DEPARTMENT OF ECONOMICS

WORKING PAPER SERIES

2001-05

McMASTER UNIVERSITY

Department of Economics
Kenneth Taylor Hall 426
1280 Main Street West
Hamilton, Ontario, Canada
L8S 4M4

<http://socserv.socsci.mcmaster.ca/~econ/>

This paper is a working draft not to be quoted without the permission of the authors.

Volunteering a Public Service: An Experimental Investigation

Marc Bilodeau

Indiana University - Purdue University at Indianapolis

Jason Childs

McMaster University

Stuart Mestelman

McMaster University

20 August 2001

Abstract

In many situations, it is advantageous for heterogeneous groups to be coordinated by a single individual. This individual will bear private costs for acting as the leader while enabling each member of the group to achieve maximum potential gains. This environment is modeled as a war of attrition in which everyone is tempted to wait for someone else to volunteer. The hypothesis that individuals use backward induction to determine their actions identifies the volunteer as the individual who has the largest benefit-cost ratio of volunteering. Two alternative hypotheses are introduced which focus on the beginning of the game. The *focal point* hypothesis, like the backward induction hypothesis, implies that the volunteer will act immediately. The *play-against-nature* hypothesis has predictions identical to the focal point hypothesis; however, it does not imply immediate action. Laboratory results provide more support for the play-against-nature hypothesis than the others.

1. Introduction

Questions regarding voluntary contributions to a public good and the free-riding problem have so far generated a sizable amount of theoretical modeling and experimental investigation.¹ The simplest way to model the free-riding problem in public good provision is through a Prisoners' Dilemma type of game.² A more general approach models the public good provision decision as a game akin to a Cournot duopoly game. In this game, each player selects a contribution level toward the public good.³ In these models, the public good being provided is an incremental public good in the sense that the quantity of the public good being consumed depends on the sum of individual contributions.

One question which has received comparatively little attention in the economic literature is the problem of providing a public good that can be produced through "weakest-link" or "best-shot" technologies.⁴ The provision of a public service can often be considered a best-shot decision. Examples of such situations include driving for a car pool, organizing a fund-raising event, getting up at night to quiet a crying baby, or slaying the dragon that threatens the village.⁵ In this type of situation, only one individual needs to bear the cost of providing a non-incremental service that will benefit

¹ See Ledyard (1995) for a comprehensive, but now dated, survey.

² An early example of this can be found in Buchanan (1967).

³ The classic reference for this approach is Bergstrom, Blume and Varian (1986).

⁴ See Hirshleifer (1983).

⁵ The dragon-slaying example is from Bliss and Nalebuff (1984). As further examples, Bilodeau and Slivinski (1996) also mention cleaning shared toilets and chairing an academic department.

everyone. Such a situation is best modeled as a game of Chicken instead of a Prisoners' Dilemma.⁶

One characteristic of a game of Chicken is that it generally has multiple equilibria. For example, a two-player game of Chicken has two pure strategy equilibria in which either player gives in and the other one does not (it also has a mixed strategy equilibrium in which each player gives in with certain probabilities). To solve this type of game, therefore, one must select an equilibrium which appears more plausible than others. One widely used equilibrium selection criterion, applicable in multistage and dynamic games, is the concept of subgame perfection.⁷ In dynamic games, some equilibria are deemed implausible because they rest on non-credible threats. Subgame perfection rules them out by insisting that the equilibrium strategy be optimal for each player not only along the equilibrium path, but at every point in the game – even those that will never be reached.

The dynamic version of a game of Chicken is known as a War of Attrition game.⁸ In this game, each player becomes progressively more injured as time wears on until one gives in and stops the game. The player giving in first gets a lower payoff than he would have received if someone else had given in. In a public service provision context, each player may choose to wait before volunteering to provide the service, and avoid the cost of providing it if someone else volunteers in the meantime. However, no one

⁶ The game of Chicken is described in several introductory game theory textbooks, for example in Rasmusen (1989, p. 73). The game of Chicken is also sometimes referred to as the Hawk-Dove game, particularly in evolutionary biology.

⁷ The concept of subgame perfection is explained in several game theory textbooks, for example in Fudenberg and Tirole (1991, p. 92).

⁸ War of Attrition games can be divided into two variants according to whether they are stationary or not. See Fudenberg and Tirole (1991, pp. 119-126) for a description and discussion of both cases. The game we investigate experimentally in this paper is non-stationary.

can enjoy the benefits of the service until someone provides it. Like games of Chicken, War of Attrition games also generally have multiple equilibria in pure and mixed strategies.⁹ However when the game is not stationary, subgame perfection can be applied to select a unique pure strategy equilibrium. Given the wide acceptance of subgame perfection as an equilibrium selection criterion, it is tempting to single out the unique subgame perfect equilibrium as the solution of the game. This is the approach taken by Bilodeau and Slivinski (1996). The present paper is an attempt to verify experimentally whether this conclusion is warranted.

Given the fallibility of backward induction in laboratory environments, two alternate behavioral hypotheses are tested.¹⁰ Both rest on the hypothesis that instead of looking backward from the end of the game to unravel the equilibria that do not meet the subgame perfection criterion, subjects will focus on the beginning of the game .

The first and simplest hypothesis is that subjects will look at the payoffs of the different players and will try to detect a focal point. Subjects may realize that it is wasteful for more than one of them to volunteer. It is also wasteful to let the payoffs decline before someone does. Therefore, they may seek to coordinate their strategies around a focal point to avoid these two types of losses. They may also anticipate that they will play different roles in different rounds of the game and that if everyone always plays his part, everyone's payoffs will be maximized. This views the subjects as essentially trying to cooperate to coordinate their strategies and maximize total gains.

⁹ See Hendricks, Weiss and Wilson (1988) for a complete characterization of the equilibria of the War of Attrition game in continuous time.

¹⁰ See Roth (1995) and Davis and Holt (1993)

The second hypothesis is that the subjects fail to completely account for the strategic nature of the game they are involved in and approach it essentially as if they were playing against nature. Two distinct reasons justify this hypothesis: First, even though we provide subjects with complete information about everyone's payoffs, we may have been unable to truly elicit a game of complete information between them. Subjects may harbor enough doubts about each other's rationality to be unable to predict each other's strategies accurately. Second, since the players do not have dominant strategies in a War of Attrition game, figuring out an equilibrium strategy is a rather daunting task. It requires that each player solve the game not only from his point of view but also from the point of view of all the other players. It could be that this is too complex a task. This is especially so in a laboratory environment in which the subjects only have a few seconds to decide on a strategy. In either case, if subjects are unable to quickly and accurately forecast each other's strategies, they will simply choose a waiting time that equates the expected cost and benefit of waiting an additional second. The benefit of waiting is that it increases the probability that someone else will stop the game first and therefore that the player will avoid the cost of volunteering. The cost of waiting is the loss of payoff if no one else has stopped the game by then.

