The Role of Asymmetric Information in Sequential Resource Dilemmas with Unknown Resource Size

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Gustafsson, M. The Role of Asymmetric Information in Sequential Resource Dilemmas with Unknown Resource size. Göteborg Psychological Reports, 1999, 29, No. 1. Resource uncertainty has been found to lead to overharvesting in resource dilemmas. In previous experiments participants have had access to the same certain or uncertain information. Experiment 1 investigated the effects of asymmetric information. Four distributions of information were studied. (1) All group members knowing resource size with certainty (CC); (2) All group members facing resource uncertainty (UU); (3) First group member facing resource uncertainty, following group members knowing resource size with certainty (UC); (4) First group member knowing resource size with certainty, following group members face resource uncertainty (CU). An optimism hypothesis derived from earlier results regarding the explanation of overharvesting under resource uncertainty was tested. In line with the hypothesis the rank order of harvest sizes was uc=uu>cc>cu. Results also showed that requests were lower in the positional than in the sequential protocol. Experiment 2 compared a group condition without fate control with an individual condition the sequential protocol. Uncertainty of resource size was either low or high. An alternative egoism bias explanation predicted that the effect of resource uncertainty would be larger in the group condition than in the individual condition. However, lending further support for the optimism bias explanation, overharvesting occurred in equal magnitude in both conditions.

Keywords: Social dilemmas, resource dilemmas, sequential protocol, positional protocol, resource uncertainty.

Author Note: This research was financially supported by grant #94-0012:01 to Tommy Gärling from the Bank of Sweden Tercentenary Foundation. I thank Tommy Gärling and Anders Biel for their help during various phases of the research.
In many situations there exists a conflict between the interest of the individual and the interest of the collective. Where individuals are best off by serving their own selfish interests, the collective outcome declines if they do so. Examples include fishing grounds, logging of forests, as well as problems that most people face on a daily basis such as private car use and funding for public service television (Ostrom, 1990; Ostrom, Gardner, & Walker, 1994). Interestingly, even the use of internet resources qualifies as such a conflict in that it is a public good and users are not charged in proportion to their use. It is individually beneficial to consume as much bandwidth as possible, but if a majority do that the whole Internet's performance will degrade considerably making everyone worse off (Huberman & Lukose, 1997).

The situations described have been referred to as social dilemmas with the following two defining properties (Dawes, 1980): (1) The payoff to each individual acting in his or her own interest (called defecting) is higher than the payoff for acting in the interest of the group (called cooperating) regardless of what other group members do, but (2) all individuals receive a lower payoff if all defect than if all cooperate. Social dilemmas can be divided into two main categories. In resource dilemmas the focus is on whether or not people will take from the resource despite that it may be depleted. Public good dilemmas differ by stressing whether or not people are willing to contribute to a common resource for the future benefits of everyone notwithstanding that these benefits are possible to obtain without contributing. The two experiments reported in this article will focus on the former type of dilemma. However, as has been the case in much other social dilemma research (van Lange et al., 1992), the findings reported here are likely to generalize to public good dilemmas as well.

An important factor which has received much attention in research on social dilemmas is social or strategic uncertainty. Social uncertainty pertains to the information individuals has about other people’s cooperative or non-cooperative intentions. For instance, research has shown that if participants believe that others will cooperate, they are likely to do so themselves (Dawes, McTavish, & Shaklee 1977; van Lange & Liebrand, 1989). It may be noted that expectations about other people’s behavior often reflects one’s own intentions (Orbell & Dawes, 1991). Other research has shown that communication has a positive influence on cooperation in social dilemmas (e.g., Brewer & Kramer, 1986).

Uncertainty about features of the resource such as its size is likewise an important factor influencing cooperation (Biel & Gärling, 1995; Liebrand, Messick, & Wilke, 1992). This form of uncertainty, commonly referred to as environmental or resource uncertainty, is important to take into account because it is a preeminent feature of many real-life social dilemmas. For example, groundwater levels cannot be estimated precisely, exact knowledge is lacking about the size of fish populations, and it is not known with certainty how much tax citizens must pay to
sustain the welfare of a society. If the aim is to increase the ecological validity of social dilemma research, it is therefore important to investigate the role of resource uncertainty. An additional point is that while social uncertainty sometimes is resolved in that participants adhere to an equal-share principle (e.g., Messick & Schell, 1992), resolving resource uncertainty appears much more difficult since what constitutes a fair share of a resource of uncertain size is unclear.

