How to harvest versus how much to harvest in common pool resources experiments

Marco A. Janssen
School of Human Evolution and Social Change
Center for the Study of Institutional Diversity
Arizona State University
PO Box 872402
Tempe, AZ 85287-2402
Phone: 480 965 1369 / Fax: 480 965 7671
Email: Marco.Janssen@asu.edu

ABSTRACT

Case study analysis shows that long lasting social-ecological systems have institutional arrangements regulating where, when and how to appropriate resources instead of how much. In typical commons dilemma experiments the only possible decision is how much to appropriate. Using a real-time, spatial, renewable resource environment, we can study the informal norms that subjects develop in an experimental resource dilemma setting. We find that the informal institutions developed are based on when, where and how to appropriate the resource, not how much. Furthermore, the specific arrangements vary to fit the ecological dynamics in the different treatments. Finally, we find that the amount and distribution of communication messages and not the content of the communication explains the differences between group performances.

JEL Code: B52, C92, D70, Q20

KEY WORDS • common-pool resources • laboratory experiments • communication • institutional innovation

1. Introduction

Common Pool Resource dilemmas are characterized by the difficulty to exclude appropriation and the negative impact of an individual's appropriation on other's returns. Examples are forests, groundwater basins, grazing lands, and fisheries. An iconic image of the difficulty to cope with this dilemma is the "Tragedy of the Commons" metaphor of Hardin (1968). Within the environmental economics literature this problem had been addressed earlier by Gordon (1954) and Scott (1955) who developed bio-economic models that show that open access conditions of fishery resources leads to the economic destruction of the resource.

According to Hardin (1968) the only way to sustain resources was to privatize the resource or impose control by a central government. However, self-governance of common pool resources has frequently been observed in field studies (Dietz et al., 2003). The ability to self-organize in common pool resources has also been replicated in laboratory experiments (e.g. Ostrom et al., 1994). The ability to communicate, even without enforceable consequences of broken promises, and the ability to punishment defectors, even at a cost to the punisher, has been found important explanations for these observations (Dawes et al., 1977; Ostrom et al., 1994; Sally, 1995; Ostrom & Nagendra, 2006).

The traditional bio-economic models define optimal policies in the optimal amount to harvest from the resource (e.g. Gordon, 1954; Scott, 1955; Clark, 1990). The focus on the amount of harvest is also seen in the discussion on resource management. The optimal quantity of harvest can be derived via different policies, such as direct policies via quota and permits, or indirectly via prices and taxes (Weitzman, 1974). Such direct or indirect policies on the quantities have led to different levels of success and are no panaceas for environmental management (e.g. Tietenberg, 2002).

Studies of long lasting social-ecological systems, such as fisheries, show that rules are mainly based on where and when to harvest and not on how much to harvest (Schlager 1994; Wilson et al. 1994; Ostrom, 2005). The laboratory experiments that showed that self-governance was possible were based on the notion of quantities since the only appropriation decision that could be made was the amount to harvest from the common resource (Ostrom et al., 1994). In this paper we will perform experiments with a dynamic spatially explicit resource and observe the kind of informal arrangements subjects make. When subjects have the opportunity to discuss the use of common resource, will they focus on the amount to be harvested, or where, when and how the resource is harvested?

In our experiments, we allow participants to communicate via text messages. It is observed in other studies that communication increase the performance of the group (Ostrom et al., 1994). Not all groups who are allowed to communicate are equally successful. A question also addressed in this study is why some groups are more effective in self-organization than others? We focus especially on the communication patterns and investigate what makes communication among subjects in some groups more effective than others to increase their earnings?

Debate exists as to why communication alone leads to better results (Buchan et al. 2006). In some experiments with a relatively simple payoff function, research has shown that increased performance with communication is not due to better understanding of the

experiment (Edney and Harper 1978; Kerr and Kaufman-Gilliland 1994). In the common-pool resource experiments, where the more complex, quadratic harvesting equation originally posited by Gordon (1954) has been used for the payoff function, subjects spent time initially to be sure they understood what harvesting level was the equivalent of the group optimum and how to allocate that to individuals (Ostrom 2006; Simon and Schwab 2006). Orbell et al. (1988) conclude that two possible explanations exist for the effect of communication (a) group discussion enhances group identity or solidarity, and (b) group discussion elicits commitments to cooperate. A review by Shankar and Pavitt (2002) come to a similar conclusion and suggests that voicing of commitments and development of group identity and norms seem to be the best explanation for previous experimental results.

In this paper we investigate what kind of norms and rules groups develop, and whether they come up with different norms and rules for different ecologies. We also explore whether some groups are more effective than others because they have the ability to communicate. We use a novel experimental environment where subjects can collect tokens rapidly in a spatially explicit renewable resource. Between rounds the subjects can exchange text messages. We analyze the communication patterns to test how the content and process of communication affects the group performance. Furthermore, we investigate the types of institutional arrangements the groups develops and whether these types are related to the different resource dynamics.

In the following section we introduce the experimental environment. In Section 3, we discuss the experimental design. Section 4 presents the results of the experiments, and Section 5 concludes the paper with the main findings of this study.

2. A Virtual, Dynamic Spatial Experiment

The experimental environment we use in this study contains more types of decisions that subjects can make than most previous experimental environments for common-pool resources. Subjects make decisions regarding how much, where and when to collect tokens. This enables us to investigate the type of informal institutions crafted. Subjects interact in real-time to harvest tokens from a spatially explicit renewable resource. Subjects move their avatars on the screen and make decisions on where to go on a grid to collect tokens, how to collect tokens and how fast to move on the screen. Therefore, they make hunderds of decisions during the few minutes of each round in an experiment instead of one decision per round (and perhaps 25 to 30 total decisions in the full experiment). If they overharvest the resource, they will face an empty screen after a while. To delay the collapse of the virtual commons, they need to cooperate and collect tokens wisely in a coordinated spatial and temporal manner.