The data from our experiments fit these two alternative hypotheses better than the hypothesis that they will play a subgame-perfect strategy combination.

2. Modeling the Provision of a Public Service

In this section, we present a simplified version of the public service provision game modeled in

Bilodeau and Slivinski (1996).¹¹ Consider a group of n individuals who would all stand to benefit for some time if a public service was provided by one of them. Each must decide whether and when to volunteer to provide the public service. Each individual i is characterized by three parameters. Let u_i be the payoff he receives each period once the public service is provided. Let C_i be the cost of providing this service. This cost must be borne entirely by the volunteer and no side payments are possible. And let T_i be the (finite) time horizon during which he could benefit from the public service.

Suppose for simplicity that time is measured in discrete increments and that each period, until the public service is provided, all individuals receive a payoff of 0. Therefore, if the individual volunteers at time $t \in [0, T_i]$, his payoff is $(T_i - t)u_i - C_i$, while if someone else volunteers at time t his payoff is $(T_i - t)u_i$. Assume that for all individuals $u_i > 0$, $C_i > 0$, and $T_i u_i > C_i$; also assume that all these parameters are common knowledge and that every player's rationality is common knowledge. Then, the game is a well-defined War of Attrition in discrete time with complete information.¹²

This game has Nash equilibria in which any one of the players volunteer immediately and all the others wait. Intuitively, if player i volunteers immediately then everyone else is better off waiting; and, if everyone else is waiting, then player i is better off volunteering immediately. The same holds for all players.

¹¹ Bilodeau and Slivinski (1996) model the public service provision decision as a War of Attrition in continuous time with discounting. They also allow individuals to differ in the payoff they receive each period the public service is not provided. They also allow the cost of providing the public service to include both a one time fixed cost and an ongoing cost.

¹² For completeness, we also need to define the payoffs if two or more individuals volunteered simultaneously. We could do this in many ways; but the simplest formulation, assuming that both would incur the cost C_i , will do.

However, only one of these equilibria is selected by the backward induction method. To show this, we note first that it is a dominant strategy for i not to volunteer at any t such that $(T_i - t)u_i - C_i \neq 0$. Since the payoffs are decreasing in t , we can calculate from this the critical value $t_i^* = T_i - (C_i / u_i)$ beyond which the individual never volunteers. Without loss of generality, order the individuals such that $t_1^* > t_2^* \geq t_3^* \geq \dots \geq t_n^*$.¹³ Now, consider individual 1. If the game reaches t_2^* or any time between t_2^* and t_1^* , it is optimal for him to volunteer since by then no one else would and his payoff from volunteering would still exceed 0 and would continue to decrease if he waited any longer. Expecting individual 1 to volunteer at t_2^* , all other individuals would then hold off on volunteering for some interval immediately preceding t_2^* . Therefore, individual 1 could do no better than to volunteer at any time in this interval. The others would then hold off volunteering in another preceding interval and so on until individual 1 volunteers at $t = 0$ and all others wait. If $t_1^* > t_2^*$, the game has a unique subgame-perfect equilibrium in which individual 1 volunteers immediately and all others abstain.¹⁴

The critical value t_i^* depends on the three parameters that characterize each individual and is increasing in T_i and u_i , and decreasing in C_i . So *ceteris paribus*, the individual with the longest time horizon, the lowest cost of providing the service, or the one who would gain the most when the service is provided (or equivalently who would lose the most when the service is not provided), will be the one for whom the critical value t_i^* is the largest. If the game unfolds according to the subgame perfect

¹³ If $t_1^* = t_2^*$ the subgame perfect equilibrium would not be unique.

¹⁴ To be precise, we should say that individual 1 volunteers at every t between 0 and t_1^* and abstains after that, while all others abstain at every t . A strategy in this game is a complete statement of what a player would do at every point in the game, including points off the equilibrium path.

equilibrium prediction, this individual will volunteer immediately.

3. Laboratory Representation of The Game

In a War of Attrition game, payoffs decline with time for all players. In order to create this type of environment in the laboratory, subjects were given an initial endowment and then told that this would be their payoff if someone took action immediately to stop the game. Subjects were also told that their payoff would decline for every second that the game continued until one of them stopped it. The cost of taking action, if the subject chose to volunteer, would then be deducted from his payoff. Stopping the game, then, is a public service that the volunteer provides to everyone at a private cost to himself.

There were 14 sessions of this experiment run over the computer network at the McMaster University Experimental Economics Laboratory in Hamilton, Ontario, Canada. Each session of this experiment consisted of twelve rounds, and each round lasted 105 seconds. Twelve subjects participated in each session of the experiment and a total of 168 subjects were recruited from the student population of McMaster University.

In each round, subjects were randomly assigned to a group with two other subjects. These groupings changed every round and no two subjects were in the same group in consecutive rounds. At no time were subjects made aware of who were the other members of their group. The three parameters which characterize the subjects, C_i , u_i , and T_i , were varied across subjects systematically.

Table 1 presents the five treatments in the experimental design. In each of the first three treatments, subjects had two of three parameters in common. In Treatment 1, all three subjects in a group had the same time horizon and the same benefits from the provision of the public service;

however, they differed in the cost of providing the public service. In Treatment 2, subjects differed only in the benefit they received per unit of time the service was provided; and, subjects differed only in the length of time they could receive the benefit of the public service in Treatment 3. In Treatment 4, subjects differed in both time horizon and benefit per unit of time the service was provided. Finally, in Treatment 5, subjects differed by time horizon and the cost of volunteering to provide the service.

When a round begins, each subject's screen displays three graphs: one that represents his payoff and two representing the payoffs of the two other subjects with whom he was matched. Figure 1 presents a screen for a round in Treatment 3. In this example, all three subjects have a cost of volunteering of \$5 and a benefit per second that the service was provided of \$0.20. One subject has a time horizon of 100 seconds, another has a time horizon of 85 seconds, and the third has a time horizon of 70 seconds.

On each of the three graphs is a light blue line representing the payoff that subject will receive if the service is provided by someone else. As time elapses, this line is filled in progressively with darker blue until someone stops the game. Below the blue line, each graph also contains a white line representing the subject's payoff if he volunteers. This line is filled in with red as the round progresses until someone volunteers to stop it. This gives the subjects a visual indication of their current payoffs at any point in the game. Located above the graphs is a button labeled "Action" on which subjects can click using their computer mouse if they wish to volunteer.

In each round, after the subjects' computers displayed the screens, subjects were given 15 seconds to make a decision or formulate a strategy before their payoffs started to decline. This period was intended to give subjects an opportunity to familiarize themselves with their own payoffs and the

payoffs of the two other subjects with whom they were matched before having to make a decision.

