

# Cost asymmetry and incomplete information in a volunteer's dilemma experiment

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Received: 6 February 2017 / Accepted: 26 March 2018 / Published online: 3 April 2018  
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**Abstract** We utilize a laboratory experiment to examine the effect of asymmetric costs in the volunteer's dilemma, a public goods game where all players receive a benefit if at least one person volunteers and nothing otherwise, which presents a social dilemma where the optimal action for the individual differs from that for the group. Additionally, we introduce uncertainty to explore the role of information and find that individual behavior aligns most closely with the more intuitive Nash equilibrium strategies under full information and to a lesser extent with incomplete information. Although uncertainty about fellow group members' costs incentivizes greater volunteering and thus has the potential to improve efficiency, we find that the inability to coordinate prevents groups from experiencing welfare gains as a result.

## 1 Introduction

In 2012, a Southern California high school art teacher was taking the 91 freeway to get to work when he smelled smoke. Although he was able to pull to the side of the road before the van caught on fire, his wheelchair was stowed away and he could not

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This study was funded by the Russell Sage Foundation (Grant no. 15-2-25115-80715) and a Loyola Marymount University grant and the authors gratefully acknowledge this support. We thank Ted Bergstrom, Greg Leo, Jean-Francois Mercier, the participants at the Western Economic Association meetings in June 2016 and the participants at the University of Virginia Experimental Social Science conference in September 2016. We gratefully acknowledge comments from two anonymous reviewers as well.

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escape. Two strangers saw the fire, stopped on the freeway, and pulled him out just before flames engulfed the car. The “angel” volunteers suffered smoke inhalation, but saved the man’s life (Molina and Chambers 2010).

Stories like these abound, crossing borders and even species, throughout time. Calling situations like these a “volunteer’s dilemma,” Diekmann (1985) created a variation of a public goods game that parallels a variety of real-world situations like the one above. In this unique game, all players receive the full benefit of the public good if a certain level of contribution is provided, and zero benefit if that level is not reached. This presents a dilemma where the optimal action for the individual differs from the action optimal for the group. Take, for example, the basic dilemma proposed by Diekmann:  $N$  individuals are sentenced to prison for 10 years unless at least one of the individuals volunteers to confess. Any volunteer who confesses serves 1 year of the sentence and the others are released. The group benefits as long as at least one individual is willing to pay the cost to produce this collective good and an individual benefits from volunteering if no one else volunteers. An individual has an incentive to volunteer only if there are no other volunteers, but, given that volunteering is costly, the individual would strictly prefer to free ride off the contribution of another individual.<sup>1</sup> However, because players cannot coordinate amongst themselves, the potential for redundant volunteers can result in a wasteful outcome, creating a second social dilemma.<sup>2</sup>

In the basic  $N$ -person uncoordinated volunteer’s dilemma, each individual in the group faces a binary set of options that includes a costly decision to volunteer and a no volunteer choice. Only one volunteer is needed to supply the public good. Additional volunteers have no impact on the level of public good provided or on the cost required to volunteer in this uncoordinated game. As in prior studies of the volunteer’s dilemma (e.g., Goeree et al. 2017), we model the situation as  $N$  members of a group receiving a monetary payoff of  $V$  if at least one player volunteers at a cost of  $C$ . If there are no volunteers, all group members receive a lower payoff of  $L$ . Since  $V > L$ , each individual prefers that the public good be provided, but that someone else volunteers. However, since it is assumed that  $C < V - L$ , volunteering at cost  $C$  is better than a no-volunteer outcome for every individual player. The relatively small amount of experimental attention that the volunteer’s dilemma has received is perhaps surprising given the multitude of real-world analogues suggesting the potential for considerable external validity. Moreover, fairly little research to date has considered variation in

<sup>1</sup> Diekmann applied this reasoning to the case of Kitty Genovese, a New Yorker who was stabbed to death in from of a building block where a significant number of people allegedly witnessed the attack. No one supposedly came to her rescue or even called the police. This situation demonstrates a volunteer’s dilemma; everyone likely would have benefitted if at least one person called the police, yet there was a diffusion of responsibility where everyone apparently believed that someone else would make the call. This resulted in the non-optimal outcome where the public good, in this case the arrival of the police, was not provided.

<sup>2</sup> There is also a *coordinated* volunteer’s dilemma where, if more than one person volunteers, only one player is randomly selected to serve as the volunteer so there is no redundant volunteering. The coordinated game models scenarios where a maximum of one volunteer may bear the cost, resulting in a different set of strategies and potential outcomes. See Bergstrom et al. (2015) for theory and experimental findings on coordinated volunteer’s dilemma games.

important characteristics of the volunteer's dilemma that parallel real-world volunteering situations like multiple volunteers of differing ability, for example.

In this article, we contribute to the literature by examining how differences in an individual group member's ability to volunteer (using the cost of volunteering as a proxy for ability) impacts an individual's likelihood of volunteering and the overall efficiency of the group in providing the public good. Introducing a variance in the cost to volunteer enables us to replicate important decisions in which standard economic theory makes unintuitive predictions. For example, Diekmann (1993) describes a situation in which three bystanders observing a victim in danger of drowning. If only one of the bystanders is able to swim, such that  $C_k < C_i$ , it seems apparent that the bystander who can swim should save the victim. However, one Nash solution to the game, shown in Diekmann and also in Weesie (1993), indicates a greater likelihood for the non-swimmers to jump in the water to save the victim. Bliss and Nalebuff (1984) look at cost variation in the context of a waiting game, similar to the war of attrition, where the length of time an individual waits is related to their own cost and to the perceived distribution of others' costs. More recently, Myatt and Wallace (2008) explore the existence of individuals that are "enthusiastic" and/or "reliable" to reverse this counter-intuitive outcome. The low-cost individual is the most enthusiastic player and therefore the most efficient provider. However, the low cost player could be unreliable and therefore the high cost individual may still participate, although less frequently.

Our experimental results show just that—when costs differ, the low-cost or "strong" players volunteer significantly more than their high-cost (or "weak") counterparts (91.9% of the time versus 6.5% of the time, respectively). However, note that the low cost player does not *always* volunteer, which lends support to the theory of the "unreliable" low-cost (and thus high-ability) player.

By introducing variance in the ability (cost) to volunteer, we're also able to consider the role of information and uncertainty in the volunteer's dilemma. Continuing the above drowning victim example, this feature addresses the uncertainty that bystanders face regarding each other's swimming abilities. How does this uncertainty influence the decisions made by individual swimmers about whether to jump into save the potential victim? The theoretical prediction, explored in Weesie (1994), indicates that the likelihood of volunteering may actually increase with uncertainty, provided that the group is sufficiently large ( $N > 2$ ). The theoretical results suggest that incomplete information may have the potential to foster, rather than hamper, efficiency.

We are able to show that uncertainty has a positive impact on an individual's likelihood of volunteering; the average volunteer rate increases from 37.5 to 46.5%, all else equal, when incomplete information is introduced into the model (*p value of two-sided t-test* = 0.005). However, despite the increase in the volunteer rate, group efficiency is harmed by redundant volunteers that duplicate efforts, thus social efficiency does not improve under uncertainty.

## 2 Related literature

There are many examples of real-world volunteer's dilemmas ranging from organizational to biological to technological. Weesie (1993) applies this idea to household

chores like deciding who should take out the trash or get out of bed to comfort a crying child in the middle of the night. Murnighan et al. (1993) illustrate a dilemma where a group of soldiers see an enemy grenade fall into their trench. The soldier that jumps to cover the grenade saves his fellow soldiers, but at the cost of his own life. Archetti (2009) discusses several biological scenarios, such as groups of vertebrates that rely on alarm calls as a defense against approaching predators. One individual may be sufficient to sound the alarm but being the volunteer in this situation may also draw attention and result in being attacked. Johnson (2002) considers a more modern example of voluntary open-source software. Only one programmer is required to provide the good, which comes at a cost, while everyone benefits from its existence. Note that these examples speak to uncoordinated games, where redundant volunteering is possible and simultaneously wasteful, creating a uniquely “best” or most-socially-efficient equilibrium with exactly one volunteer (no more, and no less).

Prior studies of the volunteer’s dilemma have produced theoretical predictions (e.g. Diekmann 1985) and social psychology research has tested staged field experiments (Darley and Latane 1968).<sup>3</sup> Two-person and multiple-person games, like the prisoner’s dilemma, have been studied to capture similar situations where self-serving or free-riding behavior harms group efficiency (Baron 2008). Multi-round games reveal mixed-strategy equilibria as studied by Ochs (1995) where players may exhibit adaptive learning strategies. The game of chicken (also known as hawk-and-dove) is equivalent in incentives to the volunteer’s dilemma; in this well-known game, two players must choose between staying and swerving where both players would strictly prefer the outcome in which one player stays and one play swerves (one of two pure equilibria), while both players would strictly prefer to be the one that stays (hence, no dominant strategies). De Heus et al. (2010) find experimental evidence that players are more cooperative in the game of chicken than in a prisoner’s dilemma, which they attribute to participants seeing defection as the more risky option in the chicken game, but not as risky in the prisoner’s dilemma.