In the experiment, groups of four subjects share a renewable resource that grows on a 28x28 spatial grid of cells. They can collect tokens during five rounds, each of which is four minutes. The length of a round is known to the subjects and a clock on the screen shows how much time is remaining for that round[1]. Subjects move their avatar by pressing the arrow keys (left, right, up, and down). There are two ways of collecting tokens using an implicit or explicit mode. In the implicit mode a green token is collected automatically by moving the avatar onto the location of the token. In the explicit mode the subject also locates the avatar on the location of the token but (s)he only collects the token if the space bar is also pressed. With the explicit mode one can move one's own

avatar around without harvesting tokens. This enables participants to harvest using a checker board pattern which the optimal spatial pattern for this set of experiments. Each token harvested is worth $0.02.

The resource renewal rate is density dependent. As the number of green tokens around an empty cell increases, the probability increases that in the next time step a green token will appear on the empty cell (see Figure 1). The probability p_t is linearly related to the number of neighbors: $p_t = p*n_t/N$ where n_t is the number of neighboring cells containing a green token, and N the number of neighboring cells (N = 8 because we use a Moore neighborhood). The parameter p is defined after a series of pre-tests in such a way that the renewal of the resource is quickly enough to be observed by the subjects, but sufficiently slow that the subjects experience a dilemma between immediate, individual benefits and longer-term, group benefits. If subjects quickly collect as many tokens as they can, there will be no tokens remaining on the screen. Once every token has been harvested, no further opportunity exists for any new token to be created. Subjects do not receive information on the individual earnings of other subjects in the group, but after the round is completed, they do receive information about the average earnings of the subjects in their group.

[Figure 1 about here]

Due to the richness of the experimental environment, it is suitable to study how subjects craft norms in a complex environment. While it is difficult to precisely determine the total quantity of resource units available, the subjects can see resource renewal patterns. This enables them to craft innovative arrangements for allocating space and time to one another as a way of using the common resource. Thus, this experiment enables us to examine institutional innovation in a virtual, dynamic resource. Subjects developed various norms that mainly focus on dividing the 'turf' in equal amounts or the timing of their harvesting (Janssen and Ostrom, 2008).

In previous experiments with a similar environment we found that communication among subjects increased performance in an open-access situation (Janssen and Ostrom, 2008). These communication experiments were face-to-face conversations. In this paper we report on experiments were the subjects can only exchange text messages. They do not know the identity of the persons who are in their group. As a consequence we can analyze all the content of the communication and potentially analyze why some group do better than others.

In Bochet et al. (2005) different forms of communication in public good experiments are compared. They had similar findings to those of other experimental studies that face-to-face communication increased cooperation considerably. They also found that communication via text messages in a chat format, preserving anonymity and excluding facial expression was almost as effective as face-to-face communication. On the other hand, just exchanging numbers of proposed investments via computer terminals was found not to be effective. The relative similar effect of exchanging text messages with current generation of subjects in laboratory experiments supports our decision to use text messages as a way to communicate in laboratory experiments.

3. Experimental Design

The experiment is designed to learn more about how groups develop informal arrangements to govern a spatially explicit common resource[2]. While we know that cheap talk increases cooperation, we were especially interested in the type of informal institutional arrangements subjects developed.

We began the experiment with an individual practice round in which we asked subjects to collect tokens during a four minute period on a 14x14 spatial grid. They could restart the distribution of the tokens during this practice round. They did not share the resource with somebody else and did not know they would do so later in the experiment. After this practice round, the first round is again an individual round, but this time they cannot reset the distribution of tokens. After this first round, we announce that they will share a resource that is four times bigger with three other subjects in the room with whom they have been randomly matched. We had two, three or four groups at the same time in the experimental laboratory dependent on the number of subjects that responded to our invitation.

The second round is an open access situation without communication. After the second round we introduce two new aspects. The subjects are told that they can reduce the tokens of other subjects in their group after the round is finished. At a cost of one token they can reduce the amount of tokens of another subject by two tokens, up to a maximum of 50 tokens per other subject. We tested whether they understood this procedure with some quiz questions. When everybody answered the quiz questions correctly, we continued with a communication period. They were told that before each of the next rounds they could communicate for five minutes by exchanging text messages on the computer screen. They could chat about whatever they wanted as long as they did not threaten each other with any consequences after the experiment was over, and as long as no promises about side payments were made. Moreover, they were not allowed to reveal their real identity. We monitored the chat communication to confirm these rules were followed. Rounds three, four and five were all the same: first communication for five minutes, then collecting tokens for four minutes, and then an opportunity to subtract tokens from other subjects if desired.

We designed four different treatments. We compare high growth rate versus a low growth rate of the resource. And we compare a homogenous resource in time and space, with treatments where the resource growth is changing, and where the resource growth is not the same for each location. This enables us to explore the consequences of different degrees of severity of resource scarcity and complexity of the resource dynamics. The following treatments are distinguished (Table 1):

- High growth rate. A relative high regrowth of the resource which start at the optimum density of tokens on the screen (50%)
- Low growth rate. By reducing the regrowth probability by half and the initial density to 25% this environment is more challenging than the previous treatment. To maximize earnings, subjects should initially let the resource undisturbed to regrow to a 50% density.
- High growth rate/low growth rate. The first three rounds have the high regrowth situation. After the second communication round, and before they start round 4, we announce that we have changed the regrowth rate and the initial amount of tokens on the screen. Will they be able to adapt?

- Spatially mixed growth. In this case the regrowth of the resource is not spatially uniform. It has a high growth rate and 50% initial density at the top half of the screen and a low growth rate and 25% initial density at the bottom half of the screen.