During these 15 seconds it was possible for one or more individuals to volunteer. Anyone volunteering during these 15 seconds of “frozen time” was considered to have volunteered at time 0. Subjects were not informed that someone had volunteered until the end of that 15 second period. Further, subjects were never told whether there were multiple volunteers.

After this initial 15-second period, the payoffs started to decline until one of the subjects stopped the game by pushing the button labeled “Action” on his screen. In this experiment, we always referred to volunteering as “taking action” in order to prevent framing effects. Subjects were never informed of which subject had volunteered; they were only told that someone had. If 90 seconds pass with no subject volunteering, each subject receives nothing for the round. In the example shown in Figure 1, once 45 seconds pass, there is no incentive for the left-most subject (labeled “you”) to volunteer since he would then receive a negative payoff. Similarly, after 65 seconds, the middle subject has no incentive to volunteer either. After 75 seconds, none of the subjects have incentives to volunteer anymore although nothing prevents them from pushing the Action button anyway and getting a negative payoff for this round.

4. Theory Underlying the Laboratory Representation of the Game

4.1. Backward Induction and Subgame Perfection

Subgame-perfection is an equilibrium selection criterion whose purpose is to eliminate implausible equilibria, namely those that rest on non-credible threats. For example, in a simple two-stage entry-deterrence game, the implausibility of the non-subgame-perfect equilibrium outcome is

apparent to any casual observer.¹⁵ In this case, predicting that this or some other similar game would unfold according to the subgame perfect equilibrium prediction seems warranted.

However, past experimental research has so far failed to find convincing evidence that subjects in sequential decision games systematically play subgame perfect equilibrium strategies; this is particularly true for complex games or games involving long decision chains.¹⁶ In many cases, subjects do not seem to apply any sort of backward induction at all.

In a War of Attrition game such as the one induced in our experiments, it is not clear that any of the Nash equilibria are implausible. Individual 1 taking action and the other two abstaining seems just as plausible as individual 2 or 3 taking action and the other two abstaining. Instead, it is the application of subgame perfection which seems rather implausible. The mere statement of the subgame-perfect equilibrium strategy (player 1 volunteers at all t between 0 and t_i^*) seems to defy logic (a natural reaction to this statement is: how can player 1 volunteer at all t if he is stopping the game at $t = 0$?). Verifying subgame perfection requires making a fairly complex logical reasoning to figure out what players would do at every point in the game, even those they are convinced will never be reached. In a War of Attrition game, because everyone is penalized when the game continues, everyone expects that

¹⁵ A description of the two-stage entry-deterrence game can be found in several introductory game theory textbooks, for example in Rasmusen (1989, pp.85-87). This game has two Nash equilibria in pure strategy (Stay Out; Fight) and (Enter; Collude); however, only the second is subgame-perfect. For example, in classroom discussions of this type of game, many students are initially highly skeptical about the existence of a Nash equilibrium other than the one obtained from backward induction. They find it hard to accept that a strategy combination based on a non-credible threat could even be an equilibrium, let alone a plausible solution to the game. By contrast, they usually have no trouble accepting the backward induction argument and understanding the intuition behind it.

¹⁶ See for example Roth (1995) and Davis and Holt (1993, pp.102-109).

the game will be stopped early: either because another player will stop it or because the subject would stop it himself before too much of the payoffs have been lost. In the 15 seconds they have to make a decision, subjects may naturally dismiss anything that could happen at the end of the game because they do not think the game will last that long. They then concentrate on what is happening at the beginning of the game. It is not irrational for optimizing individuals to economize on decision costs by disregarding possibilities they are convinced will never occur.

These doubts regarding the accuracy of the prediction that the game will unfold according to the subgame-perfect equilibrium lead us to suggest two alternative hypotheses about how subjects may behave in this environment.

4.2. Focal Points

In a game with multiple equilibria, subgame perfection is not the only criterion that can be invoked to single out a strategy combination that will solve the game. In particular, a strategy combination could perhaps attract the players' attention and constitute a focal point even if it is not subgame perfect.

An alternative to the hypothesis that subjects will compute the subgame-perfect equilibrium and see it as the obvious way to play the game is that they will simply try to coordinate their actions around a focal point. It seems plausible to believe that all subjects readily understand that it is wasteful for more than one of them to volunteer. It is also wasteful to let the payoffs decline before someone does. To avoid these two types of losses, they must find a way to coordinate their strategies. However in the laboratory environment, they are unable to communicate so their respective payoffs are the only information they have about each other that they could use to guide their decision.

In the treatment in which individuals differ only with respect to the cost of taking action, a fairly obvious focal point can be recognized. The lowest cost individual takes action immediately and the others wait. C_i is something that all are trying to avoid so all would likely be aware of it. Moreover, this equilibrium yields the outcome that maximizes the total income and so may be seen as more efficient. It also yields the most equal distribution of payoffs; thus, this may be seen as fair. Finally, the lowest cost individual could be thought of as being the least reluctant to incur the cost and therefore be seen as most likely to take action.

In the treatment in which individuals differ only with respect to u_i , a focal point can also be recognized in which the individual with the highest value of u_i takes action immediately and the others wait. Differences in u_i appear on the game screen as differences in both “starting endowment” and the rate at which the payoffs decline. These are immediately noticeable on the computer screen. The strategy combination in which the individual with the highest u_i volunteers is the one that yields the most equal distribution of payoffs and so may be seen as fair. Also, the individual with the greatest u_i is the one who sees his payoff decline the fastest. Waiting is the most costly for him. He may be thought of as being the most anxious to stop the game quickly.

If the individuals differ only with respect to their time horizons, a focal point may be less obvious. If, as we conjecture, subjects dismiss anything that could happen at the end of the game because they are convinced that the game will never reach this point anyway, they may see differences in time horizon as being essentially irrelevant to their coordination problem. However, different time horizons also affect subjects’ payoffs at the beginning of the game, since it appears on their screens as differences in their initial endowment, $T_i u_i$. The strategy combination in which the individual with the

longest time horizon takes action immediately is the one that yields the most equal distribution of payoffs and so may be seen as fair. On the other hand, the subject with the shortest time horizon is the one who sees his payoff decline to zero first. Thus, they may be seen as more anxious to stop the decline. A focal point, if any exists in this treatment, seems to have much weaker attraction power than in the previous two treatments; therefore, subjects may have more difficulty coordinating their strategies. In this case, we would expect to observe more rounds in which more than one subject volunteers at $t = 0$ and more rounds in which a longer time elapses before someone volunteers than in the previous two treatments in which a focal point is more obvious.

When individuals differ in two characteristics, one being either u_i or C_i and the other being T_i , the greater salience of u_i and C_i makes them more attractive focal points than T_i . We would then expect individuals to coordinate their strategies around differences in u_i or C_i in the same way as above and to ignore differences in T_i .

