continued with some unrelated studies. After they finished the unrelated studies, or after 50 minutes the participants were given the money they earned during the experiment.

**3. Results**

Unless otherwise stated we use a 2 (game type: continuous versus step-level) x 2 (symmetry: symmetric versus asymmetric) mixed model analysis of variance with percentage or absolute defection as dependent variables in which we only included the first three blocks (periods 1-30). The fourth block is excluded from further analysis, because there were only six participants in the continuous asymmetric condition in this block, which is too low to base conclusions on. Game type and symmetry were entered as fixed factors, and individuals nested in groups were entered as a random factor. If the mixed model analysis yielded a significant interaction effect between game type and symmetry, we ran pairwise comparisons to find out which conditions differed significantly.

## 3.1 Defection over time

Figure 3 shows defection per condition over time. We ran the standard analysis as described in the first paragraph of this section and we included each of the 30 rounds separately in the analytics. Percentage defection significantly increased over the rounds (all block taken together) in all four conditions (*F*(1, 3397) = 179.34, *p* < .001).

The upward slope of the graphs of both continuous conditions and the step-level symmetric condition are similar, but the increase in defection is significantly stronger in the step-level asymmetric condition than in the continuous symmetric condition (*F*(1, 1896) = 6.90, *p* = .05). The slope of the step-level symmetric condition is marginally flatter than the slopes of the two continuous conditions (*F*(1, 2589) = 2.28, *p* = .13).

**Figure 3: Average percentage defection over the rounds per condition**

We repeated the standard analysis for each of the three blocks separately and for the first and the last round of the games. In the first two blocks (round 1 to 10 and round 11 to 20) there is a main effect of game type (*Mcont* = 83.1, *SDcont* = 31.7; *MSL* = 64.7, *SDSL* = 31.9; *F*(1, 2396) = 41.64, *p* < .001), a marginally significant effect of symmetry (*Msymm = 76.0, SDsymm = 31.6; Masym* = 70.6, *SDasym* = 34.5;  *F*(1, 2396) = 3.42, *p* = .07) and no interaction effect between game type and symmetry (*F*(1, 2396) = 0.08, *p* = .78). In the step-level game, cooperation is higher than in the continuous game and cooperation is slightly higher in the asymmetric conditions than in the symmetric conditions. Percentage defection is higher in the continuous and symmetric conditions than in the step-level and asymmetric conditions in the first two blocks. In block 3 (round 21 to 30) there is, in addition to the main effect of game type (*Mcont* = 78.2, *SDcont* = 34.2; *MSL* = 62.4, *SDSL*= 32.5; *F*(1, 1001) = 10.52, *p* < .001), an interaction effect of game type and symmetry (*F*(1, 1001) = 7.36, *p* = .01). Defection is significantly lower in the step-level symmetric condition (*MSLS*= 62.1, *SDSLS* = 29.5; than in each of the other three conditions in that block (*MCS*= 91.3, *SDCS* = 24.2; *MCA*= 89.4, *SDCA* = 28.3; *MSLA*= 82.6, *SDSLA* = 25.6; all *p* < .01). The other conditions do not significantly differ (*p* > 0.2).

In the very first round of the game there are no main and interaction effects of game type (*Mcont* = 56.2, *SDcont* = 38.1; *MSL* = 54.6, *SDSL*= 27.7; *F*(1, 116) = 0.09, *p* = .76) and symmetry and (*Msymm = 55.5, SDsymm = 32.1; Masym* = 55.3, *SDasym* = 34.1; *F*(1, 116) < 0.001, *p* = .98). In the last round (30) there was a main effect of game type (*Mcont* = 96.2, *SDcont* = 16.3; *MSL* = 74.3, *SDSL*= 29.8; *F*(1, 92) = 15.66, p < 0.001) and a main effect of symmetry (*Msymm = 80.3, SDsymm = 29.4; Masym* = 90.7, *SDasym* = 20.2; *F*(1, 92) = 4.86, *p* = .03). These main effects are qualified by an interaction effect: Percentage defection is lower in the step-level symmetric game than in all the other conditions in the last round (all *p* < .05). In the last round, there is no difference in percentage defection between the two continuous conditions (*MCS* = 94.7, *SDCS* = 19.2; *MCA* = 100.0, *SDCA*= 0.0; *F*(1, 40) = 0.92, *p* = .34), but defection is significantly lower in the step-level asymmetric condition than in the continuous asymmetric condition (*MSLA* = 85.4, *SDSLA* = 23.9; *F*(1, 31) = 4.43, *p* = .04).

**3.2 Additional analyses**

In additional exploratory analyses we found that the personal costs for the participants are significantly higher in the continuous conditions than in the step-level conditions (*Mcont* = 55.6, *SDcont* = 9.1; *MSL* = 43.8, *SDSL*= 25.8; *F*(1, 3401) = 48.52, *p* < .001), meaning that overall welfare was higher in the step-level games. Percentage defection was not influenced by endowment level (*F*(1, 1511) = 0.07, *p* = .91), but absolute defection was (*F*(1, 1511) = 113.66, *p* < .001). This means that individuals with a larger endowment of pollution tended to pollute more in absolute terms but not relative terms. More analyses and results can be found in Appendix E, where we also report group effects such as the influence of the previous round and the influence of starting a new block with a new group.

## 4. Discussion and conclusions

## 4.1 Discussion of the results

### 4.1.1 Continuous versus step-level.

In line with our hypothesis individuals and groups defect more in a continuous social dilemma than in a step-level social dilemma, which means our first hypothesis was confirmed. In the introduction we listed three potential reasons for defection to be lower in the step-level game: individuals have a target, and are therefore less dependent on personal ideas about fairness (Van Dijk et al., 2009); contributing can be in a person’s self-interest in the step-level dilemma if his or her contribution is critical for reaching the threshold, and the optimal solution in which the contribution threshold has just been reached is a Nash equilibrium in the step-level game, but not in the continuous game (Abele et al., 2010). We expected that the most important driver of the effect is that individuals can personally benefit from cooperation in the step-level game, since the key problem in social dilemmas is that individuals are driven by self-interest. We expected that having a clear target might be effective in increasing cooperation in a one-shot social dilemma game, but over time some individuals will move to defection anyway, because it is still in their own interest. The fact that the optimal strategy leads to a stable solution in step-level social dilemmas is important, but this builds upon the fact that cooperation can yield a higher personal payoff in step-level social dilemmas. Without the latter, there would be no optimal, stable solution, so we hypothesize that having personal benefits from cooperating is the most important driver in increasing cooperation in the step-level game.

### 4.1.2 Symmetry.

As hypothesized, defection was higher in asymmetric than in symmetric games. The effect of symmetry in the first rounds and overall is not significant, but over time the effect increased. By the end of the game (round 30) percentage defection was higher when there was asymmetry. Two previous studies (Van Dijk & Grodzka, 1992; Van Dijk & Wilke, 1995) show the negative effect of asymmetry in a one-shot social dilemma game. In the current study we did not find an effect of symmetry in the first round which may indicate that individuals behave differently in one-shot versus repeated games. People seem more cooperative in the first round of an asymmetric repeated game than in a single round in a one-shot asymmetric game. Another study showed in a 7-round study that asymmetry increased defection (Tavoni et al., 2011), but unfortunately, since only the aggregated results for all rounds together are reported, we are not able to compare our results of the first round with theirs. Overall, we consider it safe to conclude that, as in these other studies, asymmetry was detrimental to cooperation rates, because people are more likely to follow those fairness rules that are in their own interest. In this case may mean that people with low endowments used ‘minimize differences in final outcomes rule’, while people with high endowments used the ‘proportional contribution’ rule.

**4.1.3 The interaction between type of game and symmetry**

As expected, the interaction between game type and symmetry was also significant: If we look at the results more specifically, overall defection is lower in the step-level symmetric condition than in the other three conditions. This may happen because this condition offers an easy and salient target for the players (taking the pollution threshold and dividing by the number of players), thus facilitating cooperation.

Defection significantly increases in all conditions over time, but from the third block onwards defection was significantly lower in the step-level symmetric condition than in the other three conditions. Apparently it is harder to coordinate contributions when there is asymmetry, or individuals are less willing to contribute when the benefits are not equally distributed. This is also illustrated by the results in Appendix F: in the step-level symmetric condition 41% of the groups managed to exactly hit the threshold, whereas only 10% of the groups in the step-level asymmetric condition hit the threshold.