[Table 1 here]

At the end of the experiment, subjects complete a survey while the experimenters prepare the payments. We asked subjects a short set of questions to derive basic demographic information such as their major, gender, age, and whether they were satisfied with the payments and understood the instructions.

The real-time spatial environment makes it difficult to calculate precisely the best strategy. Theoretically it would be best to keep the average density of the tokens to 50% distributed in a checkerboard diagram and harvest all the tokens in the last second of the round. This leads to upper boundaries of the number of tokens individuals can collect if they cooperate: 162 tokens for the low growth case, 248 for the mixed growth case, and 334 for the high growth case. The resulting cooperative earning, including the five dollar show-up fee, would be about $21 for the low growth case, $30 for the mixed growth case, $31 for the high/low growth treatment and $38 for the high growth case.

4. Experimental Results

We performed this series of experiments in the Fall 2006 and Spring 2007 semesters in the Computer Assisted Research Laboratory at Arizona State University. Twenty two groups of four subjects were involved in the communication experiments, for a total of 88 subjects. The average age of subjects was 21 years. One third of the subjects were female. The earnings (including the five dollar show-up fee) varied from $5.48 to $35.86 and were on average $21.78. We will first present some summary statistics before we go into detail for a number of issues.

General statistical results

In all treatments we see a significant drop of the average earnings in round 2 (open access) compared to round 1 (individual round) (Table 2). A one way ANOVA test shows that this is significant for the high growth rate treatment, $F(1,18)=5.24$, $p=0.03$; and the mixed growth rate treatment, $F(1,10)=17.35$, $p=0.002$, although not for the low growth resources, $F(1,10)=3.63$, $p=0.09$.

After the first round of communication the average earnings increase significantly (high growth rate: $F(1,18)=9.41$, $p=0.007$; low growth rate: $F(1,10)=5.24$, $p=0.03$; and mixed growth rate: $F(1,10)=31.57$, $p=0.0002$). There is no significant improvement between round 3 and 4, and between round 4 and 5. Since the first round of communication is most instrumental to increase the group performance, our analysis of the impact of communication focuses mainly on this first communication round.

Not surprisingly, in treatment 3 where subjects unexpectedly faced a low regrowth rate and 25% initial density of tokens in round 4, the number of tokens collected dropped significantly ($F(1,10)=30.13$, $p=0.0003$). Interestingly, the drop in round 4 is to a similar level as round 3 in the low growth rate treatment ($p=0.93$). Subsequent discussion between round 4 and 5 in experiments HL1-6 does not change the

level of tokens collected. Since the subjects discussed for two rounds the high growth rate experiment before being confronted with a low growth rate, and had similar outcomes as the low growth case, this suggests that the specific coordination of token collection is less important compared to the fact that they had a group discussion. This echoes the importance of group identity as suggested by Orbell et al. (1988).

Note that the subjects developed different solutions to the problem in different treatments. In the slow-growth L1-L6 experiments, the arrangement was to wait for 2 or 3 minutes and let the resource replenish. In the fast-grow Hl1-HL6 experiments they slowed down the collection of tokens. We will discuss this in more detail below.

[Table 2 about here]

Resource dynamics

Figure 2 shows the average level of tokens on the screen for the different treatments. It shows the rapid decline of tokens in round 2 (open access without communication) compared to other rounds. It also shows the different responses in Rounds 3, 4 and 5 for the low growth versus the high growth treatments. In the low growth treatments the basic strategy of subjects is the wait to let the resource replenish, while in the high growth case the level of resources is maintained at the 50% density. If the aim is to maximize the earnings, the optimal strategy in the low growth case is not to harvest for about the first 2 minutes, except tokens who have eight neighboring cells occupied with tokens until a density of 50% is reached. In the high growth rate case the optimal strategy is to keep the token density at 50%. Since the time remaining in the experiments is known to the subjects, it is not surprising to observe a rapid decrease of the resource in the last minute of the experiment until no tokens are left at the end of the round.

[Figure 2 about here]

Sanctioning

A surprising finding is that subjects did not make use of altruistic sanctioning. The option to do this was phrased as "reducing the token amount of another by two at a cost of one to you". The maximum reduction of somebody else's level of tokens is 50 tokens. The total number of possible cases in which a subject could subtract tokens is 792^3 and subjects made use of this option only 13 times by a total of 7 subjects. In the communication rounds one of the first topics of discussion is expressing the opinion that they should not make use of the option to reduce tokens. People argued that nobody would benefit from it to "steal" tokens. This was generally agreed upon. There were also some subjects responding in the survey that they found that one of the other subjects did not follow the agreements from the communication and reduced the tokens of others. From the responses in the survey we also know that a few times the subject did not know why (s)he subtracted tokens from another subject. Maybe (s)he thought one should have to type in some numbers.

Although the option to reduce tokens was almost never used, this does not mean that observed disobedience of agreed upon arrangements was ignored. In the discussions there are evaluations of past behavior, including observations of others not following the

rules. For example, the following discussion is after round 4 in a low growth rate resource experiment.

Avatar C: “u guys started early”
Avatar D: “somebody started moving before 70secs”
Avatar C: “hey rules r rules ok?”
Avatar A: “well i took my area. i didn't pilfer anyones”
Avatar C: “70 means 70 not 78”
Avatar D: “yea dumbass”
Avatar B: “yeah”

Communication analysis
To analyze the content of the communication we coded each line of the about 3300 text messages exchanged between the subjects. We developed a code-book that captures the topics of discussion. The author and a research assistant were the coders. Both independently coded first a few sessions and compared their agreements via kappa scores (Cohen, 1960)[4]. The code book was adjusted when unclear definitions of categories were observed. When the final code-book was agreed upon the entire data set of text messages was coded (Appendix). Table 3 presents the frequency of the different categories observed and the agreement between the coders of the entire data set.