4.3. Play Against Nature

The second alternative hypothesis is that the subjects approach the game as if they were playing against nature rather than against strategic opponents. As mentioned in the introduction, two distinct reasons justify this hypothesis. First, no matter how much information we seek to provide the subjects, it is not possible to truly elicit a game of complete information between them because it is impossible to insure that everyone's rationality is common knowledge. If subjects have any doubt about another's rationality or about whether anyone doubts anyone else's rationality, they will be unable to predict each other's strategies accurately. Second, finding an equilibrium strategy combination may be too difficult for many subjects. Contrary to a simple Prisoner's Dilemma, subjects do not have a dominant strategy

in a War of Attrition game. Selecting a best response to every strategy combination by the other players requires recalculating an optimization problem for each of their strategies. Figuring out an *equilibrium strategy combination* is even more complex than merely selecting a best response strategy. It requires that each player solve the game not only from his point of view but also from the point of view of all the other players; and, they must verify that each is playing a best response to everyone else. This may be too complex a task for many subjects, especially in a laboratory environment in which they only have 15 seconds to decide on a strategy. In either case, if subjects are unable to quickly and accurately forecast each other's strategies, they will approach this game as if they were playing against an unpredictable opponent instead of against two other *purposeful* players.

A simple model which may capture the subjects' behavior in this laboratory environment is one in which subjects chose their strategy as if they are playing against nature. Nature does not play strategically. It takes action randomly at some time t according to a discrete probability distribution $g(t)$ over $[0, T_i]$ known by i .¹⁷ We can also interpret $g(t)$ as the subjective belief that someone else will volunteer at time t . There may be a positive probability that nature takes action at $t = 0$ and so $g(0) \geq 0$. Furthermore, $g(T_i) \geq 0$ allows for a positive probability that nature will not take action during individual i 's time horizon. Individual i 's payoff from taking action at time t against an opponent who plays according to $g(t)$ is:

$$P_i(t) = \{1 - \sum_{j=t}^{T_i-1} g(j)\} [u_i(T_i - t) - C_i] + \sum_{j=t}^{T_i-1} g(j) [u_i(T_i - j)] \quad (9)$$

¹⁷ If the individual did not know $g(t)$, we could reinterpret it as his belief about the probability that nature would take action at time t . This would complicate the analysis somewhat without shedding additional light on the question at hand.

$$j = 0$$

$$j = 0$$

The first term on the right-hand side is the expected payoff if nature has not taken action by time t and individual i takes action himself. In this case, he pays the cost C_i and receives u_i from time t through T_i .

The second term is the expected payoff if nature takes action before time t . In this case the individual receives u_i from that time on through T_i . It is noteworthy that $P_i(t)$ is not necessarily decreasing in t , so volunteering at $t = 0$ is not necessarily optimal. The specific form of the function depends upon $g(t)$, C_i , and u_i .

Given this expected payoff function, the individual will choose to take action at the time t which maximizes $P_i(t)$. The expected gain from waiting one more second is:

$$P_i(t+1) - P_i(t) = g(t)C_i - \left\{ 1 - \sum_{j=0}^t g(j) \right\} u_i \quad (10)$$

The first term to the right of the equal sign contains the probability of avoiding the cost C_i by waiting one more second and the second term contains the probability of losing the return u_i if nature does not act by time t . The trade-off between taking action and waiting is clear: Each second the individual waits costs him u_i if nature does not take action; however, this increases the probability that nature will take action in the next second, sparing him the cost C_i . *Ceteris paribus*, the larger C_i , the longer an individual will choose to wait before taking action, and the larger u_i , the shorter the time the individual will choose to wait before taking action. It is noteworthy that the time horizon, T_i , does not appear in the equation. When individuals have incomplete information, or are unable accurately forecast others' strategies, the decision of how long to wait before taking action depends only on the expected gain and cost of waiting, and T_i is irrelevant to this decision.

4.4. Summary of Predictions

The parameter values used to generate predictions are reported in Table 2.¹⁸ Predictions are summarized in Table 3.

4.4.1. Backward Induction Hypothesis

According to this hypothesis, the individual with the highest value t_i^* volunteers at time 0. For Treatments 1, 2 and 3, subjects differ by only 1 parameter. In the first treatment, subjects differ only by the cost of providing the public service. The individual with the lowest cost of providing the service, C_i , will be the subgame perfect equilibrium volunteer. When individuals differ only by the benefit received per unit of time that the public service is provided, u_i , the individual with the largest value of u_i will be the volunteer in the subgame perfect equilibrium. Further, in a situation in which individuals differ only by their time horizons, T_i , the individual with the greatest value of T_i will be the one to volunteer in subgame perfect equilibrium. For all of the parameter sets in each of Treatments 1, 2, and 3, the individual identified as subject A is the individual with the highest value t_i^* and is predicted to volunteer at time 0.

In Treatment 4, subjects differ in both T_i and u_i , but subject A has the largest t_i^* for each parameter set and is therefore the predicted volunteer. In Treatment 5, the predicted volunteers differ across the parameter sets. In the parameter set 1, subject C is the predicted volunteer and subject A is the predicted volunteer in parameter set 4. With parameter set 2, all of the subjects have the same

¹⁸ For each treatment, four different parameter sets are used. In addition, the roles of each subject are changed after each round. This is done so that subjects do not see themselves playing the same game round after round.

value of t_i^* and therefore subgame perfection does not rule out any of the pure strategy Nash equilibria.

With parameter set 3, $t_A^* = t_B^* > t_C^*$ so that there are subgame-perfect equilibria in which either subjects A or B volunteer first. In the cases where the application of subgame-perfection does not single out a unique equilibrium, factors other than those controlled for in the design (such as personality, sex, age, and education) ultimately determine who will volunteer. Because subjects were labeled randomly as A, B or C, then each is as likely to volunteer as any other.

4.4.2. Focal Point Hypothesis

As discussed above, the parameters C_i and u_i appear to provide stronger focal points than T_i . Accordingly, if individuals differ only by C_i , the individual with the lowest value of C_i will volunteer. In cases where individuals differ only by u_i , the prediction is that the individual with the highest value of u_i will be the volunteer. These first two predictions are the same as those of the backward induction hypothesis. Individual A will volunteer in Treatments 1 and 2. In treatment 3 where individuals differ by T_i only, we hypothesize that differences in T_i do not provide a strong enough focal point to allow the subjects to systematically coordinate their actions. In this case, random factors outside the experimental design will again determine whether the volunteer will be subjects A, B or C.

In the treatments where the subjects differ by more than one parameter, the predictions are unambiguous and different from the predictions of the backward induction hypothesis. In treatment 4 where subjects differ by both u_i and T_i , the prediction is that the individual with the highest value of u_i will be the volunteer. In treatment 5 where subjects differ by C_i and T_i , the subject with the lowest value of C_i will be the one to volunteer. This is individual C in all cases for Treatments 4 and 5.