Budescu, Suleman, and Rapoport were first to demonstrate the detrimental effects of resource uncertainty on cooperation in resource dilemmas (e.g., Budescu, Rapoport, & Suleiman, 1990; Rapoport, Budescu, Suleiman, & Weg, 1992). In their experiments resource uncertainty was varied as the size of an interval defining the upper and lower limit on resource size. The main finding was that as uncertainty (the interval) was increased, the requests by the participants increased. Thus, resource uncertainty resulted in overharvesting and depletion of the resource. Studies replicating the overharvesting effect due to resource uncertainty include Gustafsson et al. (1997a, 1997b, 1998), Hine and Gifford (1996), Roch and Samuelson (1997), and Wit and Wilke (1998).

An important question to ask is what causes people to overharvest when they experience increasing resource uncertainty. Three main explanations have been offered. One of the explanations, suggested by Rapoport et al. (1992), is that overharvesting occurs because participants perceive a positive relationship between measures of central tendency (e.g., the mean) and variability. Under increasing resource uncertainty, this would thus lead participants to overestimate the size of the resource and therefore to request too much.

A second explanation offered by Rapoport et al. (1992) rests on the assumption that participants weigh the upper and lower bound of the resource when estimating its size. It is further assumed that they overweight the upper bound, resulting in an upward shift of their estimates, and request too much. In contrast to the first explanation, motivational reasons are highlighted such as, for instance, optimism or risk taking. This explanation is in line with demonstrations of a so-called outcome-desirability bias (e.g. Buckley & Sniezek, 1992; Budescu & Bruderman, 1995; Fischer & Budescu, 1995; Olsen, 1997; Weinstein, 1980; Zakay, 1983), that is, that subjects judge desirable outcomes to be more likely than warranted.

In a social dilemma individual outcomes also depend on others’ decisions. The third explanation emphasizes the role of this interdependence for the overharvesting effect to occur. The constrained-egoism hypothesis suggested by Wilke (1991) states that although individuals are greedy and therefore try to maximize their own outcomes, their greed is constrained by the motives to maintain the resource efficiently and to achieve fairness among the group members. Based on this hypothesis, De Vries and Wilke (1992) assumed that overharvesting due to resource uncertainty occurs because adhering to an equal-share fairness norm feels less compelling when the size of the resource is uncertain.
In an effort to discriminate between the different explanations, Gustafsson et al. (1997a, 1997b, 1998) conducted a series of experiments in which different groups either made perceptual estimates of resource size when it was uncertain, requested from an uncertain resource when the outcome only depended on the resource size, or requested from an uncertain resource when the outcome depended both on the resource size and the requests by others.

Gustafsson et al. (1998) investigated whether participants request more or less from an uncertain resource when they were informed about other group members’ pessimistically biased estimates of its size. It was predicted that egoistic participants would exploit this information and request more for themselves. However, they requested in fact less when being informed about others’ estimates. Since the same results were obtained when the outcome only depended on one own’s requests, it was concluded that information about others’ pessimistically biased estimates reduce the outcome-desirability bias.

In all studies referred to participants have had equal (incomplete) knowledge of resource size. A more typical situation is that the degree of resource uncertainty differs between members of groups with access to a common resource. Such situations characterized by asymmetric information pose new questions about the role of resource uncertainty. This situation is in some respects similar to that studied in Gustafsson et al. (1998) with the difference that in this case the participant does not know the others’ estimates but has to infer this from uncertain information. Having access to the information others base their estimates on might have a different effect than when one knows the estimates made by others. Consider a scenario in line with the former case where a participant has certain information knowing also that others have to rely on uncertain information. Will this participant assume that others are also susceptible to an outcome desirability bias and if so will this influence his or her behavior? In Experiment 1 we address this question and offer a hypothesis about individual harvesting behavior when group members do not have the same knowledge about resource size. We test this hypothesis under different combinations of symmetrically versus asymmetrically distributed information in sequential resource dilemmas.