Although well studied theoretically, few incentivized economics experiments have been conducted that consider the uncoordinated volunteer’s dilemma game and its distinctive implications, which is somewhat surprising given the many real-world analogues and potential for external validity as described above. Murnighan et al. (1993) found that increasing group size decreases volunteer rates in classroom experiments with MBA students. Goeree et al. (2017) explored the relationship between group size and volunteering, where the Nash equilibrium predicts the probability of volunteering to be a decreasing function of group size and that the probability of a no-volunteer outcome is increasing in the number of players. Testing group sizes  $N = 2, 3, 6, 9,$  and  $12$  experimentally, the authors find evidence to support the former hypothesis but not the latter. Archetti (2009) finds that relatedness among group members increases the probability of volunteering, particularly for larger groups. While the probability of volunteering still decreases as group size increases when relatedness is high, the

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<sup>3</sup> In Darley and Latane (1968), the experiment involved recruiting college students under the ruse that they were taking part in a conversation with another student about college life over an intercom system. Then, one of the students would have a, “very serious nervous seizure similar to epilepsy.” The dependent variable in the experiment was how long each subject took to report the emergency to the experimenter.

probability of a no-volunteer outcome decreases with  $N$ . Other experimental studies include Diekmann's (1993) survey examining different levels of volunteer costs presented in matrices and Weesie and Franzen's (1998) mailed questionnaire looking at the effect of cost sharing on the probability of volunteering. More recently, Bergstrom et al. (2015) explore individual preferences in a coordinated volunteer's dilemma, testing the responsiveness of "let me do it" types to differing costs and public recognition. Finally, Hillenbrand and Winter (2018) test a one-shot game and find that uncertainty about the number of potential volunteers increases cooperation compared to a situation where the number of players is known.

Our experimental findings build on the existing literature by examining how an increase in the cost to volunteering alters an individual's likelihood of volunteering, with costs varying across rounds to allow for within-subject comparisons. The inclusion of asymmetric cost treatments then enables us to test how information uncertainty impacts strategic decision making in the game. Typically, more information leads to greater efficiency, but if incomplete information increases the rate of volunteering, there is a distinct possibility that efficiency could actually be improved by incomplete information. However, the uncoordinated nature of the non-cooperative volunteer's dilemma frequently results in redundant volunteering, where efficiency gains may not emerge despite the greater levels of cooperation at the individual level.

Section 3 introduces the experimental design, with the theoretical model and hypotheses following in Sect. 4. Section 5 presents the results where, in addition to the findings noted above, we explore how path dependence may play a role in determining the likelihood of volunteering in any given period and how individuals' preference-types may provide some additional insights.

### 3 Experimental design and procedures

The experiment was conducted at Loyola Marymount University Experimental Economics Laboratory (LEEL) with 144 undergraduate students. The design featured 10 experimental sessions testing cost asymmetry in the volunteer's dilemma, with complete and incomplete information, across group sizes of  $N = 2$  and  $N = 6$ . The cost to volunteer varies within-subject, while the information and group size treatments vary across sessions. Table 1 presents the design and treatments.

The experimental values for  $V$  (the payoff subjects receive if at least one subject volunteers) and  $L$  (the payoff when nobody volunteers) are \$1.00 and \$0, respectively. For all sessions, the cost to volunteer is either \$0.20 or \$0.60. With  $N = 2$ , the possible cost combinations are (own cost/other member's cost): \$0.20/\$0.20, \$0.20/\$0.60, \$0.60/\$0.20, or \$0.60/\$0.60. With  $N = 6$ , the possible cost combinations are (own cost/other members' costs): \$0.20/all \$0.20, \$0.20/2 members at \$0.20 and 3 members at \$0.60, \$0.60/2 members at \$0.60 and 3 members at \$0.20, or \$0.60/all \$0.60. The cost for each subject was randomly drawn in each period such that they faced a

**Table 1** Experimental design

Experimental condition	Group size	Cost to volunteer ( <i>c</i> )	Information treatment	Number of subjects per session	Number of sessions
A	2	Either 0.20/0.20, 0.20/0.60, 0.60/0.20, or 0.60/0.60	Complete	12	3
B	6	All 0.20 or 0.20/0.20/0.20 0.60/0.60/0.60 or 0.60/0.60/0.60 0.20/0.20/0.20 or all 0.60	Complete	18	2
C	2	Either 0.20/0.20, 0.20/0.60, 0.60/0.20, or 0.60/0.60	Incomplete	12	3
D	6	All 0.20 or 0.20/0.20/0.20 0.60/0.60/0.60 or 0.60/0.60/0.60 0.20/0.20/0.20 or all 0.60	Incomplete	18	2

\$0.20 cost or a \$0.60 cost with probability  $p = 0.5$  and the likelihood of *at least one* of the other members' costs being \$0.20 or \$0.60 was also 50%.<sup>4</sup>

In the complete information treatment, subjects know their cost and the costs drawn for other group members (although not the individual cost assignments in the six-person groups). In the incomplete information treatment, the subjects know their own cost and that other group members have a 50% chance of having a low or high cost, though not which cost values have been drawn. For example, in a group with six members, a subject facing a cost of \$0.20 would know that at least two other members of the group share the same cost (in this case, \$0.20), with a 50% chance that the remaining three members have a cost of \$0.20 and a 50% chance that the remaining three members had a \$0.60 cost. At the end of every round, subjects observe whether the public good was provided, but not the number of volunteers.<sup>5</sup>

All sessions lasted 24 periods. Complete experimental instructions can be found in the appendix. The groups were randomly re-matched in every period and all subjects' identities remained anonymous to prevent reputation building. The experiment lasted approximately 45 min, with subjects earning approximately US \$20 on average.

<sup>4</sup> Meaning, if  $N = 6$ , in individual that draws a \$0.60 cost knows that either all six group members have \$0.60 or that half of the group (3 other members) face a cost of \$0.20, with equal probability. The costs were randomly drawn across rounds in advance and set in the design to ensure consistency in the variation and order of cost draws experienced across experimental sessions.

<sup>5</sup> The goal is not to encourage or support learning across the experiment, but rather to make each round independent from one another in order to test how the likelihood of volunteering may vary across costs and information specifications. Thus, we provided the minimum amount of information between rounds, which is strictly whether or not there was at least one volunteer (which subjects could infer from their earnings in each round).

### 4 Theory and hypotheses

Although the volunteer decision is binary, the experimental design offers a wide range of potential Nash equilibrium predictions. Each of the  $N$  group members can choose to volunteer or to not volunteer. Volunteer  $i$  incurs a cost of  $c_i > 0$ ,  $c_i \in \{c_L, c_H\}$ . Let  $V$  denote the benefit to all  $N$  group members if at least one individual volunteers. In the event of a no-volunteer outcome, all  $N$  members receive 0. Thus, as long as  $c_i < V$ , player  $i$  would prefer to volunteer over experiencing a no-volunteer outcome, but the individual benefit is maximized when a player can free-ride off another group member’s decision to volunteer. The social benefit is then maximized when exactly one group member volunteers in each round and no other player has a lower cost to volunteer.

For each person  $i$  with cost  $c_i$ , the payoff from volunteering is  $U_v$  and the payoff from not volunteering,  $U_{nv}$ , where:

$$U_v = V - c_i \tag{1}$$

$$U_{nv} = \begin{cases} V & \text{if at least one other person volunteers} \\ 0 & \text{otherwise.} \end{cases}$$

As noted by Diekmann (1993), the game has several efficient asymmetric equilibria with exactly one volunteer and  $N - 1$  free-riders. There are also multiple other equilibria described below.