We further found that the effect of game type on defection does not occur in the very first round of the game and that defection goes down when a new block starts and increases throughout the block. The latter does not occur in the step-level asymmetric game, which might be one of the reasons for the strong increase in defection in that condition throughout the rounds. This means that if there is asymmetry between players, presenting a social dilemma as a step-level situation is only fruitful in case of few repetitions. If there is a large number of rounds, it does not help groups to cooperate (but nor does it harm them).

**4.2 Implications and future research**

Our experiment shows strong effects of game type and symmetry in a small group social dilemma game. Especially in the symmetric step level condition, the cooperation rates remained higher. Thus, framing an environmental issue as a step level public good with symmetric group members may be a way to increase cooperation in the real world. Rather than presenting problems as continuous social dilemmas in which ‘every little bit helps’, a solution might be in setting a target and communicating what the consequences are if the target is not reached. For example, governments can transform continuous social dilemmas into step-level social dilemmas by using subsidies based on contribution levels. Only if contribution exceeds a certain threshold, the subsidy will be paid. Another example of a potential application of the step-level dilemma is to implement variable gas or electricity prices in buildings where the costs of these resources are shared. If the households together succeed in staying under a certain amount of gas use, the prices will be low, but if they exceed the threshold prices per m3 of gasor kWh will strongly increase. With regard to the symmetry of actors, of course the reality is that many social dilemmas in the real world are asymmetric, but efforts can still be made to reduce the perception of asymmetry, for example by asking actors to save a percentage of their energy, rather than an absolute amount.

It should be noted that group size may make a difference in a group’s effectiveness in solving the social dilemma (Bonacich, Shure, Kahan, & Meeker, 1976; Brewer & Kramer, 1986; Isaac & Walker, 1988; Sally, 1995). In larger groups individuals have a smaller impact on the group result, so the differences between continuous and step-level games may change. On the one hand we can argue that defection will be more similar in the continuous and step-level game when using larger groups, because individuals may have the feeling they have less control over whether the threshold is reached or not and decide to take the safe option which is to defect (e.g., Isaac & Walker, 1988).

Similarly, asymmetry increases defection. It is important to realize that the exact nature of the (perceived) asymmetry between players may play a role. We chose to use a 2:3:4 ratio for the asymmetric conditions, because this ratio is commonly used in social dilemma experiments, but of course many different asymmetries are possible. In the literature we found ratios between 1:2 and 1:7 (Rapoport & Suleiman, 1993; Rapoport, 1988; Van Dijk & Grodzka, 1992; Van Dijk & Wilke, 1995). It would be interesting to study how different ratios affect cooperation and defection in step level vs. continuous public goods. It should also be mentioned that participants were mostly business students, who are known to behave in a self-interested way more than other students (e.g. Frank, Gilovich, & Regan, 1993). This may be a reason why defection rates went up to 100% in some of the conditions. To test the external validity of this study, the experiment should be repeated with people with different backgrounds.

In the discussion of the results we identified a number of interesting questions for future research. Future studies could include measures of motivation, such as questions about perceived fairness of different contribution levels (the target may help participants in the step-level conditions to have similar ideas about what a fair amount to contribute is, while we hypothesize that this is more dependent on personal ideas about fairness in the continuous conditions), perceived criticality, frustration, perceived benefits of contributing versus defecting, perceived influence on other players and whether the subjects experience the game as a lock-in. Another way to figure out why the participants defect more in the continuous game is to vary the setup of the game to find out which strategy the subjects follow in different conditions. This method can produce more reliable results because self-reports of participants about their motivations may be unreliable due to socially desirable answers and unawareness of important processes (Nisbett & Wilson, 1977). An example of varying the setup of the game is doing a continuous dilemma game with a target without consequences if it is not reached, to test whether the mere existence of the threshold affects defection. Other examples are manipulating the other group member’s contributions to vary the criticality of the subjects’ contributions (criticality has been shown to have a positive effect on cooperation, Chen, Au, & Komorita, 1996), or introducing multiple thresholds to remove the stable situation in the step-level game. Technically the continuous social dilemma game that we used in this experiment could be characterized as a step-level game with 90 thresholds. For each threshold that is exceeded, the costs increase with 2. A future study could vary the number of thresholds to see when the effect of the threshold occurs: does every threshold that is removed decrease defection or does the positive effect on cooperation only occur if there are only a few or even one threshold? Normann & Rau (2014) show that adding a second threshold further increases contributions, but does not improve public-good provision or lower payoffs.

## 4.5 Conclusions

Individuals defect less and are better able to minimize their personal costs in a step-level social dilemma than in a continuous social dilemma. Symmetry does not have an effect on defection in the first blocks, but over time asymmetry reduces the positive effect of the step-level game. Both the game type effect and symmetry effect are quite strong: in the continuous asymmetric condition defection went up to 100 per cent in the last round, whereas defection was only 67 per cent in the last round of the step-level symmetric game. In the continuous symmetric condition and step-level asymmetric condition, defection is similar to defection in the continuous symmetric condition in the last number of rounds. The knowledge gained from this study may be applied to environmental and other societal social dilemmas. These are real-life examples of the promising results of this study that step-level approaches might help solving social dilemmas.

# **References**

Abele, S., Stasser, G., & Chartier, C. (2010). Conflict and coordination in the provision of public goods: A conceptual analysis of continuous and step-level games. *Personality and Social Psychology Review*, *14*(4), 385–401.

Adams, J. S. (1965). Inequity in social exchange. Advances in experimental social psychology, 2, 267-299.

Balliet, D. (2010). Communication and cooperation in social dilemmas: A meta-analytic review. *Journal of Conflict Resolution*, *54*(1), 39–57.

Balliet, D., Li, N. P., Macfarlan, S. J., & Van Vugt, M. (2011). Sex differences in cooperation: a meta-analytic review of social dilemmas. *Psychological Bulletin*, *137*(6), 881.

Balliet, D., Parks, C., & Joireman, J. (2009). Social value orientation and cooperation in social dilemmas: A meta-analysis. *Group Processes & Intergroup Relations*, *12*(4), 533–547.

Bchir, M. A., & Willinger, M. (2013). Does a membership fee foster successful public good provision? An experimental investigation of the provision of a step-level collective good. *Public Choice*, *157*(1-2), 25–39.

Biel, A., & Gärling, T. (1995). The role of uncertainty in resource dilemmas. *Journal of Environmental Psychology*, *15*(3), 221–233.

Bonacich, P., Shure, G. H., Kahan, J. P., & Meeker, R. J. (1976). Cooperation and group size in the n-person prisoners’ dilemma. *Journal of Conflict Resolution*, *20*(4), 687–706.

Bornstein, G. (1992). The free-rider problem in intergroup conflicts over step-level and continuous public goods. *Journal of Personality and Social Psychology*, *62*(4), 597.

Brewer, M. B., & Kramer, R. M. (1986). Choice behavior in social dilemmas: Effects of social identity, group size, and decision framing. *Journal of Personality and Social Psychology*, *50*(3), 543.

Buchan, N. R., Croson, R. T. A., & Johnson, E. J. (2004). When do fair beliefs influence bargaining behavior? Experimental bargaining in Japan and the United States. *Journal of Consumer Research*, *31*(1), 181–190.

Chen, X.-P., Au, W. T., & Komorita, S. S. (1996). Sequential choice in a step-level public goods dilemma: The effects of criticality and uncertainty. *Organizational Behavior and Human Decision Processes*, *65*(1), 37–47.

Cooper, D. J., & Stockman, C. K. (2002). Learning to punish: experimental evidence from a sequential step-level public goods game. *Experimental Economics*, *5*(1), 39–51.

Croson, R. T. A., & Marks, M. B. (2000). Step returns in threshold public goods: A meta-and experimental analysis. *Experimental Economics*, *2*(3), 239–259.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New trends in measuring environmental attitudes: measuring endorsement of the new ecological paradigm: a revised NEP scale. *Journal of Social Issues*, *56*(3), 425–442.

Erev, I., & Rapoport, A. (1990). Provision of Step-Level Public Goods: The Sequential Contribution Mechanism. *Journal of Conflict Resolution*.

Fehr, E., Fischbacher, U., & Gächter, S. (2002). Strong reciprocity, human cooperation, and the enforcement of social norms. *Human Nature*, *13*(1), 1–25.

Fischbacher, U. (2007). No Title. *Experimental Economics*, *10*(2), 171–178.