In Experiment 2 we once again address the different explanations of overharvesting due to resource uncertainty. By removing fate control, that is, the possibility for individuals in a resource dilemma to punish others players by requesting more than is left, we attempt to distinguish between the egoism and optimism explanations of overharvesting due to resource uncertainty.
Experiment 1

In Experiment 1 the aim was to test how asymmetrical information about resource size affects requests from a resource in a sequential and positional protocol. In the sequential protocol requests is made in a pre-specified order. Participants are informed about their positions in the order and how much others have requested prior to the resource before them. The positional protocol is identical to the sequential protocol except that participants are not informed about how much others have requested prior to them.

Budescu, Rapoport, and Suleiman (1992) and Budescu, Au, and Chen (1995) compared the sequential and positional protocols in resource dilemmas with resource sizes which were unknown. They found a negative relationship between position and amount requested, that is, participants in early positions requested more than those in later positions. They termed this effect the first-mover advantage (FMA). In one of the studies (Budescu et al., 1995) the results of the sequential and the positional protocol were similar. Thus, in the positional protocol participants appeared to make inferences about how much others had taken from the resource previous prior to them.

In Experiment 1 participants were told that they were part of three-person groups. Each group member could request and obtain as much as they wanted from a resource (sum of money). However, if the total requests exceeded the resource, none would receive anything. Participants were always in the first position (i.e., the group member who could request first from the resource). Four conditions constituting different combinations of information were used: (1) Participants were informed about resource size and that the other two group members also know resource size with certainty (CC); (2) Participants were provided uncertain information about resource size and were informed that the other two group members were also provided uncertain information about resource size (UU); (3) Participants were informed about resource size and that the other two group members were provided uncertain information about resource size (CU); (4) Participants were provided uncertain information about resource size and were informed that the other two group members knew resource size with certainty (UC).

Consistent with the outcome-desirability bias explanation (Gustafsson et al., 1997a, 1997b, 1998), it is first assumed that participants overestimate the size of an uncertain resource which represents value to them. Second, it is assumed that participants will request an amount which is based on their estimates of resource size. A third assumption is that participants believe that other group members overestimate an uncertain resource size and request an amount based on that estimate exactly as they themselves do. Fourth, based on the FMA findings (Budescu et al., 1995), it is assumed that participants believe that other group members accept that they request more than an equal share of the
(estimated) resource size (FMA). From these assumptions it is predicted that requests in the different conditions will confirm to the rank order $UC=UU>CC>CU$. In the CC condition participants are expected to show a FMA and request more than an equal-share. In condition CU participants will however believe that the others will overestimate the resource size and therefore request less than in condition CC. In condition UU participants will request more than in condition CC since they overestimate resource size. The same will hold in condition UC since participants believe that their estimates are accurate (not systematically biased) and therefore do not deviate from the other group members’ estimates.

In the study of Budescu et al (1995), no differences were found between the sequential and positional protocol. As noted above, Budescu et al. hypothesized that this was due to participants ability to make inferences from temporal (position in request order) to cumulative information (how much that have been taken). However, one might speculate whether a participant who requests first and who knows that the following group members will not be informed about previous requests might become more cautious. The inability to clearly signal one’s intentions could perhaps make participants less inclined to use their FMA and instead choose to play it safe. In Experiment 1, both protocols were included in order to test this question.

Type of protocol was varied between participants. Whether participants were given certain or uncertain information about resource size was also varied between participants (group CU+CC vs. group UU+UC), whereas whether participants were informed that the other group members were given certain or uncertain information was varied within subjects.

Method

Participants

Thirty-two male and 32 female undergraduates at Göteborg University volunteered as participants in return for the equivalent of USD 7. An equal number was randomly assigned to four groups.

Procedure

Participants served individually or three at a time. Upon arrival to the laboratory, they were seated separately in private booths. In each booth a PC controlled presentation of the material.