First, in the symmetric game when all group members have the same cost  $c$ , and each individual volunteers with probability  $p$ , the likelihood of having at least one member of the group volunteer from the  $N - 1$  others is  $1 - (1 - p)^{N-1}$ . We equate the expected payoff from volunteering and not volunteering, which gives us:

$$V - c = V[1 - (1 - p)^{N-1}]. \tag{2}$$

The probability of volunteering in the mixed-strategy Nash equilibrium is:

$$p = 1 - \left(\frac{c}{V}\right)^{\frac{1}{N-1}} \tag{3}$$

and the likelihood that none of the  $N$  group members volunteer is:

$$P = (1 - p)^N = \left(\frac{c}{V}\right)^{\frac{N}{N-1}}. \tag{4}$$

Considering the game when the cost to volunteer is not symmetric across players, both the expected payoff from volunteering  $U_v$  and the expected payoff from not volunteering  $U_{nv}$  are the same as in (1). However, the probability of volunteering will vary across cost levels  $c_L$  and  $c_H$ . Diekmann (1993) solves for the likelihood

of defection in the mixed-strategy Nash equilibrium, which can be inverted to the probability of volunteering for player  $i$  as follows:

$$p_i = 1 - \frac{V}{C_i} \left( \prod_{j=1}^N \frac{C_j}{V} \right)^{\frac{1}{N-1}} \quad (5)$$

where  $j$  is the  $N$  group members. The likelihood that none of the  $N$  group members volunteer is:

$$P = 1 - \left( \prod_{j=1}^N \frac{C_j}{V} \right)^{\frac{1}{N-1}}. \quad (6)$$

We use these formulas in the following sections to explore the numerous symmetric, asymmetric and mixed strategy Nash predictions using the experimental parameters. We differentiate the intuitive equilibria from those that are counter-intuitive relative to social efficiency. We then consider how changes in one's cost to volunteer and the cost of other players impacts behavior across smaller ( $N=2$ ) and larger ( $N=6$ ) group sizes. Finally, we examine how incomplete information, modeled as a Bayesian game with common priors, offers insights into how uncertainty over relative cost alters the predicted strategy in the volunteer's dilemma.

#### 4.1 Full information

Each player has the same likelihood of drawing a high or a low cost, so there are exactly three outcomes for group size  $N$ : either all group members have symmetric low costs, all group members have symmetric high costs, or there is cost asymmetry (where half of the members have low and the other half have high costs). If at least one player volunteers, all group members receive the benefit of \$1.00.

In the full information condition, each player is informed of the cost draw for the entire group before making the volunteer decision. In the two symmetric cost cases modeled in Diekmann (1985), when  $N=2$  players face the same cost to volunteer, both players employ a mixed strategy where an individual player's probability of volunteering  $p$  while facing cost  $c$  satisfies the equation  $p = 1 - c$ . A player can either guarantee themselves a return of  $1 - c$  with certainty or choose to not contribute, in which case the expected return is  $p$ . These volunteer rates appear in the top portion of Table 2 along with the associated likelihood that the group experiences a no-volunteer outcome for this equilibrium.<sup>6</sup>

When the cost to volunteer differs across members of the group, there are two asymmetric Nash equilibria in pure strategies: one where the low cost player volunteers

<sup>6</sup> There are also asymmetric equilibria where one person volunteers and other group member (or members, when  $N=6$ ) do not, even when costs are identical. The random re-matching function of the experimental design would make this equilibrium challenging for coordination, but it is worthwhile to note.



**Table 2** Selected Nash predictions

	Costs	Types	Prediction for $p_i$	Predicted likelihood of a no-volunteer outcome
Full information				
Group size $N = 2$	Symmetric	$c_i = 0.2, c_j = 0.2$	0.8	0.04
		$c_i = 0.6, c_j = 0.6$	0.4	0.36
	Asymmetric	$c_i = 0.2, c_j = 0.6$	1.0	0
		$c_i = 0.6, c_j = 0.2$	0	0
Group size $N = 6$	Symmetric	$c_i = 0.2, c_{-i} = 0.2$	0.28	0.14
		$c_i = 0.6, c_{-i} = 0.6$	0.1	0.53
	Asymmetric	$c_i = 0.2, c_j = 0.6$	0.55	0.09
		$c_i = 0.6, c_j = 0.2$	0	0.09

**Table 2** continued

	Costs	Types	Prediction for $p_i$	Predicted likelihood of a no-volunteer outcome
Incomplete information				
Group size $N = 2$	Symmetric	$c_i = 0.2, (c_{-i} = 0.2)$	1.0	0
		$c_i = 0.6, (c_{-i} = 0.6)$	0	1
	Asymmetric	$c_i = 0.2, (c_j = 0.6)$	1.0	0
		$c_i = 0.6, (c_j = 0.2)$	0	0
Group size $N = 6$	Symmetric	$c_i = 0.2, (c_{-i} = 0.2)$	0.55	0.008
		$c_i = 0.6, (c_{-i} = 0.6)$	0	1
	Asymmetric	$c_i = 0.2, (c_j = 0.6)$	0.55	0.09
		$c_i = 0.6, (c_j = 0.2)$	0	0.09

and the high cost player does not, and vice versa. Although both are potential equilibria, Diekmann (1993) describes the equilibrium where the low-cost player is more likely to volunteer as the “more intuitive” equilibrium, as long as it is reasonable to assume that a player is more likely to volunteer if their costs are low than when they are high. The other more unintuitive equilibrium, where the high-cost player volunteers, provides the inspiration for Diekmann’s “unreliable” low-cost player where the high-cost player must step into provide the public good. Diekmann refers to the former case as the more “eligible” equilibrium, as it is the equilibrium that leads to the socially efficient, “aspirational” equilibrium in the volunteer’s dilemma.<sup>7</sup> Therefore, we identify the specific pure-strategy asymmetric equilibrium where the low-cost player volunteers

<sup>7</sup> There is also a mixed strategy Nash equilibrium that is similarly counter-intuitive. For  $N = 2$ , the probability that the low-cost player contributes is  $2/5$  and the high-cost player contributes with probability  $4/5$ .

(and the high-cost player defers) as the “more-intuitive” prediction that we use to compare to our experimental data.

When  $N = 6$ , there are three possible outcomes: all six players draw \$0.20, all six players draw \$0.60, or three players draw \$0.20 and the other three players draw \$0.60. In the two symmetric cost cases when all group members face the same cost to volunteer, players employ a mixed strategy where an individual player’s probability of volunteering  $p$  while facing cost  $c$  satisfies the equation  $1 - c = 1 - (1 - p)^{1/5}$ , thus  $p = 1 - c^{1/5}$ , similar to when  $N = 2$ . When costs differ, the more intuitive Nash equilibrium would again have the  $k$  low cost players in the group use a mixed strategy over a subgroup of  $k$ , while the high-cost players do not volunteer. If there are  $k$  players with low costs, the low cost players volunteer with probability  $p$ , where  $p = 1 - c^{1/(k-1)}$ . These more-intuitive volunteer predictions appear in Table 2 along with the associated likelihood that groups of  $N = 6$  experience a no-volunteer outcome under those predictions.<sup>8</sup>

Under the full information treatment, the more-intuitive Nash strategies lead to the low-cost player volunteering with greater frequency, which leads to greater social efficiency. Thus, we identify two hypotheses regarding these specific equilibria, as follows:

**Hypothesis 1a** An individual’s likelihood of volunteering  $p$  will exhibit the following among cost specifications: For  $p_{ij}$  where  $i$  is player  $i$ ’s cost and  $j$  represents the cost level of the other player (when  $N = 2$ ) and whether three other group members face the same or opposite cost (when  $N = 6$ ), we theorize that:

$$P_{H|L} < P_{H|H} < P_{L|L} < P_{L|H}. \quad (7)$$

**Hypothesis 1b** The likelihood of a no-volunteer outcome  $P$  is increasing in group size, which is predicted to be more than twice as likely when  $N = 6$  ( $P = 0.21$ ) than when  $N = 2$  ( $P = 0.1$ ).