Frank, R. H., Gilovich, T., & Regan, D. T. (1993). Does Studying Economics Inhibit Cooperation? *The Journal of Economic Perspectives*, *7*(2), 159–171.

Isaac, R. M., & Walker, J. M. (1988). Group size effects in public goods provision: The voluntary contributions mechanism. *The Quarterly Journal of Economics*, 179–199.

Kirby, K. N., Petry, N. M., & Bickel, W. K. (1999). Heroin addicts have higher discount rates for delayed rewards than non-drug-using contro ls. *Journal of Experimental Psychology: General*, *128*(1), 78.

Medina, F. J. L., Quesada, F. J. M., & Lozano, V. A. (2014). The Production of Step-Level Public Goods in Structured Social Networks: An Agent-Based Simulation. *Journal of Artificial Societies and Social Simulation*, *17*(1), 4.

Messick, D. M., & Cook, K. S. (1983). Equity theory. Psychological and sociological perspectives, New York.

Moxnes, E., & Van der Heijden, E. (2003). The effect of leadership in a public bad experiment. *Journal of Conflict Resolution*, *47*(6), 773–795.

Murphy, R. O., Ackermann, K. A., & Handgraaf, M. (2011). Measuring social value orientation. *Judgment and Decision Making*, *6*(8), 771–781.

Myers, R. A., Rosenberg, A. A., Mace, P. M., Barrowman, N., & Restrepo, V. R. (1994). In search of thresholds for recruitment overfishing. *ICES Journal of Marine Science: Journal Du Conseil*, *51*(2), 191–205.

Nisbett, R. E., & Wilson, T. D. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review*, *84*(3), 231.

Normann, H.-T., & Rau, H. A. (2014). Simultaneous and Sequential Contributions to Step-level Public Goods One versus Two Provision Levels. *Journal of Conflict Resolution*, *59*(7), 1273–1300.

Osbaldiston, R., & Schott, J. P. (2012). Environmental sustainability and behavioral science: Meta-analysis of proenvironmental behavior experiments. *Environment and Behavior*, *44*(2), 257–299.

Rapoport, A. (1988). Provision of step-level public goods: Effects of inequality in resources. *Journal of Personality and Social Psychology*, *54*(3), 432.

Rapoport, A., & Suleiman, R. (1993). Incremental contribution in step-level public goods games with asymmetric players. *Organizational Behavior and Human Decision Processes*, *55*(2), 171–194.

Sally, D. (1995). Conversation and Cooperation in Social Dilemmas A Meta-Analysis of Experiments from 1958 to 1992. *Rationality and Society*, *7*(1), 58–92.

Simpson, B. (2006). Social identity and cooperation in social dilemmas. *Rationality and Society*, *18*(4), 443–470.

Sonnemans, J., Schram, A., & Offerman, T. (1998). Public good provision and public bad prevention: The effect of framing. *Journal of Economic Behavior & Organization*, *34*(1), 143–161.

Strathman, A., Gleicher, F., Boninger, D. S., & Edwards, C. S. (1994). The consideration of future consequences: Weighing immediate and distant outcomes of behavior. *Journal of Personality and Social Psychology*, *66*(4), 742.

Suleiman, R., & Rapoport, A. (1992). Provision of step-level public goods with continuous contribution. *Journal of Behavioral Decision Making*, *5*(2), 133–153. http://doi.org/10.1002/bdm.3960050205

Tavoni, A., Dannenberg, A., Kallis, G., & Löschel, A. (2011). Inequality, communication, and the avoidance of disastrous climate change in a public goods game. *Proceedings of the National Academy of Sciences*, *108*(29), 11825–11829.

van Dijk, E., de Kwaadsteniet, E. W., & De Cremer, D. (2009). Tacit coordination in social dilemmas: the importance of having a common understanding. *Journal of Personality and Social Psychology*, *96*(3), 665.

Van Dijk, E., & Grodzka, M. (1992). The influence of endowments asymmetry and information level on the contribution to a public step good. *Journal of Economic Psychology*, *13*(2), 329–342.

Van Dijk, E., & Wilke, H. (1993). Differential interests, equity, and public good provision. *Journal of Experimental Social Psychology*, *29*(1), 1–16.

Van Dijk, E., & Wilke, H. (1995). Coordination rules in asymmetric social dilemmas: A comparison between public good dilemmas and resource dilemmas. *Journal of Experimental Social Psychology*, *31*(1), 1–27.

Van Dijk, E., & Wilke, H. (2000). Decision-induced focusing in social dilemmas: give-some, keep-some, take-some, and leave-some dilemmas. *Journal of Personality and Social Psychology*, *78*(1), 92.

Van Lange, P. A. M., Joireman, J., Parks, C. D., & Van Dijk, E. (2013). The psychology of social dilemmas: A review. *Organizational Behavior and Human Decision Processes*, *120*(2), 125–141.

Wade-Benzoni, K. A., Tenbrunsel, A. E., & Bazerman, M. H. (1996). Egocentric interpretations of fairness in asymmetric, environmental social dilemmas: Explaining harvesting behavior and the role of communication. *Organizational Behavior and Human Decision Processes*, *67*(2), 111–126.

Weber, J. M., Kopelman, S., & Messick, D. M. (2004). A conceptual review of decision making in social dilemmas: Applying a logic of appropriateness. *Personality and Social Psychology Review*, *8*(3), 281–307.

Zelmer, J. (2003). Linear public goods experiments: A meta-analysis. *Experimental Economics*, *6*(3), 299–310.

# Appendix A – Number of participants per block per condition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Block 1 (round 1-10) | Block 2 (round 11-20) | Block 3a (round 21-25) | Block 3b (round 26-30) | Block 4 (round 31-40) |
| Continuous |  |  |  |  |  |
| Symmetric | 30 | 30 | 30 | 30 | 21 |
| Asymmetric | 27 | 27 | 21 | 12 | 6 |
| Step-level |  |  |  |  |  |
| Symmetric | 33 | 33 | 33 | 33 | 33 |
| Asymmetric | 30 | 30 | 21 | 21 | 15 |

# Appendix B – Instructions for participants

*There are four different versions of the instructions for the participants (one for each condition). Instructions that are the same for all conditions are aligned to the left and condition-specific instructions have an indent and a coloured heading with the condition name.*

Welcome to this study! Please read the instructions carefully. Communication with other participants is strictly forbidden throughout the study. In this study you are going to play a game in which your decisions have consequences for the amount of money you receive for participating in the study. If you have any questions, please raise your hand. After reading the instructions you will be tested to make sure you understand the rules of the game.

This study involves multiple participants. Each participant is presented with the same series of choices. Your payment this study is dependent on the decisions you make as well as the decisions of the other participants.

You will be assigned into groups of three people. The other two people are playing the game at the same time as you in this room, but you will not be told who the other two people in your group are and they will not know who you are. You will play multiple rounds with the same two people.

For this game, imagine you are running a business and that your company is located next to two other businesses at the shore of a lake. The three businesses are together responsible for the maintenance of the lake.

**Symmetric conditions**

Your business and the other businesses are each producing 30 units of waste every period.

**Asymmetric conditions**

One business is producing 20 units of waste, one business is producing 30 units of waste and the third business is producing 40 units of waste every period.

There is a waste disposal service that you can use to get rid of your waste, but this costs money: $1 million per unit. To reduce these costs, you can dump your waste in the lake instead.

**Continuous conditions**

Dumping your waste creates costs for the three companies together, because the lake needs to be cleaned at the end of each period to return it to its original state. Cleaning the lake costs $2 million per unit of waste and these costs will be equally divided among the three businesses (including you). The more pollution there is, the more everyone has to pay. During a period you and the other two businesses will be given the choice of how many, if any, units of waste you want to put in the lake. After each period, (1) the lake is cleaned, and (2) the waste that was not dumped will be picked up by the waste treatment company, at the associated costs.

Your costs per period will equal the money you pay to the waste treatment company ($1 million per unit) plus the costs from cleaning the lake (the costs of $2 million per unit are divided over the three companies)

**Step-level conditions**

Dumping your waste may create costs for the three companies together, because the lake may needs to be cleaned at the end of each period to return it to its original state. If 46 or more units of waste are dumped in the lake, the lake needs to be cleaned. The costs of cleaning are $180 million and these costs will be equally divided among the three businesses (including you). If 45 or less units of waste are dumped cleaning is not needed, so there will be no cleaning costs for the businesses. During a period you and the other two businesses will be given the choice of how many, if any, units of waste you want to put in the lake. After each period, (1) the lake is cleaned if needed, and (2) the waste that was not dumped will be picked up by the waste treatment company, at the associated costs.