4.4.3. Play-Against-Nature Hypothesis

If individuals have the same beliefs, this hypothesis leads to predictions identical to those of the focal point hypothesis *except that the model does not predict that the first to volunteer will always act at time zero or that there will always be only one volunteer*. In the treatments in which individuals differ with respect to the cost of volunteering, C_i , (Treatments 1 and 5) the one with the smallest C_i , will take action first. In treatments 2 and 4 where individuals differ with respect to u_i , the individual with the greatest value of u_i will volunteer first. If the individuals do not differ with respect to C_i or u_i (treatment 3), one is as likely to volunteer as another. Given the limited information they have, it may be optimal for everyone to wait before taking action, or for everyone to volunteer at $t = 0$.

5. Results

If in a game of complete information the first subject volunteers at $t > 0$ or more than one volunteers at $t = 0$, the strategy combination played does not constitute a pure strategy Nash equilibrium. We will first examine what the experimental data reveals about the timing of volunteering and the incidence of multiple volunteers to determine to what extent the subjects tended to play Nash equilibrium pure strategy combinations. Then, we will look at the characteristics of the subjects who volunteered first and what this reveals about the equilibrium selection question.

5.1 Late and Multiple Volunteers

Table 4 reports the frequency distributions of the time elapsed before the first subject took “action.” Of the 544 rounds played, the median time was 0 and the median time for “action” in the remaining rounds occurred in the first second. Only 6% of the rounds lasted more than 20 seconds.

87% of all rounds had a single volunteer. Figure 2 shows the cumulative incidence of volunteering in the first 20 seconds of each 90-second game. By the tenth, second the “Action” button had been pushed in 91% of the rounds. This quick stopping of the games by a single subject shows that there is a strong tendency toward Nash equilibrium play.

Including those individuals who volunteer shortly after time 0 as playing a Nash equilibrium strategy is reasonable because of the specific nature of the laboratory game. Subjects were not informed that someone had volunteered until the round had truly commenced. Thus it is not a large deviation from Nash equilibrium timing for an individual to wait until the ninety-second count-down begins before volunteering.

Nonetheless, even if volunteering *immediately* can be extended through the first two seconds of a round, this leaves approximately 27% of the rounds without a volunteer after the first two seconds (see Table 4). This observation suggests that a behavioral hypothesis such as playing against nature, which permits *all* subjects to rationally wait some time before taking action, might better characterize the behavior of individuals in this environment.

According to the focal point hypothesis, outcomes in which no one took action at time zero and outcomes in which more than one subject takes action at time zero may be attributed to coordination failures. When the focal point is not sufficiently salient to clearly select an obvious solution to the game, individuals who expected someone else to stop the game need some time to reassess their strategies. Additionally, some individuals who volunteered at $t = 0$ are surprised to later learn that someone else had also done so. Therefore, in treatments with less obvious focal points, we expect to see more outcomes in which more than one individual took action at time zero and more outcomes with later

stopping times.

As discussed in the previous section, if we believe that differences in C_i and u_i provide more obvious focal points than differences in T_i and that differences in more than one parameter dilute the attraction of a focal point, then we would expect the shortest stopping time and the least multiple volunteers in treatments 1 and 2, followed by treatments 4 and 5, and the longest average stopping time and the most multiple volunteers in treatment 3. However, the time frequency distributions for the different treatments (see Table 4 and Figure 2) do not confirm these predictions. Treatment 2 appears to be different from the others with longer average and median stopping time than the other treatments. The null hypothesis that these five distributions coincide can be rejected ($\chi^2(20) = 46.021$, $p = 0.000$); however using the conventional significance level of 5%, the hypothesis that the distributions of volunteering times coincide for Treatments 1, 3, 4 and 5 cannot be rejected ($\chi^2(15) = 23.779$, $p = 0.069$). In spite of the statistically significant difference of the distribution of the volunteering times in treatment 2 from those of the other treatments, the magnitudes are small. Table 4 reports the median time at which action is taken across all rounds for each treatment and the median time at which action is taken for the remaining rounds. The median time for “action” is one second in Treatment 1, 2 seconds in Treatment 2, and 0 in Treatments 3, 4 and 5. Action is taken in 75% of all rounds by the first second in Treatments 4 and 5, the second second in Treatment 3, the fourth second in Treatment 1, and the eighth second in Treatment 2. Before 10% of the time in each round had passed, action had been taken in more than 75% of all rounds.

With regards to multiple volunteers, the percentage of rounds with multiple volunteers are 11% for Treatment 1, 4% for Treatment 2, 10% for Treatment 3, 9% for Treatment 4, and 23% for

Treatment 5. These data again fail to support the focal point hypothesis. The percentage of multiple volunteers in Treatment 3 is average, contradicting our prediction that it has the weakest focal point, while it is significantly larger in Treatment 5. It is noteworthy that in Treatment 5 two of the four parameter sets used did not identify a unique subgame-perfect equilibrium. It may be that the unique subgame-perfect equilibrium has the most focal attraction, and that the lack of a unique subgame-perfect equilibrium confused many subjects and resulted in multiple volunteers.

5.2 Predictions of Volunteers

The predictions based on the *focal point* and *backward induction* hypotheses are summarized in Table 3. The predictions based on the *play-against-nature* hypothesis are identical to those of the focal point hypothesis. Across the five treatments, 544 decision rounds are played. Aggregating the predictions, the triple (492, 20, 32) would characterize the pattern of volunteering across the three subject types (A, B, and C) under the backward induction hypothesis, while the triple (256, 32, 256) would characterize the focal point hypothesis.¹⁹ The pattern of volunteering that is actually realized, including those instances in which two or more subjects volunteered at time 0, is summarized by the triple (229, 167, 209).

By applying Savage's "interocular trauma test" (Friedman and Sunder 1994, p. 92) we may

¹⁹ These triples are constructed by assuming that when there is a prediction of multiple volunteers, only one person will volunteer but the person who volunteers is randomly determined. Therefore, if A and B are identified as the subjects to volunteer in 96 decision rounds, the ultimate outcome will be A volunteering 48 times and B volunteering 48 times. If the prediction is interpreted as predicted both will volunteer each time, then the relevant triples are (520, 48, 48) for the backward induction hypothesis and (320, 128, 320) for the focal point hypothesis.

argue that the backward induction hypothesis is not the best of the alternate behavioural hypotheses.

The realized pattern (229, 167, 209) differs much more from the one predicted by the backward induction hypothesis (492, 20, 32) than from the one predicted by the focal point hypothesis (256, 32, 256).

Using the pooled data, the focal point hypothesis offers the best explanation of individual behavior. The pooled data, however, may disguise variations across treatments. For this reason each treatment is examined separately.