## 4.2 Incomplete information

Modeled as a Bayesian game with common priors, each player knows their own cost in every round and they know the process of how other player(s) costs are distributed, but not the outcome in a given round. For  $N = 2$ , player  $i$  can volunteer and guarantee herself a return of  $1 - c_i$  with certainty. Following the strategy of volunteering when costs are low (and not when costs are high), because the other player’s cost is independently drawn with equal probability of  $c_L$  or  $c_H$ , the expected payoff of not volunteering is 0.5. For a player with  $c = 0.2$ , the guaranteed rate of return for volunteering is 0.8. Thus, given the expected returns, the low-cost player should always opt to volunteer. If  $c = 0.6$ , the return for volunteering is 0.4, while the expected payoff of not volunteering is still 0.5, so the high-cost player should never volunteer. Thus, there is a symmetric

<sup>8</sup> There is no purely mixed strategy equilibrium when  $N = 6$  with 3 of each type of player (low cost or high cost), as noted in Diekmann (1993). For  $N = 6$ , this means that players may be constrained to an equilibrium where one type (the high-cost player) does not mix, which is supported by the experimental data.

pure strategy Bayes–Nash equilibrium where both players volunteer if they have low costs and both players do not volunteer when they have high costs. The volunteer rates for the symmetric cost conditions and associated likelihood of a no-volunteer outcome appear in the lower portion of Table 2.<sup>9</sup>

When  $N = 6$ , there is no Bayes–Nash equilibrium using the strategy where one low-cost player volunteers and the other players do not volunteer in pure strategies.<sup>10</sup> However, there is again an intuitive mixed strategy equilibrium where low-cost players volunteer with probability  $p < 1$  and players with high costs do not volunteer. If the low-cost players volunteer with probability  $p$ , then each player will expect the other group members to volunteer with independent probabilities  $p/2$ . When this is the case, the probability that none of the other five group members will volunteer is  $1(1 - p/2)^5$ . Here, the return to the low-cost player who volunteers is 0.8, thus the low cost players volunteer with probability  $p$  if  $1 - (1 - p/2)^5 = 0.8$ . When  $N = 6$ , this leads to  $p = 0.55$ . This equilibrium prediction appears in the lower portion of Table 2, along with the associated likelihood that groups of  $N = 6$  experience a no-volunteer outcome.<sup>11</sup>

Under incomplete information, the intuitive Nash strategies predict volunteer rates as follows:

**Hypothesis 2a** An individual’s likelihood of volunteering  $p$  will exhibit the following among cost specifications: For  $p_i$  where  $i$  is player  $i$ ’s cost draw and whether other group members face the same or opposite cost is unknown to player  $i$ , we expect that:

$$p_H < p_L. \tag{8}$$

**Hypothesis 2b** The likelihood of a no-volunteer outcome  $P$  is increasing in group size, which is more likely when  $N = 6$  ( $P = 0.3$ ) than when  $N = 2$  ( $P = 0.25$ ).

Despite the potential for uncertainty to increase an individual’s inclination to volunteer, the likelihood of a no-volunteer outcome may still be higher, on average, under incomplete information than if players have full information, all else equal. The ability to recognize when there is cost asymmetry helps players to identify the more “reasonable” volunteer (either themselves or another group member) in the full information treatments. With incomplete information, the low-cost players may over-volunteer when the cost to volunteer is low and under-volunteer when the cost to volunteer is high, particularly when costs are symmetric. Thus, although there is the potential to

<sup>9</sup> For  $N=2$ , the expected rate of return to volunteering is always positive when the cost draw is low, while the expected return with a high-cost draw is always negative, so there are no mixed-strategy equilibria with  $N=2$  with incomplete information.

<sup>10</sup> It is straightforward to show that there is an asymmetric pure strategy equilibrium where the low cost players volunteer with probability  $p = 1$  and the high cost players do not volunteer if and only if  $N \leq 3$ . The payoff to the low-cost volunteers is 0.8. If we assume the high-cost players do not volunteer, the expected return to a low-cost player who does not volunteer is  $1 - (1/2)^{N-1}$ . There will be a pure strategy of this type only if  $1 - c > 1 - (1/2)^{N-1}$ , which is only true for  $N \leq 3$ .

<sup>11</sup> Although we use the more-intuitive predictions to make comparisons to the experimental data, it is worthwhile to note that the many other asymmetric and mixed-strategy Nash equilibria are still possible regardless of whether or not they are intuitive.

**Table 3** Observed volunteer rates ( $p$ ) across group sizes and information treatments

Group Size	Full Information			Incomplete Information		
	$N=2$	$N=6$	All	$N=2$	$N=6$	All
Volunteer rate ( $p$ )	48.3	26.6	37.5	57.3	35.7	46.5
$p$ when $c=\$0.20$	71.0	39.6	55.3	78.1 ( <i>1.0</i> )	60.2 ( <i>0.55</i> )	69.2
$p$ when $c=\$0.60$	25.9	13.7	19.8	36.1 ( <i>0</i> )	11.1 ( <i>0</i> )	23.7
$p$ when $c_i=\$0.20$ $c_{-i}=\$0.20$	51.4 ( <i>0.8</i> )	25.9 ( <i>0.28</i> )	38.7	79.8	64.8	72.3
$p$ when $c_i=\$0.60$ $c_{-i}=\$0.60$	37.0 ( <i>0.4</i> )	20.8 ( <i>0.1</i> )	28.9	34.3	10.2	22.3
$p$ when $c_i=\$0.20$ $c_{-i}=\$0.60$	91.9 ( <i>1.0</i> )	53.2 ( <i>0.55</i> )	72.6	76.5	55.6	66.1
$p$ when $c_i=\$0.60$ $c_{-i}=\$0.20$	15.7 ( <i>0</i> )	6.5 ( <i>0</i> )	11.1	38.1	12.0	25.1

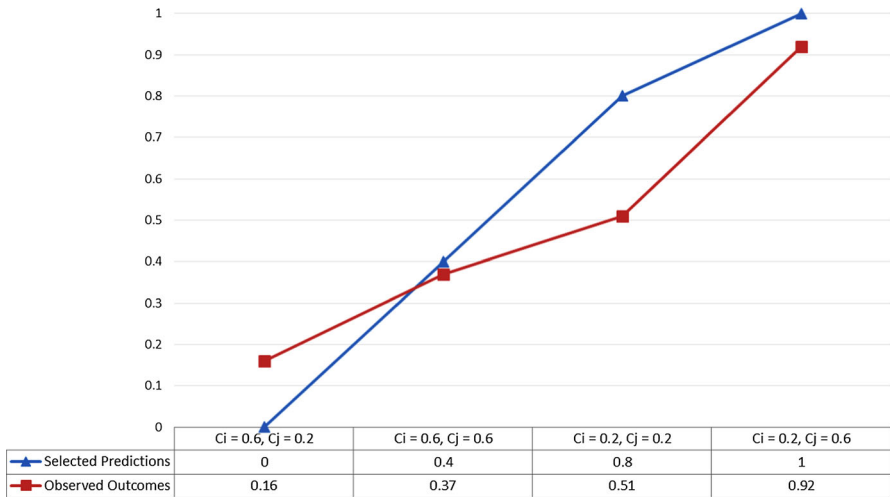
Selected Nash predictions are included where appropriate for comparison (italicized). The shaded areas in the table indicate empirical data for which subjects are unaware of which exact cost specification has been drawn, but are included here for completeness

see increased volunteerism and social welfare gains as a result of incomplete information, even the more-intuitive equilibrium strategies do not predict it as an outcome of the game.

## 5 Results and discussion

Several noteworthy results emerge from the experimental data. Table 3 shows the rate of volunteering under each of the treatments, partitioning the results into four cases; when all subjects in a group have a low cost to volunteer, when all subjects in a group have a high cost to volunteer, when the subject faces a cost of \$0.20 and at least one other group member has a high cost, and when the subject faces a cost of \$0.60 and at least one other group member has a low cost.

Overall, we find that people behave as predicted by the more-intuitive Nash strategies presented above, particularly in the full information treatments. The comparative results reveal that although incomplete information increases volunteer rates, the full



**Fig. 1** Actual and predicted probabilities of volunteering for player  $i$   $N = 2$ , complete information

information treatments remain more socially efficient overall. We go into further detail in each subsection below.

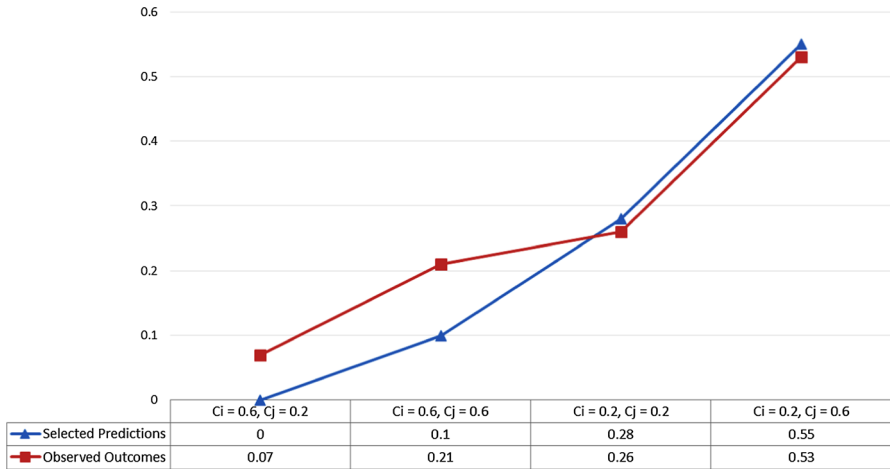
### 5.1 Full information

Starting first with full information and symmetric costs, we compare the second row of Table 3 with low costs ( $p$  when  $c = 0.20$ ) to the third row with high costs ( $p$  when  $c = 0.60$ ), and find that subjects are more likely to volunteer when they face a low cost than when their costs are high. Subjects appear to be sharing the responsibility of volunteering when costs are low by volunteering about half of the time when  $N = 2$  and around 26% of the time when  $N = 6$ .<sup>12</sup> In contrast, when the cost to volunteer is high for the entire group, the volunteer rates fall to 37 for  $N = 2$  and 21% for  $N = 6$ .