[Table 3 about here]

In the first communication round subjects tend to focus first on a general strategy beneficial to the entire group and then they may develop some more specific strategies. In the second and third communication rounds there is only discussion on specific strategies that they urged one another to follow and an evaluation of what had happened in the past rounds (Table 4). Another topic discussed at the start of the communication process is the option to reduce tokens of others (sanction), which is generally agreed not to be a good idea to pursue. The subjects argue that it is in nobodies benefit to ‘steal’ tokens.

In the low growth rate treatment there is relatively more discussion about time-based strategies, mainly how long to wait until they can start harvesting. They mention some times how long to wait before to start harvesting and agree on a specific time, say after two minutes. In the mixed growth rate treatment there is a lot of discussion on space-based strategies. Initially they divided up the space in four equal parts but those who got quadrants at the bottom of the screen started to argue that they want to change locations. This leads to a discussion on potential rotation schemes or dividing up the space vertically.

In treatments where cooperation provides relatively more benefits than other treatments (the low growth and the mixed growth treatment) the subjects devoted more discussion to explicit strategies. This is in line with findings of Pavitt et al. (2005). They discuss communication patterns in common pool resource dilemmas for different levels of regrowth of the common resource and find that subjects discuss more about the game strategy and less about the game itself if cooperation leads to a relative higher benefit.

[Table 4 about here]

Statistical analysis

What is affecting the level of tokens collected? We perform ordinary least squares regression analyses to test the significance of demographic factors on the number of tokens collected. Table 5 shows a modest gender and academic discipline effect in the individual round, round 1. Male students and economics students collect more tokens than others. However, in round 2, the open access situation without communication, the level earnings is lower when more males are in the group. This may indicate a competitive nature of the male subjects and is in line with findings from previous experiments (Gneezy et al., 2003; Janssen et al., 2008). The fraction of economics oriented subjects has a positive effect on the level of tokens collected. After communication between round 2 and 3, however, neither gender nor academic major continues to have a significant effect. Group discussion leads to the disappearance of the impact of the individual characteristics of the subjects. Consequently, it is now time to discuss what the effect of communication is and what are the elements of the discussion that explain group differences?

[Table 5 about here]

The effect of communication

There is a modest effect of the number of lines of communication on the relative improvements of the earnings in round 3 compared to round 2 (Table 6). More important is whether all subjects contribute to the discussion. We included the Gini coefficient of the number of lines contributed to the discussions by the different subjects, and find that groups who have a more even contribution of group members have a higher increase of the earnings after a round of communication. Echoing the findings of Pavitt et al., (2005) we do not find a specific topic of discussion leading to increased performance.

[Table 6 about here]

Why would the content of discussions not relate to the relative improvement of earnings after communication? Our initial interest is to study which information exchanged between subjects and future research may focus on how the information is exchanged. A possible reason is that each discussion does not necessarily leads to better coordination. For example, in one of the groups in the mixed growth treatment, one subject convinced other subjects that the tokens regrew from the center of the screen. Therefore, the subject argued that first the tokens on the outside of the screen needed to be collected and then one needed to wait for the regrowth. Because the earnings were more equal in round 3, three of the four group members experienced an improvement in their earnings and were convinced to continue this strategy although the group level earnings only improved slightly. Hence communication is not a guarantee that correct information is exchanged.

Another significant effect as a consequence of communication was the positive effect of male subjects in round 3 (Table 6). Although the subjects do not know their identity - but they may guess their gender from the text exchange - it is striking that more

male subjects in a group lead to higher earnings of the group. One reason for this is the observed gender difference in negotiations leading women less eager to take initiative to improve their situations (Babcock and Laschever, 2003). Another reason is the larger drop in tokens collected in the first group round, round 2, without communication when more male subjects are in a group. Without communication the open access situation might be perceived as a competitive environment, where male subjects are found to be more aggressive (Gneezy et al., 2003). Text communication may change the perceived problem and the gender effect disappears (Table 5).

Informal rules

What were the informal institutional arrangements derived in the first communication round and how did this affect the earnings? We classified each group whether they had mentioned the following three item: make use of the explicit mode; specific statements when to start collecting tokens, and specific spatial allocations where subjects were allowed to harvest. Although we can identify those lines in the discussion, we are not sure that every group member agrees, understood or noticed these statements. Nevertheless, this exercise leads to interesting differences among the treatments (Table 7). In the high growth rate treatment the main topic specifically mentioned was to use the explicit mode, something that cannot be observed by others. In the more challenging low growth and mixed growth treatments, arrangements were made that could be observed by the subjects themselves. In the low growth treatment, specific statements on how long to wait before starting the collection of tokens were discussed in 5 of the 6 experiments. In the mixed growth treatment there was significant discussion where to harvest and how to allocate the space, and four out of six experiments had specific allocations of the space.

[Table 7 about here]

Despite the specific statements of how, when and where to harvest tokens, such statements did not have a significant effect on the level of earnings (Table 8). We get the same findings when we only have one dummy variable indicating whether there are explicit statements or not.

We checked whether this was caused by violations of the statements, but found that almost each informal norm was violated by some subjects. Since no formal arrangements were derived, for example by voting on specifically stated rules, we are not sure whether all subjects saw these informal arrangements or norms as their guiding principle and whether these informal rules were well understood by all group members. Since the informal norms also varied in their specificity it was not possible to quantify the level of violation.

[Table 8 about here]

5. Conclusions

A real-time and spatially explicit renewable resource experiment was used to study informal efforts to develop norms to improve returns obtained from the commons. The treatments used in these experiments varied in the resource growth rates and the spatial and temporal distribution of regrowth. As observed in case studies, we find that subjects

develop institutional arrangements restraining when, where and how to appropriate resources instead of how much. The type of arrangements they developed fit with the ecological dynamics (resource regrowth). When resource growth is low, harvesting pressure is reduced over time, when resource growth is spatially diverse, more attention is given to the spatial locations where to harvest.