All participants were told that they were part of a group consisting of three students at the university who had never met before and who all
could request from an available resource consisting of a sum of money. They were furthermore told that the group members would request from the resource one after another. In the sequential protocol participants knew that those group members who requested later would be informed about the size of previous requests. In the positional protocol participants were told that other group members would not know about the size of previous requests. All participants were also told that it had been determined by a random procedure had that he or she was always the first to request from the resource. Finally, the participants were informed that they would receive a bonus, which was proportional to what they had requested on a randomly determined trial if the total amount requested did not exceed the resource size on this trial. The maximum bonus promised to participants was the equivalent of USD$28.

In the UU+UC group participants were told that they would have to infer the current size of the resource from 12 numbers symbolizing its size on prior occasions. The sequences of numbers were randomly sampled from a uniform probability distribution. Sixteen different sequences of numbers were sampled and transformed so that the average size on half of the trials were 6,000 (USD$470) and on the other half 9,000 Swedish Crowns (USD$700) and the SD 1068.9. The participant was also told that he or she would also see the information given to the other group members. In half of the trials (UU) participants were told that the other group members had access to the same information about resource size as themselves. In the other half participants were informed that the other group members knew the size of the resource with certainty.

In the CC+CU group participants were on all trials informed about the exact size of the resource. On half of the trials (CC) they were informed that the other group members also knew the size of the resource with certainty. In the other half of the trials (CU) they were first presented with the sequence of numbers and were informed that the other group members were only given this uncertain information about the resource size.

A session lasted for about 30 minutes whereafter participants were debriefed and paid a bonus equivalent of US$7.

Results and Discussion

Mean requests are given in Table 1. As may be seen, the amount requested differs between the different conditions. Highest requests were as expected observed in the UU and UC conditions. Furthermore, also as expected, requests were higher in condition CC than in condition CU. Although this pattern was the same in both protocols, overall higher requests were made in the sequential protocol. These observations were confirmed by a 2 (protocol: sequential vs. positional) by 2 (information presented to first mover: uncertain vs. certain) by 2 (information presented to other group members: uncertain vs. certain) mixed analysis
of variance (ANOVA) with repeated measures on the last factor. The ANOVA yielded significant effects of protocol, $F(1, 60) = 14.50, p<.001, MS_e= 487,007.1$, of information presented to first mover, $F(1, 60) = 14.74, p<.001, MS_e= 109,837.2$, of information presented to other group members, $F(1, 60) = 16.13, p<.001, MS_e= 487,007.1$, and of the interaction between information presented to first mover and information presented to other group members, $F(1, 60) = 10.01, p<.01, MS_e= 109,837.2$. Fisher-Heyter tests at $p< .05$ confirmed the prediction $UC=UU>CC>CU$ in that UC and UU did not differ reliably while both differed reliably from CC which in turn differed reliably from CU.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>CC</th>
<th>CU</th>
<th>UU</th>
<th>UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positional protocol</td>
<td>2372</td>
<td>1992</td>
<td>2897</td>
<td>2731</td>
</tr>
<tr>
<td>Sequential protocol</td>
<td>3059</td>
<td>2498</td>
<td>3248</td>
<td>3307</td>
</tr>
</tbody>
</table>

An unexpected finding was that requests were higher in the sequential than in the positional protocol. This result was different from those of Budescu et al. (1995). Budescu et al. suggested that participants were able to make inferences from temporal information in order to estimate how much that had been taken from the resource. In the present study one may speculate that participants who knew that the other group members would not know about previous requests became more cautious. Perhaps they realized that they could not signal to the others their intentions and thus instead of being risk seeking decided to play it safe and not use their first-mover advantage.

All in all, the results were thus in line with the predictions based on the outcome-desirability bias explanation. Thus, the effect of resource uncertainty (Gustafsson et al. 1997a; Rapoport et al. 1992) was observed in that participants requested more when resource size was uncertain than when it was certain. In addition, participants anticipated what others will do when faced with resource uncertainty in that they lowered their requests when knowing the resource size with certainty and that others had uncertain information.
Experiment 2