Figures 1 and 2 show how the experimental results compare to the selected predictions identified in Sect. 4.1. In particular, we find that the experimental data aligns with the intuitive Nash predictions quite well for  $N = 2$  with symmetric, *high* costs, and for  $N = 6$  with symmetric, *low* costs. However, when  $N = 2$  and costs are symmetric and low, the subjects under-volunteer ( $p = 0.51$  versus 0.8), but when  $N = 6$  and costs are symmetric and high, subjects over-volunteer ( $p = 0.21$  versus 0.1), which altogether replicate the findings regarding group size and volunteer rates found by Goeree et al. (2017).

Extending the analysis into the asymmetric cost treatments, we show that subjects are more likely to volunteer when the cost draw is low (as a more “able” volunteer in the group). The highest volunteer rate across the experiment was found for individual  $i$

<sup>12</sup> Although subjects in this experiment could not communicate, other experiments with repeated games have found successful instances of turn-taking. For example, in common-pool resources games (Cason et al. 2013), or in repeated allocation games (Kuzmics et al. 2014), or theoretically (in Leo 2017).



**Fig. 2** Actual and predicted probabilities of volunteering for player *i* when  $N = 6$ , complete information

when  $c_i = 0.2$  and  $c_j = 0.6$  and  $N = 2$ , which was  $p = 0.92$ . The lowest volunteer rate was found for individual *i* when  $c_i = 0.6$  and  $c_j = 0.2$  and  $N = 6$ , which was  $p = 0.065$ . For  $p_{ij}$  where *i* is player *i*'s cost and *j* represents the cost level of the other player(s), with the observed volunteer rates appearing in parentheses, we find support for Hypothesis 1a for both  $N = 2$ :

$$p_{H|L}(0.16) < p_{H|H}(0.37) < p_{L|L}(0.51) < p_{L|H}(0.92), \tag{9}$$

and for  $N = 6$ :

$$p_{H|L}(0.07) < p_{H|H}(0.21) < p_{L|L}(0.26) < p_{L|H}(0.53). \tag{10}$$

The asymmetric cost treatments demonstrate that a subject's relative cost of volunteering, as compared to their other group members, is an important determinant of their decision of whether to volunteer. We find that the rate of volunteering is positively correlated with other group members' costs, which suggests that people are more likely to volunteer when the other group members face a relatively high cost. This finding suggests that individuals make decisions in accord with the efficient outcome; that is, they volunteer when most necessary (when their own costs are relatively low or when all costs are high) to better ensure the public good is provided.<sup>13</sup>

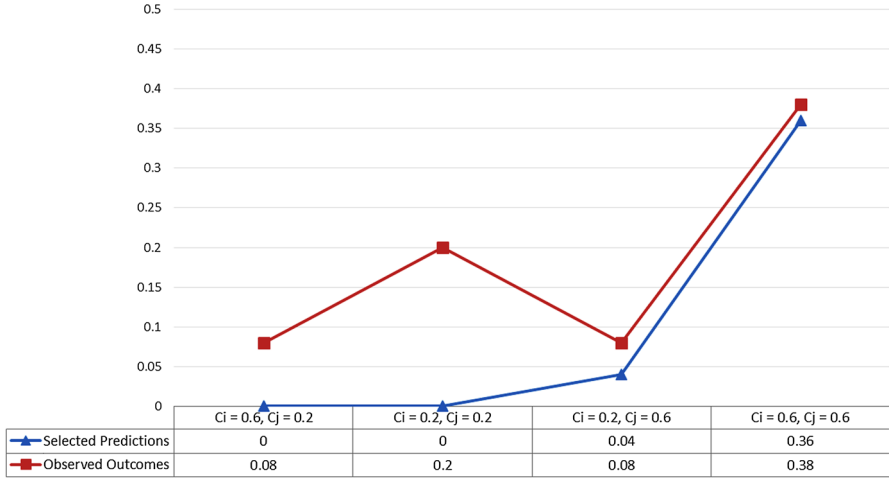
To confirm the above findings, we ran OLS regressions where we control for a variety of subject characteristics with the results appearing in Table 4. Each column represents an independent OLS regression with the dependent variable in the first row

<sup>13</sup> Hillenbrand and Winter (2018) find that lower costs to volunteer do not increase a player's likelihood of volunteering, but there are two critical experimental differences: (1) they use a one-shot version of the game so subjects only experience one cost specification and thus there is no opportunity to observe how an individual subject would change strategies in response to differing costs, and (2) the cost variations in that study were quite small, with a "low" cost of 4€ or a "high" cost of 5€, both with a benefit of 10€, which also likely contributed to the non-finding.

**Table 4** OLS regression results

	Volunteer probability ( <i>p</i> )	<i>p</i> when <i>c</i> = \$0.20	<i>p</i> when <i>c</i> = \$0.60	<i>p</i> when <i>c<sub>i</sub></i> = \$0.20 <i>c<sub>-i</sub></i> = \$0.20	<i>p</i> when <i>c<sub>i</sub></i> = \$0.60 <i>c<sub>-i</sub></i> = \$0.60	<i>p</i> when <i>c<sub>i</sub></i> = \$0.60 <i>c<sub>-i</sub></i> = \$0.20	Earnings (\$)
Group size (=1 if <i>N</i> = 6)	-26.58*** (6.04)	-23.86*** (8.82)	-28.43*** (6.95)	-15.88 (10.29)	-27.42*** (9.42)	-28.23*** (7.95)	3.38*** (0.64)
Information (=1 if full)	-10.52* (5.36)	-9.45 (9.69)	-17.65** (7.65)	-33.29*** (11.30)	-4.60 (10.35)	-28.36*** (8.74)	2.42*** (0.71)
Gender (=1 if female)	-5.69 (3.52)	-5.14 (4.10)	3.00 (3.23)	-5.70 (3.74)	4.16 (4.78)	5.08 (3.69)	0.010 (0.298)
College semesters completed	0.67* (0.35)	0.54 (0.51)	0.82** (0.41)	0.42 (0.60)	1.13** (0.55)	0.43 (0.46)	-0.02 (0.04)
Experience in experiment paid	-4.50 (2.82)	2.38 (4.12)	-10.39*** (3.24)	-0.30 (4.79)	-9.94** (4.39)	-11.01*** (3.70)	0.64** (0.29)
Major (=1 if bus/econ)	-0.59 (2.76)	3.22 (3.99)	-3.34 (3.15)	4.32 (4.66)	-7.33* (4.26)	0.80 (3.59)	0.36 (0.29)
R-squared	0.419	0.344	0.358	0.406	0.268	0.362	0.559
Observations	3456	1728	1728	864	864	864	3456

The dependent variable for each specification appears in the first row  
 Standard errors are clustered at the session-level. Robust standard errors in parentheses, \*significant at 10%, \*\*significant at 5%, \*\*\*significant at 1%



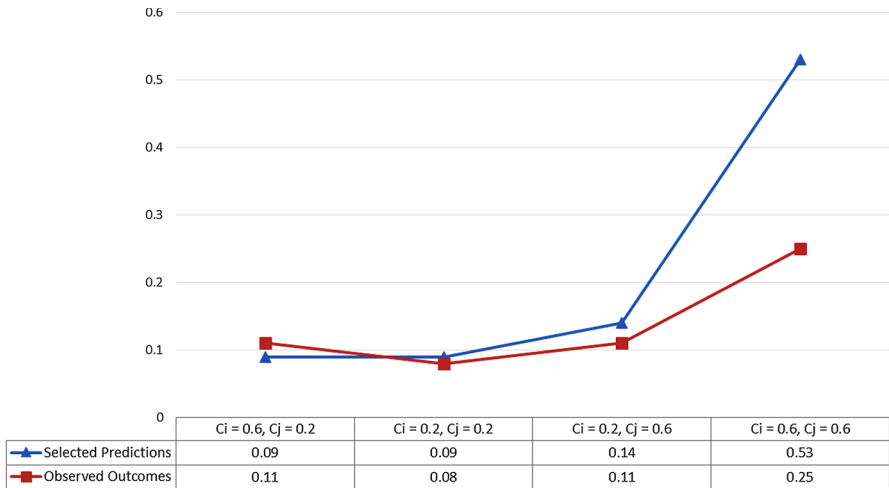
**Fig. 3** Actual and predicted probabilities of a no-volunteer outcome when  $N = 2$ , complete information

of the table. The first column tests the impact of group size, information, and other subject characteristics on the overall rate of volunteering. The focus of the remaining columns (2–7) is narrowed to examine each treatment specification in greater detail. The first column indicates that, overall, increasing the group size from 2 to 6 decreases an individual’s likelihood of volunteering, confirming the summary results from Table 3 presented above. Examining the different treatments further, we find that group size is relevant in all cases except when all group members face a low cost to volunteer.