5.2.1. Treatment 1 (Subjects Differ Only by C_i)

Under Treatment 1 subjects differ only by the cost of providing the public service. The backward induction hypothesis predicts that the individual with the lowest cost of providing the service will be the one to volunteer. The focal point hypothesis makes the same prediction. The distribution of volunteers across subjects A, B and C are reported in Table 5. From the 128 rounds played, subject A volunteers 89 times (in nearly 70% of all opportunities). The distribution of volunteers (89, 27, 26) across subjects A, B, and C reported in Table 5 is significantly different from a uniform distribution ($\chi^2(2) = 52.914, p < 0.001$).²⁰ The predictions of both the backward induction and focal point hypotheses are consistent with these results.

5.2.2. Treatment 2 (Subjects Differ Only By u_i)

²⁰ This χ^2 test compares the realized distribution of volunteers across subjects and compares it to a uniform distribution of the same number of volunteers. If we assume that only one individual will volunteer each time, and this number of volunteers is used to compute the χ^2 statistic, its value would be larger. Using the actual number of volunteers biases the test in favor of accepting the null hypothesis that the distribution is uniform (and in a sense, subjects volunteer randomly). Both statistics are included in Table 6.

Under Treatment 2 subjects differ only by u_i (the benefit they receive per unit of time that the public service is provided). Both the backward induction and the focal point hypotheses predict that the individual with the highest benefit per unit of time will volunteer. The distribution of volunteers across subjects A, B and C are reported in Table 5. From the 96 rounds played, subject A volunteers 53 times (in nearly 56% of all opportunities). The distribution of volunteers (53, 24, 23) across subjects A, B, and C reported in Table 5 is significantly different from a uniform distribution ($\chi^2(2) = 16.103, p < 0.001$). The predictions of both the backward induction and focal point hypotheses are consistent with these results. Yet, these results are not as strong as the results in Treatment 1.

5.2.3. Treatment 3 (Subjects Differ Only By T_i)

Under Treatment 3, subjects once again differ by only one parameter. The length of time over which subjects are able to receive benefits from the public service differs across subjects. The backward induction hypothesis predicts that the individual who can receive benefits from the public service for the longest time will be the one to volunteer; this is individual A in every case. The play-against-nature hypothesis predicts that differences in T_i do not matter. Therefore, the first volunteer will be determined by characteristics not controlled for in the experiment and distributed randomly to subjects A, B or C. We also argue that there is no obvious focal point allowing the subjects to consistently coordinate their strategies, so the volunteers will be equally distributed across subjects A, B and C.

The distribution of volunteers across subjects A, B and C are reported in Table 5. From the 96 rounds played, subject A volunteers 42 times (in nearly 44% of all opportunities). Although Subject A volunteers more often than any other subject, this is the first treatment for which subject A does not

volunteer more often than do the other two subjects together. Subject B volunteers 31 times and Subject C volunteers 33 times. The distribution of volunteers (42, 31, 33) across subjects A, B, and C reported in Table 5 is not significantly different from a uniform distribution ($\chi^2(2) = 3.188, p > 0.20$). This supports the focal point hypothesis over the backward induction hypothesis.

5.2.4. Treatment 4 (Subjects Differ by u_i and T_i)

Subjects differ by both the benefits they receive per unit of time that the public service is provided and the length of time over which they can receive those benefits under Treatment 4. The backward induction and focal point hypotheses provide different predictions about the subject who will volunteer. The backward induction hypothesis predicts that the individual who can wait the longest and still benefit from volunteering to provide the public service will volunteer immediately (individual A). The focal point hypothesis predicts that the individual who has the greatest potential loss for each round that a volunteer does not act will volunteer immediately (individual C).

The distribution of volunteers across subjects A, B and C are reported in Table 5. From the 128 rounds played, subject A volunteers 26 times (20.3% of all opportunities). This is the first treatment for which subject A does not volunteer more often than either of the other two subjects. Subject B volunteers 44 times and Subject C volunteers 69 times (nearly 54% of all opportunities). The distribution of volunteers (26, 44, 69) across subjects A, B, and C reported in Table 5 is significantly different from a uniform distribution ($\chi^2(2) = 19.080, p < 0.001$). The distribution of volunteers is skewed in the direction of the focal point hypothesis' prediction.

5.2.5. Treatment 5 (Subjects Differ by C_i and T_i)

Subjects differed both by the cost of providing the public service, C_i , and the length of time

over which they could receive benefits from the public service, T_i , in Treatment 5. The four different parameter sets each provide a different prediction for the backward induction hypothesis. For all of the parameter sets, however, the focal point model predicts that Subject C, the individual with the lowest cost of providing the public service, will volunteer.

5.2.5.a. Parameter Set 1

The backward induction hypothesis predicts that individual C will volunteer. This prediction is not different from that of the focal point hypothesis. The realized distribution of volunteers A, B, and C (3, 7, 15) shows a strong tendency to support these predictions. This distribution is significantly different from a uniform distribution ($\chi^2(2) = 8.964, p < 0.020$).

5.2.5.b. Parameter Set 2

Under parameter set 2 in Treatment 5, there is a subgame-perfect equilibrium in which any of the subjects volunteers and the others wait. Who volunteers will then depend on random factors other than the controlled variables. The focal point hypothesis, however, predicts individual C will volunteer. The resulting distribution of volunteers (8, 11, 12) is not different from a uniform distribution ($\chi^2(2) = 0.839, p > 0.500$). This outcome tends to support the backward induction hypothesis over the focal point hypothesis.

5.2.5.c. Parameter Set 3

There are subgame-perfect equilibria in which either subjects A or B volunteer. The focal point hypothesis again predicts that subject C will volunteer. The resulting distribution of volunteers (6, 12, 14) is more strongly skewed towards the focal point prediction than in the previous case. Neither model is strongly supported by this outcome. Nearly half of the volunteering is accounted for by

subject C; this should not happen under the backward induction hypothesis. More than half of the volunteering is accounted for by Subjects A and B, which should not occur under the focal point hypothesis.

5.2.5.d. Parameter Set 4

The fourth parameter set of Treatment 5 provides different unique predictions of volunteers under the backward induction and focal point hypotheses. Under the former, individual A should volunteer. Under the latter, individual C should volunteer. The distribution of volunteers (2, 11, 17) much more strongly supports the focal point hypothesis than do the other parameter sets under this treatment. This distribution is significantly different from a uniform distribution of volunteers ($\chi^2(2) = 11.400, p < 0.010$) and it is skewed towards the prediction of the focal point hypothesis. More than half of the volunteers are subject C, while fewer than ten percent are subject A.