Communication via text messages was analyzed to explore how differences in communication patterns affect the performance of groups. We find that communication via text messages increases the performance of groups in all treatments. Content analysis of the communication results in the finding that the topic of communication does not explain the differences in increased earnings between groups after group discussions which is in line with Pavitt et al. (2005). The communication process itself, and the composition of the group does have a significant effect. Groups have a relative higher increase of the earnings after communication when they exchange more messages, especially if the contributions are evenly distributed among the group.

The kind of arrangements that were discussed in groups relate to the dynamics of the resource. In the high growth rate treatment, where subjects experience a more forgiving common resource than other treatments, the informal norms relate mainly which mode to use for collecting tokens. Using the explicit mode would slow down the rate of harvesting, but which mode one is using is not observable for other subjects. In the low growth treatment where the initial situation is a modest depleted state, the informal norms focus on the recovery of the resource. Finally, the mixed growth treatment focuses mainly on spatial allocations to distribute where one should to harvest while the resource regrowth is not uniform. We see the differences in arrangements echoed back in the observed spatial and temporal patterns of the token collection. However, group differences within the same treatment cannot be explained by differences in the specificity of the arrangements they have made.

There is some indication that results of this study confirm earlier findings of the benefit of group discussion, which seem to relate to the formation of group norms and group identity (Orbell et al., 1988; Ostrom, Gardner, and Walker, 1994). Specific arrangements how, when and where to collect tokens does not explain group differences. We see groups referring to themselves as a team. When the seconds of the chat period count down to zero we see many subjects wishing other group members good luck or typing “go team!”. As we see in round 4 of treatment 3 where the subjects were surprised with a lower growth rate and initial distribution, their earnings were statistically similar to the low growth treatment of round 3 while they had no specific discussion on what to do in a different environment. More specific research is required to confirm the group norms and group identity components in this type of experimental environments.

To conclude, our findings suggest that when subjects have the option to craft institutional arrangements on when, where and how to appropriate resource, they do so, and those arrangements fit the ecological dynamics of the resource. Moreover, the communication process is more important than the content of the communication in explaining differences in between groups in common resource dilemma experiments.

Acknowledgments
The author appreciates the support of the National Science Foundation for the grant ‘Dynamics of Rules in Commons Dilemmas.’ The author thanks Allen Lee and Deepali

Bhagvat for implementing the software and providing assistance during the experiments. Clint Bushman is acknowledged for his help in coding the chat data, and Amber Wutich for her advice on the content analysis of the communication patterns. The author benefited from feedback derived from presentations of earlier versions of this paper at Toulouse University (France), Stockholm University (Sweden), University de los Andes (Colombia), Florida State University, and Indiana University, and from feedback on earlier manuscripts by Elinor Ostrom, Robert Tobias and Abigail York.

NOTES

[1] As we would expect, there are some end of round effects due to the known time available. In earlier experiments with this environment the duration was not known as we experienced that this uncertainty led subjects to grab as many tokens as soon as possible. (Janssen et al., 2008; Janssen and Ostrom, 2008).
[2] The instructions for the experiment and the survey can be received upon request
[3] 792 is derived by multiplying 22 (groups) times 3 (rounds in which sanctioning could be used) times 4 (subjects in each group) times 3 (others in the group a subject can sanction).
[4] Kappa score quantifies the agreements between two coders beyond chance. It divides the observed probability of success and the probability of success by chance. A value of one means perfect agreement, while values above 0.6 indicate a good agreement between coders.

REFERENCES

Babcock, L., Laschever, S., 2003. Women Don't Ask, Princeton University Press

Bochet, O., Page, T., Putterman, L., 2005. Communication and punishment in voluntary contribution experiments. Journal of Economic Behavior & Organization 60(1), 11-26

Buchan, N. R., Johnson, E.J., Croson, R.T.A., 2006. Let's Get Personal: An International Examination of the Influence of Communication, Culture and Social Distance on Other Regarding Preferences. Journal of Economic Behavior and Organization 60(3): 373–98.

Clark C.W., 1990. Mathematical bioeconomics: the optimal management of renewable resources, 2nd edn. Wiley, New York.

Cohen, J., 1960. A coefficient of agreement for nominal scale. Educational and Psychological Measurement 20, 37-46

Dawes, R.M., McTavish, J., Shaklee, H., 1977. Behavior, Communication, and Assumptions about other peoples behavior in a commons dilemma situation, Journal of Personality and Social Psychology 35(1), 1-11

Dietz, T., Ostrom, E., Stern, P.C., 2003. The struggle to govern the commons, Science 302, 1907–1912

Edney, J.J., Harper, C.S., 1978. The Effects of Information in a Resource Management Problem: A Social Trap Analog. Human Ecology 6, 387–395.

Gordon, H.S. 1954. The Economic Theory of a Common Property Resource: The Fishery. Journal of Political Economy 62, 124–142.

Gneezy, U., Niederle, M., Rustichini, A., 2003. Performance in competitive environments: Gender differences. Quarterly Journal of Economics, 1049-1074.

Hardin, G., 1968. The tragedy of the commons. Science 162, 1243-1248.

Janssen, M.A., Goldstone, R.L., Menczer, F., Ostrom, E., 2008. Effect of Rule Choice in Dynamic Interactive Spatial Commons. International Journal of the Commons, 2(2): 288-311

Janssen, M.A., Ostrom, E., 2008. TURFs in the lab: Institutional Innovation in dynamic interactive spatial commons. Rationality and Society, in press

Kerr, N.L., Kaufman-Gilliland, C.M., 1994. Communication, Commitment, and Cooperation in Social Dilemmas. Journal of Personality and Social Psychology 66, 513–29.