As noted in prior studies (Goeree et al. 2017), the theory predicts an unintuitive result regarding group size in the volunteer’s dilemma: the likelihood of a no-volunteer outcome is increasing in group size, as a function of diffusion of responsibility. Figures 3 and 4 compare the experimental data to the predicted outcomes across group sizes. For  $N = 2$ , the observed rate of a no-volunteer outcome is greater than the Nash predictions across all cost specifications, thus smaller groups do not perform as well as the theory would predict. The last column in Table 4 regresses subjects’ earnings on the independent variables and because social efficiency is monotonically related to subject earnings in the experiment, the coefficient on this variable can serve as a proxy for overall efficiency. As seen in Table 4, the coefficient for group size is positive and significant, which indicates that larger groups are more efficient at providing the public good, and thus we do not find support for Hypothesis 1b. This may be due, at least in part, to the presence of certain “preference-type” players, which we explore in Sect. 5.4.<sup>14</sup>

<sup>14</sup> Another unintuitive result may be the lack of a significant gender effect. Vesterlund et al. (2015) find evidence from a coordinated volunteer’s dilemma that people believe that women are more likely to volunteer, but there is no evidence in our data to suggest a gender effect in any of the cost specifications or overall rate of volunteering. We revisit player behavior by gender again in Sect. 5.4.





**Fig. 4** Actual and predicted probabilities of a no-volunteer outcome when  $N = 6$ , complete information

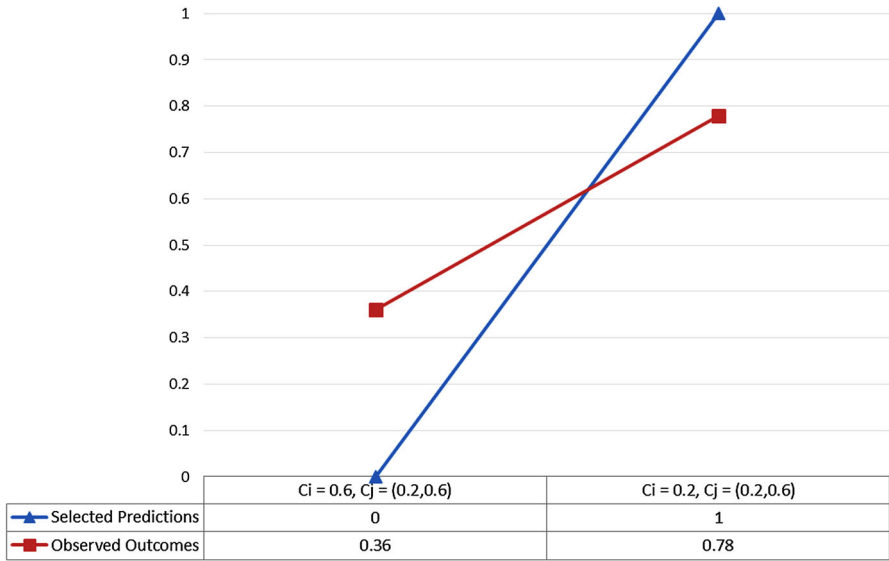
### 5.2 Incomplete information

Introducing uncertainty into the experiment adds another dimension to the volunteer’s dilemma previously unexplored. Although there are still four potential outcomes, these outcomes collapse down to two in the eyes of each player: either they face a low cost to volunteer or they face a high cost to volunteer. In either situation, it is equally likely that half of the group has the same cost or that half have the opposite cost.

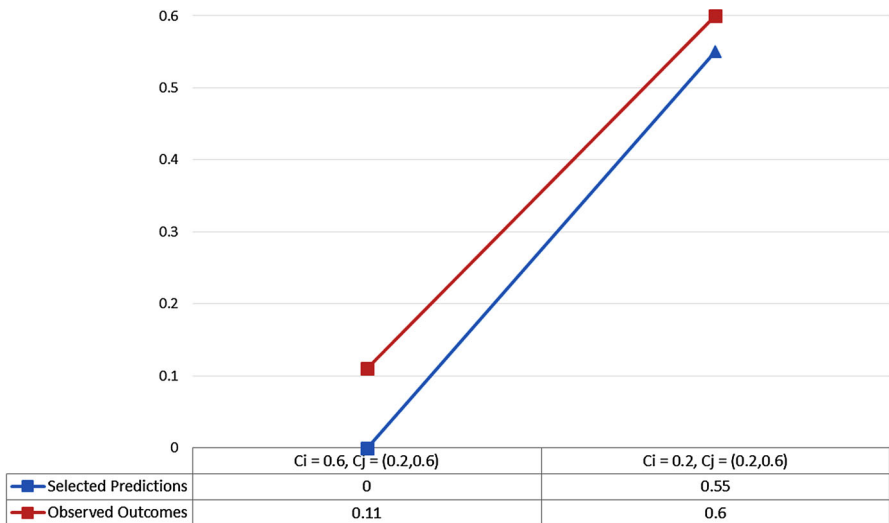
As in the full information treatment, we find that the volunteer rate when costs are low is significantly higher than when the cost to volunteer is high. Table 3 reports the average volunteer rates across cost specifications and group sizes for the incomplete information sessions. Figures 5 and 6 show the experimental results. When  $N = 2$ , subjects volunteer 78% of the time when costs are low and 36% of the time when costs are high. When  $N = 6$ , individuals volunteer approximately 60% of the time when costs are low and 11% of the time when costs are high. Thus, we find support for Hypothesis 2a across group sizes.

Figures 7 and 8 show the likelihood of a no-volunteer outcome across group sizes in incomplete information. Overall, the average likelihood of a no-volunteer equilibrium is again decreasing in group size ( $P = 0.21$  when  $N = 2$  versus  $P = 0.18$  when  $N = 6$ ), which contradicts Hypothesis 2b.

To compare the experimental results across information treatments, we begin by holding group size constant and examining volunteer rates under full versus incomplete information. Table 5 presents a series of probit regressions, with the dependent variable taking the value of 1 if the individual volunteered in the current period. Starting with  $N = 2$ , controlling for cost, subjects are significantly less likely to volunteer when they have full information. On average, when costs are low, subjects volunteer 78% of the time under incomplete information versus 71% with full information. When costs are



**Fig. 5** Actual and predicted probabilities of volunteering for player  $i$  when  $N = 2$ , incomplete information



**Fig. 6** Actual and predicted probabilities of volunteering for player  $i$  when  $N = 6$ , incomplete information

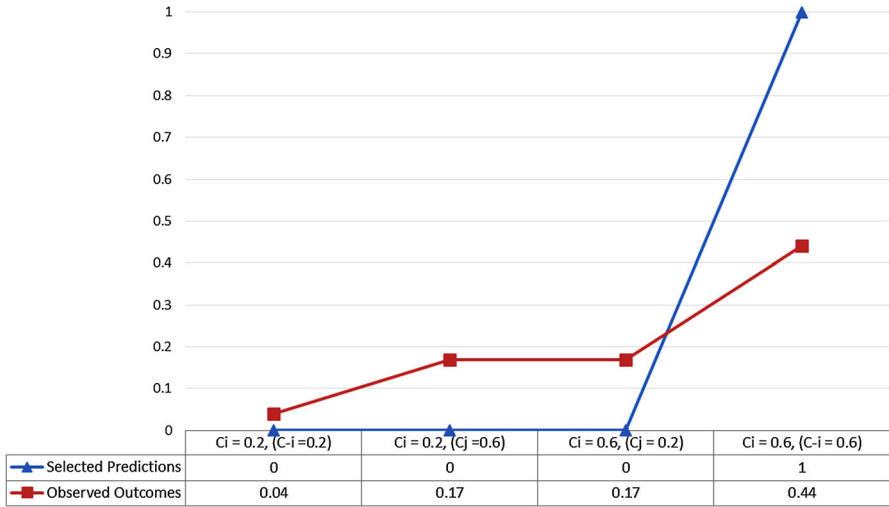
high, subjects volunteer approximately 36% of the time under incomplete information versus 26% with full information.