Table 7 summarizes the distribution of volunteers and places them within the time band within which they volunteered. The columns containing the individuals who volunteered most often in treatments in which the distribution of volunteers is different from a uniform distribution are indicated with bold figures. In Treatments 1, 2, 4, 5.1 and 5.4 the most frequent volunteer is consistent with the focal point hypothesis. In Treatments 1, 2, and 5.1 the most frequent volunteer is consistent with the backward induction hypothesis. In Treatments 3 and 5.3 the distributions of volunteers are closer to the predictions of the focal point hypothesis. However, in Treatment 5.2, the distribution of volunteers is closer to the prediction of the backward induction hypothesis. This is the only case in which the backward induction hypothesis outperforms the focal point hypothesis or the play-against-nature hypothesis.

Before concluding, it should be noted that in generating predictions from either the backward induction or the focal point hypotheses, two simplifying assumptions were made. The first assumption was that all players in the group are behaving according to the same hypothesis. So when considering the backward induction hypothesis, we assumed that all the subjects would be playing their part of the subgame-perfect equilibrium strategy combination. Similarly when considering a focal point, we assumed that all the subjects would see it as the obvious way to play the game. The second assumption was that all members of a group *believed that all other members of their group* would play in accordance with the same behavioral hypothesis. These simplifying assumptions were the basis for the predictions that a particular subject would volunteer at time zero, but are almost certainly false. Before undertaking these experiments none of us knew with certainty how the subjects would behave. So, it seems likely that the subjects who participated in these experiments were at least as ignorant as we were about how their opponents would behave. Let us ask ourselves: If I am unsure of how the other players will behave, how would I rationally play this game? The answer is definitely not to just play blindly the strategy dictated by either of these behavioral hypotheses. Instead, we would use whatever vague beliefs we have about the likelihood that other players will see a particular equilibrium, or another as focal, or about what they believe our beliefs are to determine an optimal strategy. This is the basis of the play-against-nature hypothesis.

6. Discussion and Conclusions

The evidence concerning the timing of volunteering shows that individuals are generally playing a Nash equilibrium strategy and volunteering immediately or very early in each round. However, the

evidence on which subject actually volunteered shows that they did not consistently play the subgame-perfect equilibrium strategy combination. The focal point and play-against-nature hypotheses receive the most support in the widest variety of treatments.

The data indicate that subjects in the sessions reported here were behaving in a systematic manner, but not in a manner consistent with the backward induction hypothesis. While the data are more consistent with the focal point than the backward induction hypothesis, the relatively large number of rounds in which no one volunteers within the first two seconds suggests that neither of these hypotheses completely capture the behavior of the individuals who participated in the experiment. One reason that subjects may not make decisions at time zero is that although they have complete information about the parameters determining the payoffs of the others in their groups, individuals are uncertain of their rationality and their beliefs. This generates a game of incomplete information which we approximate as a game in which individuals are playing against nature.

These experiments suggest that in the absence of communication, the decision to volunteer to provide a public service may be captured by a behavioral model in which individuals make decisions as if they were playing against nature, even though they may know the underlying parameters of the other players. This result is driven by subjects' incomplete information about the rationality and beliefs of others. An obvious important extension of this work is to consider the role of communication.

References

- Bergstrom, T., L. Blume and H. Varian, 1986. "On the Private Provision of Public Goods." *Journal Of Public Economics*, 29, 25-59
- Bilodeau, M. and A. Slivinski. 1996. Toilet Cleaning and Department Chairing: Volunteering a Public Service. *Journal of Public Economics* 59, 299-308.
- Bliss, C. and B. Nalebuff. 1984. Dragon Slaying and Ballroom Dancing: The Private Supply of a Public Good. *Journal of Public Economics* 25, 1-12.
- Buchanan, J. M. 1967. Cooperation and Conflict in Public Good Interaction, *Western Economic Journal*, March 1967, 109-121
- Davis, D. D. and C. A. Holt. 1993. *Experimental Economics*. Princeton University Press, Princeton, NJ.
- Friedman, D. and S. Sunder. 1994. *Experimental Methods: A Primer for Economists*. Cambridge University Press: New York, NY.
- Fudenberg, D. and J. Tirole. 1991. *Game Theory*. MIT Press: Cambridge, MA.
- Hendricks, K., A. Weiss and C. A. Wilson. 1988. The War of Attrition in Continuous Time with Complete Information. *International Economic Review* 29, 663-680.
- Hirshleifer, J. 1983. "From Weakest Link to Best Shot: The Voluntary Provision Of Public Goods," *Public Choice* 41, 317-386
- Ledyard, J. O. 1995. "Public Goods: A Survey of Experimental Research", in *Handbook of Experimental Economics*, J. Kagel and A. Roth, eds. Princeton University Press: Princeton, NJ, 111-194.

Rasmusen, E. 1989. *Games and Information: An Introduction to Game Theory*. Basil Blackwell:
New York, NY.

Roth, A. E., 1995. “Bargaining Experiments” in *Handbook of Experimental Economics*. J. Kagel
and A. Roth, eds. Princeton University Press: Princeton, NJ, 254-349.

Table 1 Experimental Design

Treatment	T_i	u_i	C_i	Sessions	Trials	Observations
1	Common	Common	Different	8	16	128
2	Common	Different	Common	6	16	96
3	Different	Common	Common	6	16	96
4	Different	Different	Common	8	16	128
5	Different	Common	Different	6	16	96

Note: The first 8 sessions included Treatments 1, 2, and 4. The data from Treatment 2 were inaccurately recorded because of a programming error. These data are not reported. The next 6 sessions included Treatments 2, 3, and 5. These Treatment 2 data are reported.

Table 2 Parameter Values

Treatment.Parameter Set	T_i	u_i	C_i	Observations
1.1	100	0.2	1, 3, 5	32
1.2	200	0.1	1, 3, 5	32
1.3	50	0.2	1, 3, 5	32
1.4	100	0.1	1, 3, 5	32
2.1	60	0.3, 0.2, 0.1	10	24
2.2	60	0.3, 0.2, 0.1	5	24
2.3	50	0.4, 0.3, 0.2	10	24
2.4	50	0.4, 0.3, 0.2	5	24
3.1	100, 85, 70	0.2	5	24
3.2	100, 85, 70	0.2	1	24
3.3	200, 170, 160	0.1	5	24
3.4	200, 170, 160	0.1	1	24
4.1	200, 100, 50	0.1, 0.2, 0.4	5	32
4.2	200, 100, 50	0.1, 0.2, 0.4	1	32
4.3	100, 50, 25	0.1, 0.2, 0.4	5	32
4.4	100, 50, 25	0.1, 0.2, 0.4	1	32
5.1	100, 90, 80	0.2	10, 5, 1	24
5.2	100, 90, 80	0.2	5, 3, 1	24
5.3	100, 75, 50	0.2	10, 5, 1	24
5.4	100, 75, 50	0.2	5, 3, 1	24

Note: When the entry is a triplet the first value was assigned to subject A, the second to B, and the third to C. When the entry is a single, all subjects had the same value for that parameter.