Your costs per period will equal the money you pay to the waste treatment company ($1 million per unit) plus the costs from cleaning the lake (if 46 or more units of waste are dumped, the cleaning costs of $180 million will be shared by the three companies).

On the next page are three examples of the game with a step-by-step explanation of how the costs are calculated.

|  |  |  |
| --- | --- | --- |
| **Examples continuous symmetric condition** | | |
| E**xample 1**   1. In this example all three companies brought all their waste to the treatment plant, so the total amount of waste dumped in the lake is 0 units. 2. The cleaning costs are 0\*$2 = $0, which is $0 per company. 3. Each company pays $1 million per unit of waste that is brought to the treatment plant. 4. The total costs (treatment + cleaning of the lake) are $30 million for each company. | **Example 2**   1. In this example all three companies dumped all their waste in the lake, so the total amount of waste dumped in the lake is 90 units. 2. The cleaning costs are 90\*$2 million= $180 million, which is $60 million per company. 3. No waste is brought to the treatment plant, so the companies do not have to pay for that. 4. The total costs (treatment + cleaning of the lake) are $60 million for each company | **Example 3**   1. In this example company 1 dumped all its waste in the lake, company 2 brought all its waste to the treatment plant and company 3 brought half of its waste to the treatment plant and dumped the other half in the lake. The total amount of waste dumped into the lake is 45 units. 2. The cleaning costs are 45\*$2 million= $90 million, which is $30 million per company. 3. Each company pays $1 per unit of waste that is brought to the treatment plant. This means company 1 pays $0, company 2 pays $30 million and 3 pays $15 million to the treatment plant. 4. The total costs (treatment + cleaning of the lake) are $30 million for company 1, $60 million for company 2 and $45 million for company 3. |
| CU 3P M2.jpg | CU 3P M2.jpg | **CU 3P M2.jpg** |

|  |  |  |
| --- | --- | --- |
| **Examples continuous asymmetric condition** | | |
| **Example 1**   1. In this example company 1 produces 20 units of waste, company 2 produces 30 units of waste and company 3 produces 40 units of waste. 2. In this example, all three companies brought all their waste to the treatment plant, so the total amount of waste dumped in the lake is 0 units. 3. The cleaning costs are 0\*$2 million = $0, which is $0 per company. 4. Each company pays $1 million per unit of waste that is brought to the treatment plant. 5. The total costs (treatment + cleaning of the lake) are $20 million for company, $30 million for company 2 and $40 million for company 3. | **Example 2**   1. In this example company 1 produces 20 units of waste, company 2 produces 30 units of waste and company 3 produces 40 units of waste. 2. In this example all three companies dumped all their waste in the lake, so the total amount of waste dumped in the lake is 90 units. 3. The cleaning costs are 90\*$2 million= $180 million, which is $60 million per company. 4. No waste is brought to the treatment plant, so the companies do not have to pay for that. 5. The total costs are $60 million for each company | **Example 3**   1. In this example company 1 produces 20 units of waste, company 2 produces 30 units of waste and company 3 produces 40 units of waste. 2. In this example one company 1 dumped all its waste in the lake, company 2 brought all its waste to the treatment plant and company 3 brought half of its waste to the treatment plant and dumped the other half of its waste in the lake. The total amount of waste dumped into the lake is 40 units. 3. The cleaning costs are 40\*$2 million= $80 million, which is $26.67 million per company. 4. Each company pays $1 per unit of waste that is brought to the treatment plant. This means that company 1 pays $0 to the treatment plant, company 2 pays $30 million to the treatment plant and company 3 pays $20 million to the treatment plant. 5. The total costs (treatment + cleaning of the lake) are $26.67 million for company 1, $56.67 million for company 2 and $46.67 million for company 3. |
| **CU 3P M2 (1).jpg** | **CU 3P M2 (1).jpg** | CU 3P M2 (1).jpg |

|  |  |  |
| --- | --- | --- |
| **Examples step-level symmetric condition** | | |
| E**xample 1**   1. In this example all three companies brought all their waste to the treatment plant, so the total amount of waste dumped in the lake is 0 units. 2. If 46 or more units are dumped in the lake, the lake needs to be cleaned. 0 is less than 46 units, so the cleaning costs are $0. 3. Each company pays $1 million per unit of waste that is brought to the treatment plant. 4. The total costs (treatment + cleaning of the lake) are $30 million for each company. | **Example 2**   1. In this example all three companies dumped all their waste in the lake, so the total amount of waste dumped in the lake is 90 units. 2. If 46 or more units are dumped in the lake, the lake needs to be cleaned. 90 is more than 46 units, so the cleaning costs are $180 million, which is $60 million per company. 3. The companies do not have to pay the treatment plant, because they did not make use of it. 4. The total costs (treatment + cleaning the lake) are $60 million for each company | **Example 3**   1. In this example company 1 dumped all its waste in the lake, company 2 brought all its waste to the treatment plant and company 3 brought half of its waste to the treatment plant and dumped the other half in the lake. 2. The total amount of waste dumped into the lake is 45 units. 3. If 46 or more units are dumped in the lake, the lake needs to be cleaned. 45 is less than 46 units, so the cleaning costs are $0 million, which is $0 million per company. 4. Each company pays $1 million per unit of waste that is brought to the treatment plant. This means company 1 pays $0, company 2 pays $30 million and company 3 pays $15 million. 5. The total costs (treatment + cleaning of the lake) are $0 for company 1, $30 for company 2 and $15 for company 3. |
| **SE three players 46.png** | **SE 3P M2.jpg** | SE three players (1).jpg |

|  |  |  |
| --- | --- | --- |
| **Examples step-level asymmetric condition** | | |
| E**xample 1**   1. In this example company 1 produces 20 units of waste, company 2 produces 30 units of waste and company 3 produces 40 units of waste. 2. In this example all three companies brought all their waste to the treatment plant, so the total amount of waste dumped in the lake is 0 units. 3. If 46 or more units are dumped in the lake, the lake needs to be cleaned. 0 is less than 46 units, so the cleaning costs are $0. 4. Each company pays $1 million per unit of waste that is brought to the treatment plant. 5. The total costs (treatment + cleaning of the lake) are $20 million for company 1, $30 million for company 2 and $40 million for company 3. | **Example 2**   1. In this example company 1 produces 20 units of waste, company 2 produces 30 units of waste and company 3 produces 40 units of waste. 2. In this example all three companies dumped all their waste in the lake, so the total amount of waste dumped in the lake is 90 units. 3. If 46 or more units are dumped in the lake, the lake needs to be cleaned. 90 is more than 46 units, so the lake needs to be cleaned. The cleaning costs are $180 million, which is $60 million per company. 4. No waste is brought to the treatment plant, so the companies do not have to pay for that. 5. The costs are $60 million for each company | **Example 3**   1. In this example company 1 produces 20 units of waste, company 2 produces 30 units of waste and company 3 produces 40 units of waste. 2. In this example company 1 dumped all its waste in the lake, company 2 brings all of its waste to the treatment plant and company 3 brings half of its waste to the treatment plant and dumps the other half in the lake. The total amount of waste dumped into the lake is 40 units. 3. If 46 or more units are dumped in the lake, the lake needs to be cleaned. 40 units is less than 46, so the cleaning costs are $0. 4. Each company pays $1 per unit of waste that is brought to the treatment plant. This means company 1 pays $0 to the treatment plant, company 2 pays $30 million to the treatment plant and company 3 pays $20 million to the treatment plant. 5. The total costs (treatment + cleaning of the lake) are $0 for company 1, $30 million for company 3 and $20 million for company 3. |
| **SU three players (2).jpg** | **CU 3P M2 (1).jpg** | SU three players (2).jpg |

So to calculate your costs for a round you:

1. Decide how much of your waste you are bringing to the treatment plant and how much you are dumping in the lake. These amounts should sum up to the amount of waste you have produced.
2. Sum the amounts of waste that are dumped by your company and the two other companies.

**Continuous conditions**

1. Multiply this sum by $2 million.

**Step-level conditions**

1. If the three companies together dumped 45 or less units of waste, the costs for cleaning the lake are $0. If the three companies together dumped 46 or more units of waste, the costs for cleaning the lake are $180.
2. Divide those costs by 3 (because they are equally shared by the three companies). These are your costs for cleaning the lake.
3. Add $1 million for every unit of waste that you are bringing to the treatment company.