Although the results of Experiment 1 were consistent with the results of a series of studies (Gustafsson et al. 1997a, b, 1998) which all show that the overharvesting effect due to uncertainty is accounted for by an individual outcome-desirability bias, it should be noted that in the type of resource dilemma investigated in these experiments participants would receive nothing if the total request exceeds the resource size. In a sequential resource dilemma, requesting too much may therefore lead to that other group members punish a participant by requesting so much that he or she receives nothing. Participants may thus be hesitant to act out egoistic motives of fear of being punished. A close parallel is the ultimatum game (Güth, Schmittberger, & Schwarze, 1982) where one person (the allocator) proposes a split of a sum of money between himself and another person (the recipient). After the allocator has proposed the split, the recipient can either accept or not. In the latter case neither the allocator nor the recipient receives anything. The game theoretic prediction is that the allocator should propose a split where the offer is as close to zero, which the recipient should accept. However, most empirical results are not in accordance with the game theoretic prediction. Allocators frequently propose splits that are close to even and when allocators propose splits in accordance with the game theoretic prediction, these are often rejected by the recipient (e.g. Kahneman, Knetsch, & Thaler, 1986). Fairness might be a motivating factor for proposing even splits in the ultimatum game. It may alternatively be the case, as discussed above, that participants fear that the recipient will not accept an unfair division.

In Experiment 2 fate control was removed in a group-request group so that participants did not run the risk of being punished by others, that is, the possibility that participants punish other players by requesting more than is left. This made it possible to once again test the assumption that egoism is a motivating factor for excessive harvesting under high resource uncertainty (De Vries & Wilke, 1992). The logic behind this design is outlined in Table 2 comparing the effect of high resource uncertainty in the group-request group to an individual-request group an egoism bias explanation would predict more overharvesting in the group-request than in the individual-request group.
Table 2

Predictions of Overharvesting due to Resource Uncertainty

<table>
<thead>
<tr>
<th>Explanation</th>
<th>Individual request</th>
<th>Group request</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outcome-desirability bias</td>
<td>overharvesting</td>
<td>overharvesting</td>
</tr>
<tr>
<td>Egoism bias</td>
<td>no overharvesting</td>
<td>overharvesting</td>
</tr>
</tbody>
</table>

Method

Participants

Another 16 male and 16 female undergraduate students at Göteborg University volunteered to participate in return of the equivalent of USD 7. An equal number was randomly assigned to two groups.

Procedure

Participants served individually or in groups of three. The procedure was the same as in the preceding experiment with the following changes.

Participants assigned to an individual-request group were informed that they could request and obtain any amount from an available resource consisting of a sum of money which varied in size from one to another occasion. If they requested more than was currently available, they would receive nothing but would otherwise receive what they requested.

In a group-request group participants were told that they were part of a group consisting of three students at the university who had never met before and who all could request from an available resource consisting of a sum of money. They were furthermore told that the group members would request from the resource one after another. As fate control was removed, instructions also specified that the second group member could only request as much as what was left after the first group member had requested, and the third what was left after the second group member had requested. The sequential protocol was used and therefore participants knew that those group members who requested later would be informed about previous requests. All participants were also told that by a random procedure it had been determined that he or she was the first to request from the resource. Because of the absence of fate control in the group-
request group, the payoff structure was made identical to the one of the individual request group

In both groups when participants had read and understood the instructions, a sequence of 16 self-paced trials was started. On each trial, a sequence of 12 numbers representing prior resource sizes were presented one at a time on the screen at a self-paced rate. The sequences of numbers were randomly sampled from a uniform probability distribution, either with a small or a large variance representing low and high resource uncertainty respectively. Sixteen different sequences of numbers were sampled and transformed so that the average size on half of the trials were 6,000 and on the other half 9,000 Swedish Crowns and the SDs 625.2 or 1068.9. Four random orders of different trials were used equally often.

Finally, the participants were informed that they would receive a bonus which was proportional to what they had requested on a randomly determined trial if the total amount requested by them did nor exceed the resource size on this trial. The maximum bonus promised to participants was the equivalent of US$28

A session lasted for about 30 minutes. After having completed the experiment, participants were debriefed and all paid a bonus equivalent of US$7.