Table 3 Individual(s) Who Should Volunteer by Treatment and Behavioural Hypothesis

Behavioural Hypothesis	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5.1	Treatment 5.2	Treatment 5.3	Treatment 5.4
Backward Induction	A	A	A	A	C	A, B, C	A, B	A
Focal Point and Play Against Nature	A	A	A, B, C	C	C	C	C	C

Table 4 Frequency Distributions and Medians of Times at which Action was taken and Number of Multiple Volunteers by Treatment

Time Category (seconds)	Treatment 1 (128 rounds)	Treatment 2 (96 rounds)	Treatment 3 (96 rounds)	Treatment 4 (128 rounds)	Treatment 5 (96 rounds)
0	63	37	56	76	65
1 - 2	27	17	20	29	9
3 - 5	16	13	3	7	7
6 - 10	13	12	8	8	5
11 - 20	3	6	3	4	4
>20	6	11	6	4	6
Median (seconds)	1	2	0	0	0
3 rd Quartile (seconds)	4	8	2	1	1
Number of Rounds with More Than 1 Volunteer at Time 0	13	4	11	11	19

Table 5 Frequency with which Individuals A, B, and C Volunteered by Treatment

	A			B			C		
	Freq.	% Op.	% Vol.	Freq.	% Op.	% Vol.	Freq.	% Op.	% Vol.
Treatment 1	89	69.5	62.7	27	21.1	19	26	20.3	18.3
Treatment 2	53	55.2	53	24	25	24	23	24	23
Treatment 3	42	43.8	39.6	31	32.3	29.2	33	34.4	31.1
Treatment 4	26	20.3	18.7	44	34.4	31.7	69	53.9	49.6
Treatment 5.1	3	12.5	12	7	29.2	28	15	62.5	60
Treatment 5.2	8	33.3	25.8	11	45.8	35.5	12	50	38.7
Treatment 5.3	6	25	18.8	12	50	37.5	14	58.3	43.8
Treatment 5.4	2	8.3	6.7	11	45.8	36.7	17	70.8	56.7

Note: The column headings Freq., % Op. and % Vol. indicate frequency, percentage of opportunities, and percentage of volunteers. The % Op. values by treatment may not add up to 100 because in some decision rounds more than one person volunteered during the first 15 seconds prior to the start of the 90 second countdown.

Table 6 χ^2 Test Statistics and p-Values for Tests on Distributions of Volunteers

Basis for Null Hypothesis	Opportunities	Volunteers
Treatment 1 (128, 142)	61.258 (< 0.001)	52.914 (< 0.001)
Treatment 2 (96, 100)	18.313 (< 0.001)	16.103 (< 0.001)
Treatment 3 (96, 106)	3.188 (> 0.200)	1.600 (> 0.400)
Treatment 4 (128, 139)	24.101 (< 0.001)	19.080 (< 0.001)
Treatment 5.1 (24, 25)	9.375 ($0.001 < p < 0.010$)	8.964 ($0.010 < p < 0.020$)
Treatment 5.2 (24, 31)	3.125 (> 0.200)	0.839 (> 0.500)
Treatment 5.3 (24, 32)	7.000 ($0.020 < p < 0.050$)	3.249 ($0.100 < p < 0.200$)
Treatment 5.4 (24, 30)	15.750 (< 0.001)	11.400 ($0.001 < p < 0.010$)

Notes: The first number in the parentheses under each treatment heading is the number of opportunities for a volunteer to take action (the number of rounds in a treatment); the second number is the actual number of volunteers. p-values are in parentheses below χ^2 statistics. The column labeled “opportunities” contains χ^2 statistics based on opportunities being equally distributed across Subjects A, B, and C; the column labeled “volunteers” contains χ^2 statistics based on volunteers being equally distributed across Subjects A, B, and C.

Table 7 Timing of Volunteering by Subject and Treatment

Time Category (seconds)	Treatment 1 (128 rounds)			Treatment 2 (96 rounds)			Treatment 3 (96 rounds)			Treatment 4 (128 rounds)			Treatment 5.1 (24 rounds)			Treatment 5.2 (24 rounds)			Treatment 5.3 (24 rounds)			Treatment 5.4 (24 rounds)		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
0	44	18	15	25	10	6	31	18	17	19	26	42	3	6	9	7	7	9	4	10	8	2	8	12
1 - 2	16	5	6	10	5	2	5	4	11	5	12	12	0	0	0	1	2	0	1	1	3	0	0	1
3 - 5	12	1	3	6	1	6	2	1	0	0	2	5	0	0	1	0	1	1	1	1	0	0	1	1
6 - 10	9	2	2	3	4	5	1	4	3	0	1	7	0	0	2	0	1	0	0	0	0	0	0	2
11 - 20	2	1	0	0	2	4	2	1	0	2	0	2	0	0	1	0	0	0	0	0	2	0	1	0
>20	6	0	0	9	2	0	1	3	2	0	3	1	0	1	0	0	0	2	0	0	1	0	1	1
Median (seconds)	1	0	0	1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
3 rd Quartile (seconds)	4	1	2	5	9	8	1	6	2	1	2	2	0	0	5	0	2	0	1	0	1	0	4	1

Note: The column with the bold figures identifies the individual who volunteers most often in treatments in which the distribution of volunteers is different from a uniform distribution according to χ^2 statistics reported in Table 6 based on the number of volunteers.

Figure 1 Subject's Screen Providing Information for the Three Participants in a Group

Figure 2 Cumulative Distributions of Volunteers over Time by Treatment

Recent working papers

2001-04	Robin Boadway Katherine Cuff Maurice Marchand	Equalization and the Decentralization of Revenue-Raising in a Federation
2001-03	A Johri M-A Letendre	Labour Market Dynamics in RBC Models
2001-02	R A Muller A L Robb A Diener	Inferring Willingness-to-Pay for Health Attributes of Air Quality Using Information on ranking of Alternatives and Cognitive Ability of Respondents
2001-01	John B Burbidge	'Awkward Moments in Teaching Public Finance' John F Graham Lecture at the Atlantic Canada Economics Association Annual Meetings
2000-06	Alok Johri Lohn Leach	Middlemen and the Allocation of Heterogeneous Goods
2000-05	John B Burbidge Gordon M Myers	Tariff Wars and Trade Deals with Costly Government
2000-04	Donald Dawson Lonnie Magee	The National Hockey League Entry Draft, 1969-1995: An Application of a Weighted Pool-Adjacent-Violators Algorithm
2000-03	Neil Buckley Kenneth S. Chan James Chowhan Stuart Mestelman Mohamed Shehata	Value Orientations, Income and Displacement Effects, and Voluntary Contributions
2000-02	R Cooper Alok Johri	Learning by Doing and Aggregate Fluctuations
2000-01	Yorgos Y. Papageorgiou David Pines	Externalities, Indivisibility, Nonreplicability and Agglomeration