This pattern also holds for group sizes of  $N = 6$ . The largest difference across information treatments, all else equal, comes when costs are low: subjects volunteer 60% of the time under incomplete information versus approximately 40% of the time

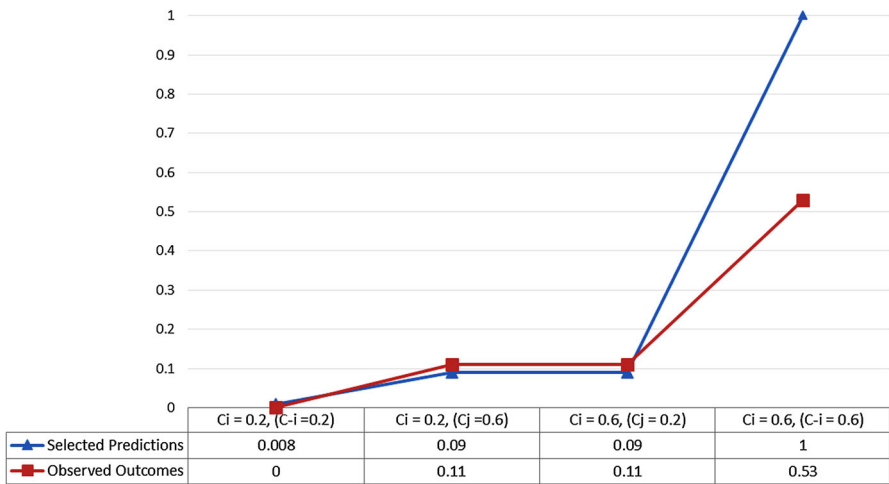
**Table 5** Probit regression results

	All treatments	Full information	Incomplete information	Group size <i>N</i> = 2	Group size <i>N</i> = 6
Group size (= 1 if <i>N</i> = 6) Information (= 1 if full)	-0.199*** (0.015) -0.082*** (0.015)	-0.20*** (0.021)	-0.182*** (0.022)	-0.084*** (0.022)	-0.085*** (0.020)
Cost in time <i>t</i> (= 1 if high)	-0.42*** (0.015)	-0.672*** (0.078)	-0.552*** (0.070)	-0.612*** (0.061)	-0.382*** (0.020)
Cost in time <i>t</i> - 1 (= 1 if high)	0.049*** (0.016)	0.195** (0.081)	0.069 (0.081)	0.129** (0.062)	0.023 (0.021)
Group members' cost in time <i>t</i> (= 1 if high)	0.068*** (0.015)	0.153*** (0.020)	-0.029 (0.021)	0.078*** (0.024)	0.074*** (0.020)
Group members' cost in time <i>t</i> - 1 (= 1 if high)	-0.072*** (0.016)	-0.068*** (0.022)	-0.065 (0.022)	-0.092*** (0.025)	-0.059*** (0.021)
Free-rider in <i>t</i> - 1	-0.07*** (0.016)	-0.036 (0.026)	-0.134*** (0.028)	-0.106*** (0.030)	-0.082*** (0.020)
R-squared	0.238	0.228	0.272	0.221	0.187
Observations	3456	1728	1728	1728	1728

The dependent variable is a dummy taking the value of 1 if the individual volunteered in time *t*. Probit coefficients are reported. Standard errors are clustered at the session-level. Robust standard errors in parentheses, \*significant at 10%; \*\*significant at 5%; \*\*\*significant at 1%



**Fig. 7** Actual and predicted probabilities of a no-volunteer outcome when  $N = 2$ , incomplete information



**Fig. 8** Actual and predicted probabilities of a no-volunteer outcome when  $N = 6$ , incomplete information

with full information.<sup>15</sup> As seen in Table 5, the coefficient for the information treatment is negative and significant, indicating that subjects volunteer less when they have full information. It is also interesting to note that the size of the effect of full information when  $N = 6$  is almost equivalent to its magnitude when  $N = 2$ . Not only does incomplete information increase the volunteer rate, it appears to have the same-sized effect on the rate of volunteering across group sizes of  $N = 2$  and  $N = 6$ .

<sup>15</sup> When costs are high, subjects volunteer approximately 11.1% of the time under incomplete information versus 13.7% with full information, which are not significantly different (*p* value of two-sided *t*-test = 0.39).

The regression results confirm the main findings that increasing group size and having complete information both have a negative effect on participation, by reducing the volunteer rate approximately 20 and 8%, respectively. Overall, increasing the cost to volunteer from \$0.20 to \$0.60 reduces the likelihood of volunteering by 42%, although this effect appears to be stronger in the full information treatment and when  $N = 2$ , and weakest when  $N = 6$ . Regardless of their own cost in the current period, a subject was 6.8% more likely to volunteer if someone else in their group faced a high cost. Not surprisingly, this effect was found only in the full information treatment when a subject knew the costs of other group members with certainty. Group size does not substantially change the size or significance of this effect.

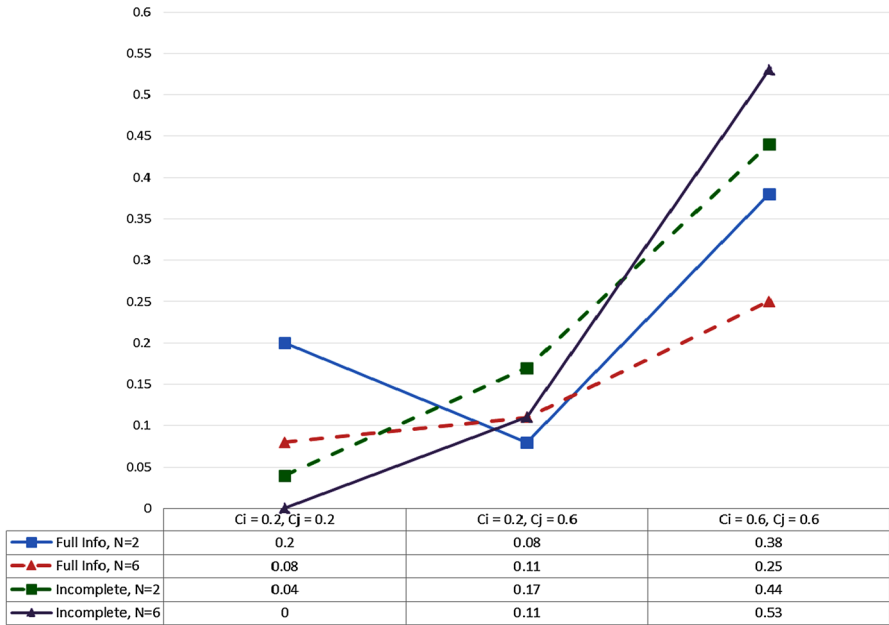
Turning last to the comparative results regarding the likelihood of no-volunteer outcomes, because average volunteer rates increase under uncertainty, the greater volunteering affords groups the potential to actually improve social efficiency by having less information. However, when we regress subject earnings on information, the coefficient for information is positive and significant, indicating that groups are still more efficient at providing the public good with full information than with incomplete information. More specifically, for  $p_{x|y}$  where  $x$  is the number of group members and  $y$  represents the information condition (full or incomplete), with the observed no-volunteer outcome rates in parentheses, we observe that:

$$P_{2|F}(0.185) < P_{2|I}(0.21) \quad \text{and} \quad P_{6|F}(0.14) < P_{6|I}(0.19). \quad (11)$$

Figure 9 presents the experimental findings across the four conditions. The likelihood of a no-volunteer outcome is greater, on average, under incomplete information than if players have full information.

### 5.3 Path-dependent behavior

In an effort to better understand the individual motives behind volunteering, we analyzed how experimental factors and outcomes from the current and prior period affect behavior in time  $t$ . We included variables for the subjects' own cost and the cost of their other group member(s) in the prior period in the probit regression presented in Table 5. If a subject faced a high cost last period, they were approximately 5% more likely to volunteer in the current period, even after controlling for all group members' costs in the current period. However, looking more closely, this result only holds for the full information treatment and when  $N = 2$ , suggesting that a subject needed to know that the other group member faced a high cost and that there was only one other person in the group available to volunteer. This finding could be capturing a situation in which a subject feels restricted from volunteering when they have a high cost, which creates a small incentive to volunteer in the next period regardless of cost.



**Fig. 9** Likelihood of a no-volunteer outcome

Additionally, we tested whether the outcome from the prior period had any effect on a subject’s likelihood of volunteering in the current period. For this test, we included a dummy variable for “free-riding” which took a value of 1 if the subject did not volunteer in the prior round and the public good was still provided. A successful free-rider was 7% less likely to volunteer in the current period even after controlling for the cost and information structure. Including an individual fixed effect to control for the overall propensity to volunteer leaves this result unchanged.<sup>16</sup> This result suggests that people are more likely to shirk the responsibility to volunteer if they see that a successful outcome was still achieved without their participation. This preference is further explored in the next section.