Results and Discussion

Mean requests in the individual and group request groups are displayed in Table 3. As can be seen, a clear effect of resource uncertainty is evident by higher requests under high as opposed to low uncertainty. Furthermore, participants in the group-request group requested more than an equal share (SEK 2,500) suggesting a FMA. However, speaking against an egoism explanation, they did not increase their requests more under high uncertainty than participants in the individual-request group did. These observations was confirmed by a 2 (group: individual vs. group request) by 2 (resource uncertainty: low vs. high) mixed ANOVA with repeated measures on the last factor yielding a main effect of resource uncertainty, $F(1, 30) = 68.39, p<.001, MS_e = 50033.4$. 
Table 3  
*Mean Requests Related to Low and High Uncertainty in Individual-request and Group-request Groups (Experiment 2)*

<table>
<thead>
<tr>
<th>Resource uncertainty</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group-request</td>
<td>3155</td>
<td>3327</td>
</tr>
<tr>
<td>Individual-request</td>
<td>2458</td>
<td>2591</td>
</tr>
</tbody>
</table>

*The means are divided by 3.*

By removing fate control in a group-request group, Experiment 2 provided a critical test of whether overharvesting due to resource uncertainty is motivated by egoism. The results speak very clearly against this hypothesis. Participants did not request more of the resource than did participants in an individual-request group even though the other group members were unable to punish them. However, exactly as in the individual-request group, an outcome-desirability bias led participants to request more when resource size was uncertain.

Experiment 2 replicated the FMA observed in Experiment 1 in that participants' requests in the group-request group far exceeded an equal share of the resource. This may be interpreted as an egoistically motivated effect but resource uncertainty did not increase it.

**General Discussion**

The two reported experiments shed light on the role of resource uncertainty under conditions of information asymmetry as well as providing more evidence of its underpinnings. In Experiment 1 we demonstrated that participants reacted differently to uncertain than to certain information and also that they seemed to be able to make inferences about what others would do with this information. The results were consistent with the proposed outcome-desirability bias hypothesis in that participants requested more when resource size was uncertain than when it was certain. Participants also anticipated what others will do when faced with resource uncertainty in that they lowered their requests when knowing the resource size with certainty and that others had uncertain information. These results show that participants inferred that the other group members would be susceptible to an outcome-desirability bias.

Although we feel that our previous results (Gustafsson et al., 1997,a, b; 1998) as well as the results of Experiment 1 have supported the outcome-desirability bias explanation, Experiment 2 with its exclusion of
fate control produced a better test of this assumption. By removing the conflict between egoistic motives and efficient resource use, we were now able to disentangle possible effects emanating from an egoism bias from that of the optimism bias. However, the results of Experiment 2 did not provide evidence refuting the optimism bias hypothesis. The only effect possibly interpreted as egoistically motivated was that participants used their first mover advantage (Budescu et al., 1995), an effect that was not amplified by resource uncertainty. This new evidence, taken together with the results of our previous studies, presents an even stronger case for the outcome desirability bias as the most likely explanation of overharvesting due to resource uncertainty.

An unexpected result was that participants in the positional protocol were more cautious than in the sequential protocol. At present we cannot offer a complete explanation of this result. In any case, under the positional protocol it did not seem that our participants, as opposed to participants in the Budescu et al. (1995) study, were able to use the temporal information in order to make inferences about what following participants would request. We speculate that participants might have felt unable to signal their intentions and therefore decided to play it safe. Participants might thus have downplayed egoistic motives out of fear of being punished by following players.

An interesting question that has been previously discussed is whether overharvesting due to resource uncertainty is a conscious or unconscious (Gärling, Gustafsson, & Biel, In press). The results of Experiment 1 might be interpreted in the way that participants actually were aware of the fact that they request more under high uncertainty in that they seemed to anticipate that others would request more when these others had uncertain information. Of course, we are making this inference from observations of what participants did when they knew that others had uncertain information, which constitutes a somewhat indirect measure of whether their own decisions when faced with uncertain information are conscious or not. Although these results are to some extent suggestive, further research is clearly needed to clarify this issue.

Our findings have some interesting implications. It might for example, be possible for those who have certain information to adjust their requests in order to avoid depletion of a resource when information is conveyed implying that others are relying on uncertain information. If possible the best way of action in this situation would be to inform these others about the exact size of the resource. However, it may not be possible to convey this information the information is may not be trusted.
References