Orbell, J.M., VandeKragt, A.J.C., Dawes, R.M., 1988. Explaining Discussion-Induced Cooperation. Journal of Personality and Social Psychology 54(5), 811-819

Ostrom, E. 2005. Understanding Institutional Diversity. Princeton University Press.

Ostrom, E. 2006. The Value-Added of Laboratory Experiments for the Study of Institutions and Common-Pool Resources. Journal of Economic Behavior and Organization 61(2), 149–63.

Ostrom, E., Gardner R., Walker, J., 1994. Rules, Games, and Common-Pool Resources. Ann Arbor: University of Michigan Press.

Ostrom, E., Nagendra, H., 2006. Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. Proceedings of the National Academy of Sciences USA 103 (51), 19224-19231

Pavitt, C., McFeeters, C., Towey E., Zingerman, V., 2005. Communication During Resource Dilemmas: 1. Effects of Different Replenishment Rates. Communication Monographs 72:3, 345-363

Sally, D. 1995. Conservation and Cooperation in Social Dilemmas. Rationality and Society 7, 58–92.

Scott, A., 1955. The fishery: The objectives of sole ownership. Journal of Political Economy 63, 116-124.

Shankar, S. Pavitt, C., 2002. Resource and Public Goods Dilemmas: A New Issue for Communication Research. The Review of Communication 2(3), 251–72.

Simon, A. Schwab, D., 2006. Say the Magic Word: Effective Communication in Social Dilemmas. Working Paper. New Haven, CT: Yale University.

Schlager, E. 1994. Fishers' Institutional Responses to Common-Pool Resource Dilemmas. In Rules, Games, and Common-Pool Resources, ed. E. Ostrom, R. Gardner, and J. Walker, pp. 247–66. Ann Arbor: University of Michigan Press.

Tietenberg, T., 2002. The Tradable Permits Approach to Protecting the Commons: What Have We Learned?. FEEM Working Paper No. 36.2002

Weitzman, M.L., 1974. Prices vs. Quantities, Review of Economic Studies 41(128), 477-491.

Wilson, J.A., Acheson, J.M., Metcalfe, M., Kleban, P., 1994. Chaos, Complexity, and Community Management of Fisheries. Marine Policy 18, 291–305.

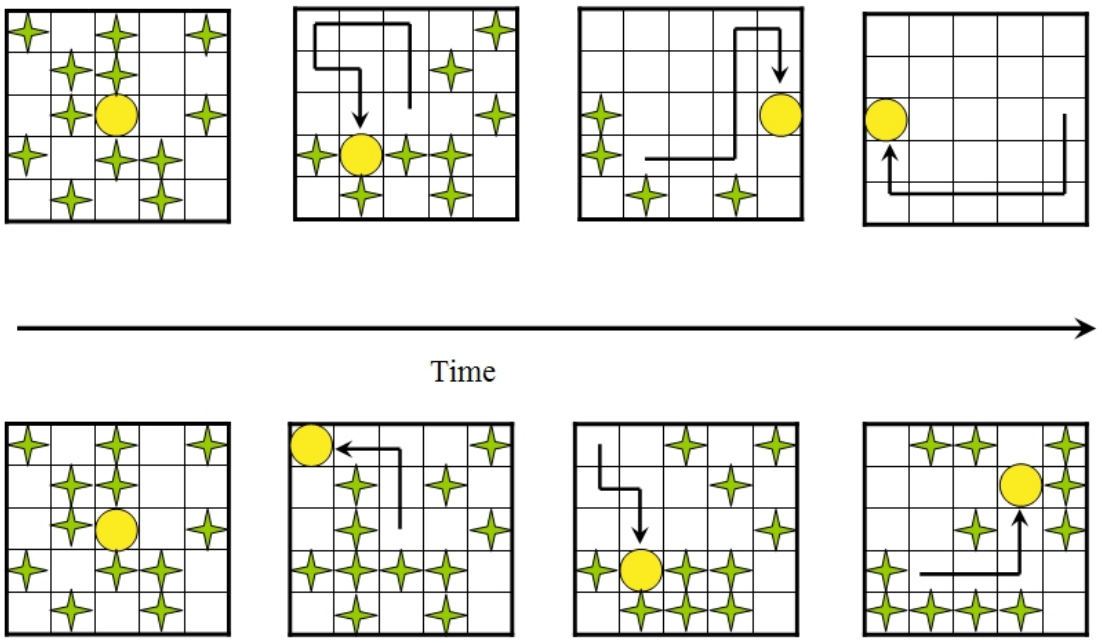

Figure 1. Four snapshots of two harvesting strategies by two different types of subjects in a hypothetical situation of a 5x5 resource, where resource units are depicted by star-shape objects. On the top row in the figure above, the subject moves their avatar (circle) eight steps per time period. There is almost no time for regeneration, and a subject following this strategy overharvests the resource by the fourth snapshot. On the bottom row, the subject moves their avatar only four steps per time step, and the resource has time to regenerate since enough tokens remain. After four time steps, the resource has not significantly declined and a subject following this strategy can continue to harvest for many more time steps.