You will repeat this game several times.

**Symmetric conditions**

You are going to play the game on your computer: in every period you produce 30 units of waste.

**Asymmetric conditions**

You are going to play the game on your computer: in the first period you either produced 20, 30 or 40 units of waste and that amount will be the same in all periods.

You must fill in the number of units you want to dump in the lake. After all people in your group have made their decision, you will see how many units of waste the other people in your group dumped in the lake, how much waste in total is dumped and how high your costs and the costs of the others are. Then you proceed to the next period.

Each new period will proceed in the same way.

**Symmetric conditions**

After each period the lake is cleaned and you and the other two businesses will start each new period with 30 units of waste.

**Asymmetric conditions**

After each period the lake is cleaned and one business starts with 20 units of waste, one business starts with 30 units of waste and the last business starts with 40 units of waste.

At the end of the study your total costs from all periods will be summed up. The height of the payment you receive for participating in this study is determined by the amount of your costs in the study: the higher your costs in the study, the lower your actual pay at the end of the study. For every $50 million increase in costs in the game, you receive $0.10 less for participating in the study, up to the minimum of $8. This means that your payment will be between $8 and $15, depending on the decisions you make.

This is the end of the instructions. If you have any question now, please raise your hand.

We will now ask you some questions to make sure the rules of the game are clear. Please answer these questions on the separate piece of lined paper you received. If you want, you can use the calculator that is open on your computer. **Assume you are company 1 in all questions.**

**Continuous symmetric condition**

1. What will be your costs if:

* You (company 1) dumps 0 units of waste in the lake
* Company 2 dumps 15 units of waste in the lake
* Company 3 dumps 30 units of waste in the lake

The costs for my company will be $....... million

1. What will be your costs if:

* You (company 1) dumps 30 units of waste in the lake
* Company 2 dumps 20 units of waste in the lake
* Company 3 dumps 0 units of waste in the lake

The costs for my company will be $........ Million

**Continuous asymmetric condition**

1. Assume that company 1 produces 40 units of waste, company 2 produces 30 units of waste and company 3 produces 20 units of waste.

What will be your costs if:

* You (company 1) dumps 0 units of waste in the lake
* Company 2 dumps 15 units of waste in the lake
* Company 3 dumps 20 units of waste in the lake

The costs for my company will be $......... million

1. Assume that company 1 produces 40 units of waste, company 2 produces 30 units of waste and company 3 produces 20 units of waste.

What will be your costs if:

* You (company 1) dumps 40 units of waste in the lake
* Company 2 dumps 10 units of waste in the lake
* Company 3 dumps 0 units of waste in the lake

The costs for my company will be $........ Million

**Step-level symmetric condition**

1. What will be your costs if:

* You (company 1) dumps 0 units of waste in the lake
* Company 2 dumps 15 units of waste in the lake
* Company 3 dumps 30 units of waste in the lake

The costs for my company will be $.......... million

1. What will be your costs if:

* You (company 1) dumps 30 units of waste in the lake
* Company 2 dumps 20 units of waste in the lake
* Company 3 dumps 0 units of waste in the lake

The costs for my company will be $........... Million

**Step-level asymmetric condition**

1. Assume that company 1 produces 40 units of waste, company 2 produces 30 units of waste and company 3 produces 20 units of waste.

What will be your costs if:

* You (company 1) dumps 0 units of waste in the lake
* Company 2 dumps 15 units of waste in the lake
* Company 3 dumps 20 units of waste in the lake

The costs for my company will be $......... million

1. Assume that company 1 produces 40 units of waste, company 2 produces 30 units of waste and company 3 produces 20 units of waste.

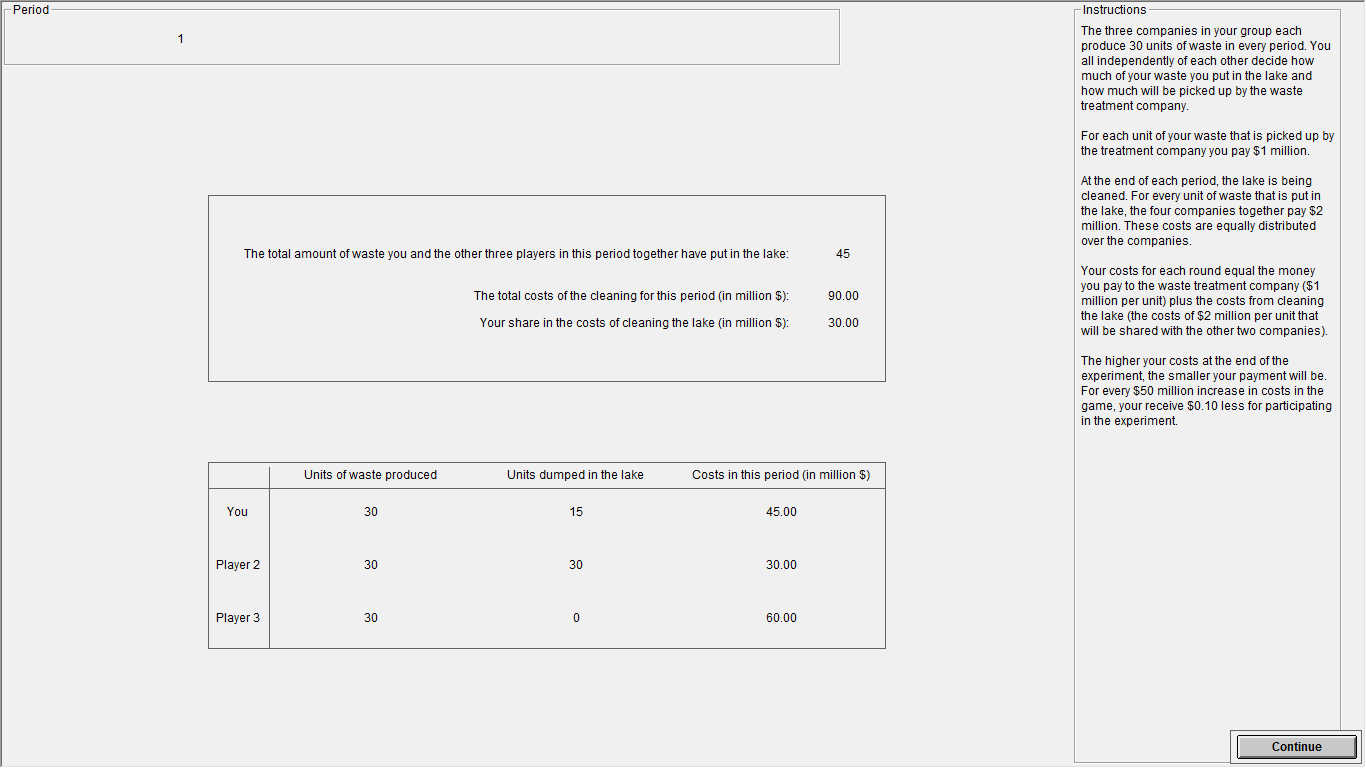
What will be your costs if:

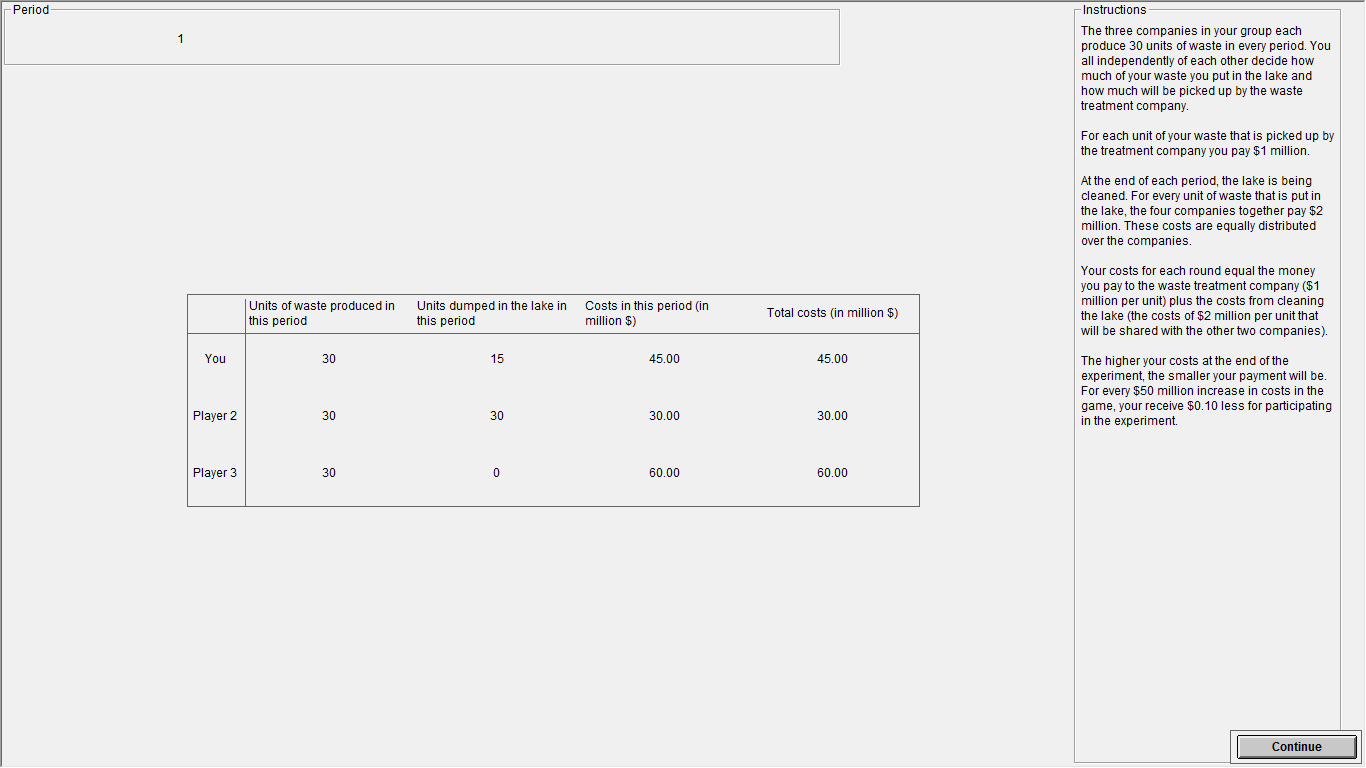
* You (company 1) dumps 40 units of waste in the lake
* Company 2 dumps 10 units of waste in the lake
* Company 3 dumps 0 units of waste in the lake

The costs for my company will be $........ Million

Please raise your hand when you have finished answering the questions.

# Appendix C - Z-tree screenshots





# Appendix D –Questionnaire

You are now going to be asked a number of questions. Do not think too long about your answer to each question; your first instinct is usually best.  
Please answer the questions as honestly as possible; there are no right or wrong answers. We are only interested in your personal opinion.

Please enter your computer number (you can find it on your left).

**Demographics**

What gender do you identify with?

* Male
* Female

What is your age?

Drop-down list from 15 – 100 years

What is the highest level of education you have completed?

* Primary School Degree
* Middle School Degree
* High School Degree
* Undergraduate Degree
* Graduate Degree
* Other

What is your major field of study?

What is your nationality?

**Numeracy item**s

Imagine that we flip a fair coin 1,000 times. What is your best guess about how many times the coin would come up heads in 1,000 flips? \_\_\_\_times out of 1,000. Fill in your answer in the box below.

In the BIG BUCKS LOTTERY, the chance of winning a $10 prize is 1%. What is your best guess about how many people would win a $10 prize if 1000 people each buy a single ticket to BIG BUCKS?\_\_\_\_person(s) out of 1,000. Fill in your answer in the box below.

In ACME PUBLISHING SWEEPSAKES, the chance of winning a car is 1 in 1,000. What percent of tickets to ACME PUBLISHING SWEEPSAKES win a car?\_\_\_\_%.”

**New Ecological Paradigm Scale** (Dunlap, Van Liere, Mertig, & Jones, 2000)

Listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you STRONGLY DISAGREE, MILDLY DISAGREE, are UNSURE, MILDLY AGREE or STRONGLY AGREE with it.

* We are approaching the limit of the number of people the Earth can support.
* Humans have the right to modify the natural environment to suit their needs.
* When humans interfere with nature it often produces disastrous consequences
* Human ingenuity will insure that we do NOT make the Earth livable
* Humans are severely abusing the environment
* The Earth has plenty of natural resources if we just learn how to develop them.
* Plants and animals have as much right as humans to exist
* The balance of nature is strong enough to cope with the impacts to modern industrial nations.
* Despite our social abilities humans are still subject to laws of nature.
* The so-called ‘ecological crisis’ facing humankind has been greatly exaggerated.
* The earth is like a spaceship with very limited room and resources.
* Humans were meant to rule over the rest of nature.
* The balance of nature is very delicate and easily upset.
* Humans will eventually learn enough about how nature works to be able to control it.
* If things continue on their present course, we will soon experience a major ecological catastrophe.

**Social value orientation** (Murphy, Ackermann, & Handgraaf, 2011)**:**

In this task you have been randomly paired with another person, whom we will refer to as the other. This other person is someone you do not know and will remain mutually anonymous. All of your choices are completely confidential. You will be making a series of decisions about allocating resources between you and this other person. For each of the following questions, please indicate the distribution you prefer most by ticking the respective box. You can only make one mark for each question.

Your decisions will yield money for both yourself and the other person. In the example below, a person has chosen to distribute money so that he/she receives 50 dollars, while the anonymous other person receives 40 dollars.

There are no right or wrong answers, this is all about personal preferences. After you have made your decision, write the resulting distribution of money on the spaces on the right. As you can see, your choices will influence both the amount of money you receive as well as the amount of money the other receives.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| You receive | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 |
| Other receives | 85 | 76 | 68 | 59 | 50 | 41 | 33 | 24 | 15 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| You receive | 85 | 87 | 89 | 91 | 93 | 94 | 96 | 89 | 100 |
| Other receives | 15 | 19 | 24 | 28 | 33 | 37 | 41 | 46 | 50 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| You receive | 50 | 54 | 59 | 63 | 68 | 72 | 76 | 81 | 85 |
| Other receives | 100 | 98 | 96 | 94 | 93 | 91 | 89 | 87 | 85 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| You receive | 50 | 54 | 59 | 63 | 68 | 72 | 76 | 81 | 85 |
| Other receives | 100 | 89 | 79 | 68 | 58 | 47 | 36 | 26 | 15 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| You receive | 100 | 94 | 88 | 81 | 75 | 69 | 63 | 56 | 50 |
| Other receives | 50 | 56 | 63 | 69 | 75 | 81 | 88 | 94 | 100 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| You receive | 100 | 98 | 96 | 94 | 93 | 91 | 89 | 87 | 85 |
| Other receives | 50 | 54 | 59 | 63 | 68 | 72 | 76 | 81 | 85 |

**Consideration of future consequences** (Strathman, Gleicher, Boninger, & Edwards, 1994)

Answers are given on a seven-point scale: Not at all like me – Not like me – Not much like me - Neutral – Somewhat like me – Like me – Just like me

* I consider how things might be in the future, and try to influence those things with my day to day behavior
* Often I engage in a particular behavior in order to achieve outcomes that may not result for many years
* I only act to satisfy immediate concerns, figuring the future will take care of itself
* My behavior is only influenced by the immediate (i.e., a matter of days or weeks) outcomes of my actions
* My convenience is a big factor in the decision I make or the actions I take
* I am willing to sacrifice my immediate happiness or well-being in order to achieve future outcomes
* I think it is important to take warnings about negative outcomes seriously even if the negative outcome will not occur for many years
* I think it is more important to perform a behavior with important distance consequences than a behavior with less-important immediate consequences
* I generally ignore warnings about possible future problems because I think the problems will be resolved before they reach crisis level
* I think that sacrificing now is usually unnecessary since future outcomes can be dealt with at a later time
* I only act to satisfy immediate concerns, figuring that I will take care of future problems that may occur at a later date
* Since my day to day work has specific outcomes, it is more important to me than behavior that has distant outcomes

**Temporal discounting** (Kirby, Petry, & Bickel, 1999)

For each of the next 9 choices, please indicate which reward you would prefer: the smaller reward today, or the larger reward in the specified number of days.