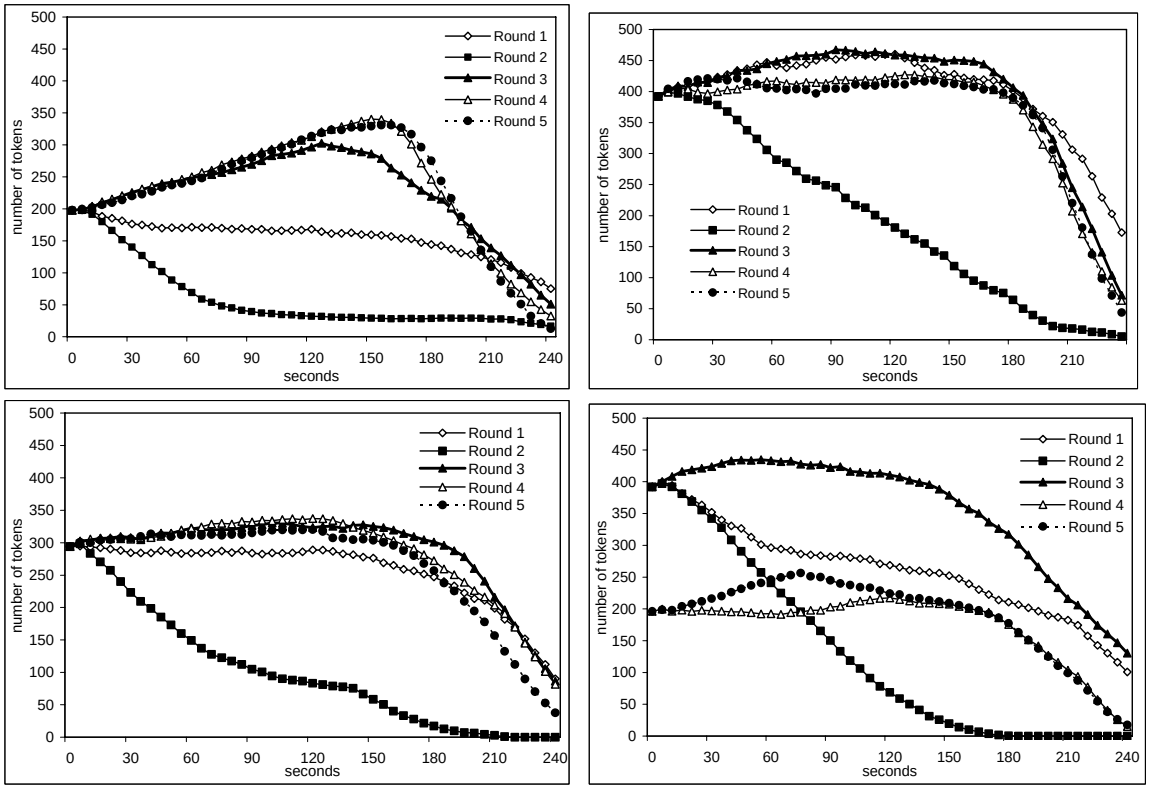

Figure 2: average number of tokens on the screen for the four different treatments and each round. Low growth (left top), high growth (right top), mixed growth (left bottom), highlow growth (right bottom)

Table 1. The four experimental treatments
Note: The label for the groups in the above figures is listed in parentheses.

Treatments (groups)	T1. High Growth (H1–H6)	T2. Low growth (L1–L4)	T3. High growth – Low growth (HL1–HL6)	T4. Mix growth (M1–M6)
Resource dynamics	*High growth* P=0.02 and an initial amount of 50% of the tokens on the screen.	*Low growth*: P=0.01 and an initial amount of 25% of the tokens on the screen.	Low growth for Rounds 1-3 and high growth for rounds 4 and 5	Mixed growth: Top half of the screen: high growth; bottom half of the screen: low growth
Practice	14x14 individual resource			
Round 1	14x14 individual resource			
Round 2	28x28 grid shared by four persons			
Round 3-5	Each round start with 5 minutes of text chat. Then 4 minutes of collecting tokens in the 28x28 grid resources shared by four persons. After the round there is a possibility to subtract tokens of others.			
Maximum earnings cooperative solution	$38	$21	$31	$30

Table 2: Average number of tokens collected at the individual and group level for each round and treatment. The standard deviation is listed between brackets.

	T1		T2		T3		T4	
	ind	group	ind	group	ind	group	ind	Group
Round 1	243.19 (45.43)	972.75 (100.76)	84.00 (25.12)	336.00 (47.94)	202.67 (55.76)	810.67 (134.30)	152.71 (32.00)	610.83 (46.40)
Round 2	208.94 (64.84)	835.75 (138.81)	68.5 (41.89)	274.00 (63.75)	170.33 (39.10)	681.33 (20.68)	113.38 (42.39)	453.5 (80.06)
Round 3	264.44 (44.07)	1057.75 (22.20)	105.75 (45.03)	423.00 (65.92)	213.33 (62.34)	853.33 (163.42)	169.33 (55.97)	677.33 (55.79)
Round 4	267.56 (42.38)	1070.25 (23.37)	117 (44.96)	468.00 (34.27)	106.88 (29.81)	427.5 (96.98)	169.67 (59.92)	678.67 (77.06)
Round 5	284.44 (32.59)	1137.75 (50.11)	120.58 (45.92)	482.33 (26.42)	104.38 (28.09)	417.5 (69.50)	174.04 (39.17)	696.17 (81.07)

Table 3: The average number of lines of text messages for the different categories distinguished. The agreement of the two coders is quantified by the kappa score. A kappa score above 0.8 suggest a very good agreement, and a kappa score between 0.6 and 0.8 a good agreement.

Topic category	Average number per round per group	Kappa score
Discussion past rounds (evaluative)	4.2	0.92
Discussion past rounds (procedural)	0.8	0.74
Sanctioning (positive)	0.3	0.74
Sanctioning (negative)	2.3	0.78
Sanctioning (general threats)	0.4	0.70
General strategy (temporal)	1.0	0.75
General strategy (spatial)	1.2	0.66
General strategy (mode)	2.2	0.63
General strategy (general)	1.4	0.84
Specific strategy (time: proposed)	0.4	0.77
Specific strategy (time: discussion)	6.9	0.82
Specific strategy (space: proposed)	0.3	0.70
Specific strategy (space: discussion)	7.6	0.80
Affirmation	0.5	0.66
Experiment (intend)	0.7	0.81
Experiment (procedures)	1.8	0.75
Experiment (software)	1.2	0.78
Experiment (uncertainty)	0.1	0.81
General discussion	9.4	0.75
Off-topic	7.4	0.85

Table 4: The percentage of text messages of classified in one of the nine main categories for each treatment and round.