* Would you prefer $54 today, or $55 in 117 days?
* Would you prefer $47 today, or $50 in 160 days?
* Would you prefer $25 today, or $60 in 14 days?
* Would you prefer $40 today, or $55 in 62 days?
* Would you prefer $27 today, or $50 in 21 days?
* Would you prefer $49 today, or $60 in 89 days?
* Would you prefer $34 today, or $50 in 30 days?
* Would you prefer $54 today, or $60 in 111days?
* Would you prefer $20 today, or $55 in 7 days?

**Purpose**

What do you think is the purpose of this study?

This was the last question of this study! Please click the ‘continue’ button and raise your hand.

# Appendix E – Spoken instructions

Welcome to this study!

I’ll read some instructions aloud now. It’s important that you pay attention to them and don’t talk to each other. If you have questions, please raise your hand and I will answer them individually.

You have just received the consent form to participate in this research. Please, read it carefully and sign it.

This study will last one hour or less, but not more than that.

After you have signed the consent form, you can read the instructions for the study on your screen. Please take time to read them carefully; it’s essential for the rest of the study that you understand everything well. Everything that is said in the instructions is true, we are using no deception.

This is a paid study, which means that you will not receive credit for participating. As you will read in the instructions the height of you payment depends on the decisions you are making in the study.

Communication and the use of mobile phones are not allowed during the study. You may have to wait sometimes, but please do not use you cell phone.

Now you can start reading the consent form and after that the instructions. Again, if you have any questions, just raise your hand.

-----------------------------------------------------------------------------------------------------------------

I will now show an example of what the program you are going to play the game in looks like. It is too small to read on the screen, but it will be readable on your screen.

On the first screen you will see the instructions in short on the right, in case you forgot them. On top you see the period number. In the box in the middle you see the number of units of waste you have produced and a box in which you have to enter how much of that waste you want to dump in the lake. After you have entered how much waste you are dumping you click the ‘OK’ button on the right bottom of the page.

After everyone has entered how much waste he or she is dumping and had clicked the OK-button, this screen appears. Again you see the instructions and the period number. In the middle you see how much waste you have dumped, how much waste in total has been dumped and what your costs of cleaning the lake are. In the table you see how much waste the other players have dumped and what their costs for this round are. These costs are the summed costs of cleaning the lake and of the payment to the treatment plant for each player. When you’re finished with these results, click the ‘continue’ button on the right bottom.

You will now get to see a screen with the same table as on the previous page, but now with the total costs of each player over the rounds that you have played. When you are finished reading this table, please click the continue button at the bottom of the page. You will be directed to a waiting screen until the other players have finished as well. Then you move on to the next period.

-----------------------------------------------------------------------------------------------------------------

That was the first block of the game. I am now going to change the groups and start the next block. Your total costs are set to 0 again, but they do still count for your payment.

**Appendix F: Additional Analyses**

### F.1 Group effects

## F.1.1 Hitting the threshold in step-level games

The participants in the step-level conditions can limit their costs from the public bad by staying under the threshold or by exactly hitting it. By exactly hitting the threshold they can reach the optimal solution: if they together exactly dump 45 units of waste they avoid the cleaning costs, while still benefitting from dumping some of their waste, and thus not paying the treatment costs. The threshold was exactly hit much more often by groups in the symmetric condition. In fact, it was hit four times as often by groups in the symmetric condition (mean = 40.9%, *SD* = 49.2) as by groups in the asymmetric condition (mean = 10.4%, *SD* = 30.5) (*F*(1, 1798) = 30.37, *p* < .001). There is no significant difference between the frequency of staying under the threshold between the symmetry conditions (*F*(1, 598) = 1.46, *p* = .23).

## F.1.2 Influence of previous round

The participants within each group are not independent of each other: they respond to each other’s decisions, they may try to influence each other. To capture some of the group dynamics we have had a look at the influence of defection of a subject’s group members in the previous round on a person’s defection in the current round. We did the standard mixed model analysis with the total percentage defection by the other group members in the previous round as a covariate. We find an overall positive effect of defection in the previous round on defection in the current round (*F*(1, 3727) = 44.61, *p* < .001): the more defection there was in the previous round, the more individuals will defect in the next round. In the step-level conditions, the chances that they will exceed the threshold also increased with higher defection in the previous round. When looking at the effect of whether or not a group exceeded the threshold in the previous period we find an interesting interaction effect. If the threshold has not been exceeded in the previous round, the chances that a group will exceed it in the current round is higher in the asymmetric condition than in the symmetric condition (*F*(1, 575) = 8.72, *p* = .02). This interaction is visualized in figure 4.

### F.1.3 ‘New group’-effect

When visually inspecting the first and last rounds of the blocks in figure 3, defection seems to go down at the beginning of each new block. If this is the case, participants behave more prosocially when joining a new group. One possible explanation for this may be that individuals are trying to set a statement and to encourage their group members to be cooperative. With a 2x2 standard mixed model analysis in which we included round (last of block or first of block) as a covariate, we tested if this observation is true. Only period 10, 11, 20 and 21 are included in the analysis, which means we were comparing the last period of a block with the first period of the next block. Overall percentage defection decreases when moving to the next new block (*F*(1, 46) = 24.3, *p* < .001), but when looking at the conditions separately we find that in the step-level asymmetric condition there is no ‘new group’-effect (*F*(1, 109) = 0.16, *p* = .70).

Apparently individuals are willing to try again to keep the shared costs low when assigned to a new group, but then increase defection over the rounds. Tit for tat explains why we find that some groups in the step-level conditions are continuously staying under the threshold and why other groups, that have once exceeded the threshold, have a hard time getting under it again after that. Individuals that are part of a ‘cooperative’ group should cooperate as well to maximize their benefits. Individuals that are part of a ‘defective’ group should defect as well, since cooperating does not make sense if the rest of the group defects.

The exception in this ‘new group’-effect is the step-level asymmetric condition. In this condition there is no decrease of defection at the start of a new block and there even seems to be a reversed ‘new group’-effect: defection increases at the beginning of a block. One explanation for this might be that the circumstances of players in the asymmetric condition often changed between blocks, and players may have interpreted these changes in a self-serving manner: perhaps when the waste endowment increased, players maintained their absolute level of cooperation, whereas when waste endowment decreased, players used the proportional rule, thus leading to great defection overall over time. Another explanation for this could be related to the difficulty of asymmetric groups to coordinate contributions that we just described: groups have a hard time coordinating their contributions if there is asymmetry, but they might learn how to do it over time. It might be that players in the asymmetric conditions, like the players in the other conditions, are willing to try to keep the shared costs low, but that it is difficult for them to do so. In the continuous conditions this effect was not visible: defection decreased at the beginning of each block. However, in the step-level asymmetric condition defection is lower than in the continuous conditions because groups are trying to stay under the threshold and the asymmetry might be a bigger issue there: what is a fair contribution, taking into account the differences in endowment height and the height of the threshold? In the first rounds of a block the uncertainty about what a fair distribution is may have a stronger effect than the urge to stay under the threshold, in sum defection increases in the first rounds.

## F.2 Personal costs

Another measure of ability of groups of reaching the solution with the highest total payoff in the different social dilemmas is the size of the costs per person in a specific round, which is the sum of the costs caused by defection paid by the group and the individual costs of cooperating. The lower the personal costs are, the better off the participants are. Figure 5 shows the average costs per round for the different conditions. We did the standard analysis as described in the introduction of the results section, but now we used personal costs instead of percentage defection as the dependent variable.

Figure F1: Average personal costs per block per condition

The costs are significantly higher in the continuous conditions than in the step-level conditions (*F*(1, 3401) = 48.52, *p* < .001). The influence of symmetry on costs is a trend (*F*(1, 3401) = 3.32, *p* = .07): in the asymmetric conditions, the personal costs are higher than in the symmetric conditions. There is a significant interaction between game type and symmetry (*F*(1, 3401) = 7.37, *p* = .01): there is no significant difference between both continuous conditions (*F*(1, 1603) = 1.92. *p* = .17), but in block 2 and 3 the personal costs are higher in the step-level asymmetric condition than in the step-level symmetric condition (*F*(1, 1798) = 6.22, *p* = .01).

To further analyze the effects over time, we included the 30 rounds separately in the analysis. The personal costs increase over time in the continuous conditions (F(1, 1601) = 84.89, *p* < .001), but in the step-level conditions the change in personal costs is not significant, because there is a lot of variance in those conditions (*F*(1, 1796) = 1.57, *p*= .21).

In the step-level symmetric game groups managed more often to keep the personal costs low than in the asymmetric game, which is consistent with the increase in defection in the step-level asymmetric condition. The personal costs increase in the continuous games, but not in the step-level games, even though percentage defection went up in all four conditions. In the step-level conditions, the subjects increased defection and thus reduced the costs of bringing waste to the treatment plant, but they avoided exceeding the threshold and thus high cleaning costs. In the continuous condition subjects reduced the private treatment costs, but at the cost of higher cleaning costs. The groups in the step-level condition are better able to manage the public bad, because a number of groups is approaching the optimal solution by (almost) hitting the threshold. This leads to more efficient use of resources and to better outcomes for all participants.

## F.3 Number of contributing players and contributions of contributing players

To better understand what is happening in the different conditions, we have had a look at the number of contributing players and at the amount of waste dumped by them (see table 8). The lower defection rates in the step-level and symmetric conditions can be explained by a) the number of contributing players and/or b) the percentage defection of contributing players. Contributing players are defined as players who kept at least one of their units of waste. We did two versions of the standard analysis with respectively the number of contributing players and their percentage defection as dependent variables. We find that there are more contributing players in the step-level game than in the continuous game (*F*(1, 3401) = 70.31, *p* < .001), but percentage defection of those contributing players is not significantly different than in the continuous conditions (*F*(1, 1493) = 0.82, *p* = .37). Asymmetry does not have an effect on the number of contributing players (*F*(1, 3401) = 0.01, *p* = .94), but it does decrease increase percentage cooperation of contributing players in the continuous condition (*F*(1, 420) = 6.05, *p* = .01).

Table F1: Mean percentage and mean size of contributions by contributing players per condition (standard deviation in parentheses)

|  |  |  |
| --- | --- | --- |
|  | Mean percentage of contributing players | Mean percentage defection by co-operators |
| Continuous |  |  |
| Symmetric | 26.2 (44.0)a | 51.5 (35.1)a |
| Asymmetric | 23.4 (44.1)a | 34.7 (31.2)b |
| Step-level |  |  |
| Symmetric | 61.0 (48.8)b | 43.9 (17.7)b |
| Asymmetric | 58.2 (49.4)b | 43.2 (20.6)b |

*Note.* Means in the same column with different superscript differ significantly (Mixed model analysis, *p* < .05)

## F.4 Effects of endowment level

In the asymmetric conditions players within each group have different endowment levels (amounts of waste). To understand what is happening in the asymmetric conditions and to find out which participants are responsible for the higher defection rates than in the asymmetric condition, we did a 2 (game type: continuous versus step-level) x 3 (Endowment amount: low, medium, high) mixed model analysis with absolute and percentage defection as dependent variables and individuals nested in groups as a random factor. We repeated the analysis with percentage defection as dependent variable. The mean values and standard deviations can be found in table 9. We only included subjects that are assigned to the asymmetric condition in the analysis. Absolute defection is higher for participants with high endowments (*F*(1, 1511) = 113.66, *p* < .001), but having lower or higher endowments does not have an effect on percentage defection (*F*(1, 1511) = 0.07, *p* = .91) and there is no interaction effect with game type (F(1, 1511) = 0.01, *p* = .79). We calculated the amount of waste that was dumped by an individual as a percentage of the total amount of waste dumped by a group. After that we tested whether that percentage was similar to the percentage you would expect based on the proportional contribution rule (22% for individuals who produce little waste, 33% for individuals who are assigned a medium amount of waste and 44% for individuals that have a lot of waste). Table 9 and t-tests reveal that the values do not significantly differ from the expected values of 22%, 33% and 44% in the continuous conditions (*t*(234) = 0.875, *p* = 0.38; *t*(234) = -.397, *p* = .69); *t*(234) = .623, *p* = .534). However, in the step-level conditions, the contributions do significantly differ from these percentages for the people with low and high endowments (*t*(269) = 2.967, *p* = .003); *t*(269) = .349, *p* = .73); *t*(269) = -1.972, *p* = .05). Individuals who produce little waste have a relatively high share in a group’s defection, whereas individuals who produce much waste have a relatively smaller share. This points in the direction of the minimize differences in outcomes rule.

Table F2: Mean absolute and percentage defection and defection as a percentage of a group’s absolute defection per game type and endowment level in the asymmetric conditions (standard deviation in parentheses)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mean absolute defection in units of waste | Mean percentage defection | Mean defection as a percentage of a group’s absolute defection | N |
| Continuous |  |  |  |  |
| Low endowment | 16.4a (6.7) | 82.0a (33.5) | 22.7 (13.3) | 9 |
| Medium endowment | 24.5b (10.7) | 81.6a (35.7) | 32.6 (17.4) | 9 |
| High endowment | 33.9c (11.8) | 84.7a (29.4) | 44.7 (17.0) | 9 |
| Step-level |  |  |  |  |
| Low endowments | 13.9a (6.5) | 69.6a (32.5) | 24.6 (14.1) | 10 |
| Medium endowment | 19.8b (9.4) | 66.0a (31.2) | 33.3 (14.7) | 10 |
| High endowments | 26.1c (13.0) | 65.4a (32.6) | 42.1 (15.6) | 10 |

*Note.* Means within the same game type condition with different superscript differ significantly (Mixed model analysis, *p* < .05)

## F.5 Individual differences

The mean scores on the individual differences scales can be found in Table 10. Fourteen participants entered an age that was lower than 18 years. These participants filled in an incorrect age and these age data are excluded from the analysis that included age. Due to a lack of time, not all participants finished the survey. The individual differences have been measured after playing the public bad game.

The scores of NEP and consideration of future consequences differ significantly between the different conditions (table 11). The NEP scores are significantly higher in the step-level asymmetric conditions than in the other conditions (*F*(1, 116) = 4.38, *p* = .04). Playing the game probably changed people’s attitudes and beliefs, leading to different scores on those questions.

The consideration of future consequences scores are significantly lower in the continuous symmetric condition than in the other three conditions (*F*(1, 111) = 4.05, *p* = .05). The other three conditions did not significanly differ from each other. When including those individual characteristics in the analysis we would assume that the scores are similar across the different conditions. Since that is not the case, we cannot include NEP and consideration of future consequences as covariates in the analysis.

Table F3: Descriptives demographics and individual differences scores

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mean SD) | Minimum | Maximum | N |
| Age | 24.3 (7.8) | 18 | 60 | 106 |
| Numeracya | 2.5 (.8) | 0 | 3 | 120 |
| SVOb | 25.6 (12.8) | -9.5 | 47.6 | 114 |
| ConsFuturec | 4.6 (.8) | 3.3 | 7 | 115 |
| Temporal  discountingd | .002 (.054) | .000 | .25 | 114 |
| NEPe | 3.67 (.5) | 2.4 | 4.93 | 120 |

a Number of items answered correctly (maximum possible=3)

b SVO-angle

c 7-point Likert scale

d Discount rate: parameter *k* from the hyperbolic formula *V* = *A* / (1+*kD*), where *V* is present value, *A* is future amount, *k* is the discount rate (fitted), and *D* is the delay in days (Mazur, 1987).

e 5-point Likert scale

Table F4: Mean NEP and Consideration of Future Consequences scores per condition (standard deviations in parentheses)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Mean NEP-score | | Mean consideration of future consequences score | |
| Continuous | |  | |  |
| Symmetry | | 3.6a (0.5) | | 4.8a (1.0) |
| Asymmetry | | 4.9a (0.5) | | 4.3b (0.5) |
| Step-level | |  | |  |
| Symmetry | | 3.6a (0.5) | | 4.6a (0.7) |
| Asymmetry | | 3.9b (0.4) | | 4.8a (0.8) |

*Note.* Means within the same game type condition with different superscript differ significantly (Mixed model analysis, *p* < .05)

Gender, SVO, temporal discounting, numeracy and age do not differ across the different conditions *(p* > .05*).* First we did five mixed model analyses with each time one of the covariates as a predictor and percentage defection as a dependent variable. None of the covariates has a significant effect on percentage defection (all *p* > .10). After that, we repeated the standard analysis as described in the introductory paragraph of the results five times. In each version we included one of the five individual differences in the model as a fixed factor, and we examined both the main effect and the interactions with game type and symmetry. The first four covariates have neither a direct nor a moderating effect on percentage defection (all *p* > .05), but adding age to the analysis removes the effect of game type (*F*(1, 2977) = 0.26, *p* = .61). Age on its own does not have an effect on percentage defection (*F* (1, 2983) = 0.65, *p* = .42).