	High growth			Low growth			High/low			Mixed		
	3	4	5	3	4	5	3	4	5	3	4	5
Past rounds	1	12	20	2	11	20	1	13	14	1	15	13
Sanctioning	5	4	1	16	5	3	14	3	2	13	6	0
General strategy	16	1	5	21	3	10	31	8	10	19	4	1
time	17	8	20	15	32	17	5	19	18	4	11	12
space	21	21	4	14	11	13	9	9	5	35	19	32
affirmation	2	1	0	2	2	2	0	0	1	1	10	0
experiment	9	12	5	4	9	7	4	4	12	9	9	8
general	19	19	18	14	13	12	29	24	22	18	12	21
Off-topic	10	21	28	13	14	17	7	20	16	1	23	13

Table 5: The statistical estimation on relation between individual and group number of tokens collected with demographic variables gender and major

	Number of tokens collected			
	Round 1 (individual)	Round 2 (individual)	Round 2 (group)	Round 3 (group)
Constant	202.318***	181.917***	867.138***	846.125***
Dummy – mixed growth	-63.451***	-67.701***	-277.244***	-249.226
Dummy – low growth	-138.599***	-112/64***	-459.712***	-528.686***
Dummy – econ major	24.476**	27.225*		
Dummy male	18.883**	-14.447		
(fraction) econ major			201.640**	602.62
(fraction) male			-245.115	1206.602
N	88	88	22	22
F	43.201	20.940	38.253	17.720

*** $p < 0.01$
** $p < 0.05$
* $p < 0.1$

Table 6: The statistical estimation of relation between relative increases of tokens collected in round 3 versus round 2 and the communication patterns.

	Relative increase of tokens collected in round 3 versus round 2	
	Round 3	Round 3
Constant	0.895 ***	0.965 ***
Dummy – mixed growth	0.326 ***	0.243
Dummy – low growth	0.386 ***	0.309 *
Fraction male	0.606 ***	0.577 **
Total chat entries	0.006 *	
Gini chat contributions	-2.978 ***	-3.08 **
Past rounds		0.003
Sanctioning		0.012
General strategy		0.003
Specific time		-0.005
Specific space		0.010
Affirmation		0.095
Experiment		0.013
General		-0.002
Off topic		0.013
N	22	22
F	10.345	5.260

*** $p < 0.01$
** $p < 0.05$
* $p < 0.1$

Table 7: Number of group with explicit discussions on the use of explicit mode, when to start or stop harvesting, and where to harvest.

	Mode	Time	Space
High growth rate (10)	7	5	3
Low growth rate (6)	3	5	2
Mixed growth rate (6)	1	2	4

Table 8: The statistical estimation of relation between relative increase of tokens collected in round 3 versus round 2 and the occurrence of explicit discussions on how, when and where to collect tokens

	Relative increase of tokens collected in round 3 versus round 2	
	Without rules	With rules
Constant	0.895 ***	0.931 ***
Dummy mixed growth	0.326 ***	0.289 *
Dummy low growth	0.386 ***	0.396 **
Fraction male	0.606 ***	0.627 **
Total chat entries	0.006 *	0.005
Gini chat contributions	-2.978 ***	-3.039 **
Mode		-0.003
Time		-0.062
Space		0.063
N	22	22
F	10.345	5.611

*** $p < 0.01$
** $p < 0.05$
* $p < 0.1$

Appendix Code Book

1. Discussion of past rounds
    a. Evaluative
       Statements that judge events in past rounds without assigning blame on any individual.
       "My corner sucked", "that was weak"
    b. Procedural
       Accusatory and investigatory accounts of the past rounds.
       Attempts to assign blame and credit to other players
       "you harvested in my area" "who stole from me"
2. Sanctioning
    a. Positive -arguments for formal sanctioning or threats to use the sanction set up in the rules of the game.
    b. Negative –arguments against the use of sanctioning "it does not make sense to take $ form each other"
    c. General threats without mention of use of in game formal sanction. There is some ambiguity between 2c and 5b this can be resolved by the use of a conditional "if you do this (harvest in my area) I will do that (break your legs)" threatening language that is not conditional is included in trash talk.
    d. Normative statements after rules have been made: "let's all follow the rules", "let's all be nice"
3. General strategy
    a. Temporal -time based strategies "go slow"
    b. Spatial -strategies based on division of space.
       "we should divide the board"
    c. Mode –strategies using the selective mode of harvesting and advice on the use of this mode.
    d. General -a dustbin for all other strategies. "we should not take all the tokens"

Specific strategy – To divine the difference between specific and general strategies a good rule of thumb is the use of specific times, numbers and/or maps.

4. Specific strategy (time)
    a. Proposal – "everyone needs to try to keep the tokens on the board until like 45 seconds to get more money"
    b. Discussion on specific time
5. Specific strategy (space)
    a. Proposal – "Each of us should take a corner and leave it at that"
    b. Discussion on specific spatial strategies, who get's which corner
6. Explicit call for affirmation (rule related) Call for affirmation "every body ok with that" "lets vote" or call to make sure people know their corners
7. Experiment
    a. Intent of the research "they are looking for …
    b. Practice of the experiment. "Is this the last round?" "what are these headphones for" "the system stops 5 seconds before the end", will they pay, how will they pay
    c. Discussion of how the software works: ("open patterns cause faster growth"; "they grow from the center of the board")
    d. Uncertainty on what will come: amount of initial tokens, etc.
8. General discussion
    On topic utterances that do not directly reference strategy i.e. "good luck", level of payments, discussion on features of avatars
9. Off topic "I like cheese" "lets get some drinks", about experimenters