### 5.4 The role of preference types

Underlying the context of the volunteer’s dilemma is the existence of preference types among individuals and how this shapes the outcome of any given round. Although each person is better off when at least one person volunteers than if no one volunteers, there exists a spectrum of individual preferences that dictate behavior in not only this game, but any game with opportunities for free-riding. The preference types range from pure free-riders, who would rather risk the possibility of the no-volunteer outcome than ever step up to volunteer, all the way to “let me” types that benefit from the provision

<sup>16</sup> If we include an individual fixed effect in the regression in column 1 of Table 4, the coefficient for free-riding in the previous period is  $-0.072$ , with a standard error of  $0.021$ . The coefficients for all the variables that vary within-subjects remain essentially equivalent to those in column 1.

of the public good, but then also receive some kind of non-monetary boost to utility from being the volunteer (perhaps a “warm glow” à la Andreoni 1989). Other people fall somewhere in between, balancing the preference for anyone to volunteer with the disincentive to actually be the volunteer.

Preference types have been studied in a coordinated volunteer’s dilemma experiment by Bergstrom et al. (2015), who used a clever variation with a timing element to ascertain what proportion of people were “let-me-do-it” types versus the “no-not-me” kind of players, along with what they referred to as “last-resort-consequentialists” who volunteer at the last possible moment. Although we are not able to observe the latter preference type given the uncoordinated nature of this game and the possibility of multiple volunteers, our experiment does allow us to sort players according to how frequently they volunteer across all 24 rounds, with the added design element of cost asymmetry. Specifically, we can further examine different preference types according to how likely an individual is to volunteer when they are “strong” (low cost) versus when they are “weak” (high cost). Thus we can identify preferences to another degree relative to the proportional burden, such as “let-me” types who become “no-not-me” types in the face of higher costs.

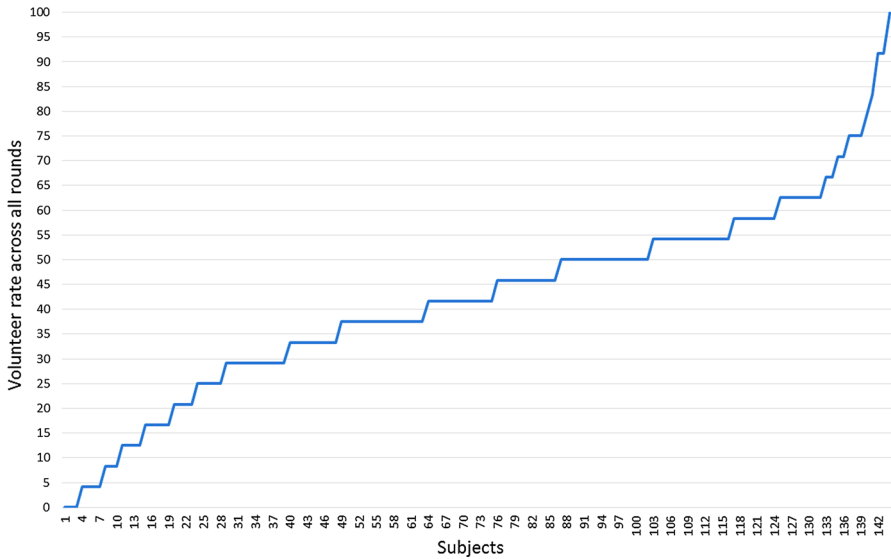
Figure 10 presents a cumulative distribution of preference types, sorted from pure free-riders (with a perfect 0% rate of volunteering) up to what we will call the “perpetual volunteer” types, who volunteer 100% of the time. As seen in the figure, almost all subjects fall somewhere in between, with the largest concentration of subjects in the 30–65% range of volunteering. Across 144 subjects, there was only one perpetual volunteer, but three pure free-riders, all male.<sup>17</sup>

Table 6 provides more information about the distribution of preference types across differing costs and group sizes. Considering first the “let-me” types, it’s clear that the disincentive to volunteer when costs are high is enough to outweigh any non-monetary boost to utility that one may experience from being the volunteer. With small groups ( $N = 2$ ) and low costs ( $c = 0.20$ ), 17% of people volunteer 100% of the time. When  $c = 0.60$ , that rate falls to 1%. With larger groups ( $N = 6$ ) and low costs ( $c = 0.20$ ), around 4% of people volunteer 100% of the time. When  $c = 0.60$ , not only does that fall to 0, the next range of rates (75–99% volunteering) also falls to 0. It would thus appear that the potential boost to utility from being the volunteer equates to less than \$0.40 in monetary terms in any given round.

Likewise, the incentive to free-ride also varies as costs increase and the relative return to free-riding changes.<sup>18</sup> In small groups ( $N = 2$ ) and low costs ( $c = 0.20$ ), 0% of people volunteer less than 25% of the time. When  $c = 0.60$ , the ratio of pure free-riders alone increases to 14%. When  $N = 6$  and  $c = 0.20$ , around 6% of people are pure free-riders, but when  $c = 0.60$ , that figure increases to 36%. Of course it’s important to note

<sup>17</sup> We found no significant gender effects in this experiment, either in rates of volunteering (*p*-value of a two-sided *t*-test = 0.905) or in preference types. Regarding the latter, is interesting to note that although those with the highest and lowest volunteer rates were men, women were the second and third next-highest volunteers in the sample, and women were also the next two lowest volunteers at the low side, right before the three pure free-riding males.

<sup>18</sup> A successful free-rider with cost  $c = 0.20$  has relative earnings of \$1.00 compared to \$0.80 if they volunteered (a 20% return on free-riding), while a successful free-rider with cost  $c = 0.60$  has relative earnings of \$1.00 compared to \$0.40 if they volunteered (a 40% return on free-riding).



**Fig. 10** Cumulative distribution of preference types

**Table 6** Frequency and distribution of preference types

Group size	Description of volunteer rates (in quintiles)	With a low cost to volunteer (quantity, ratio)	With a high cost to volunteer (quantity, ratio)	Overall (quantity, ratio)
<i>N</i> = 2	Always (100%)	12 (17%)	1 (1%)	1 (1%)
	Most of the time (75–99%)	27 (38%)	4 (6%)	7 (10%)
	Regularly (26–74%)	33 (46%)	33 (46%)	61 (85%)
	Some of the time (1–25%)	0 (0%)	24 (33%)	3 (4%)
	Never (0%)	0 (0%)	10 (14%)	0 (0%)
<i>N</i> = 6	Always (100%)	3 (4%)	0 (0%)	0 (0%)
	Most of the time (75–99%)	13 (18%)	0 (0%)	0 (0%)
	Regularly (26–74%)	39 (54%)	5 (7%)	47 (65%)
	Some of the time (1–25%)	13 (18%)	41 (57%)	22 (31%)
	Never (0%)	4 (6%)	26 (36%)	3 (4%)

that, for efficiency purposes, people should volunteer less frequently when their costs are high, but not to the level of never volunteering, since there are a significant number of rounds where all group members face a high cost. This information regarding preference types provides clear evidence of a bystander effect, which is more prevalent in larger groups than in smaller ones. All else constant, a larger group is more likely to have not just a greater number, but also a greater percentage of weak and strong free-riders (controlling for cost, when *N* = 2, 24% of people volunteer some of the time or never, but when *N* = 6, that figure rises to 58%). However, even with an increased



percentage of free-riders, larger groups are still able to provide the public good more frequently due to the greater likelihood that at least one person will volunteer.

## 6 Conclusion

While theorists have investigated how people should predictably behave in the volunteer's dilemma, only recently have social scientists used experimental techniques to investigate how people behave in a carefully controlled and incentivized environment. We contribute to the literature by examining how asymmetry in the cost to volunteer and information uncertainty affect the willingness of people to volunteer to provide the public good.

We find that increasing the cost to volunteer significantly decreases the rate of volunteering. We also able to show that the rate of volunteering is positively correlated with other group members' costs. In the context of examples presented above, our results suggest that if someone is drowning and there are two people nearby, then the better-enabled swimmer is more likely to jump into rescue the victim. The more-intuitive Nash equilibrium strategies predict subjects' behavior quite well across both full and incomplete information.

By extending the model to introduce incomplete information, we show that uncertainty about fellow group members' abilities (cost to volunteer) results in an increased volunteer rate. Although we find weak evidence that this increase in volunteering has the potential to improve social welfare in the volunteer's dilemma, primarily by reducing the likelihood of no-volunteer outcomes, the increased rate of volunteering does not lead to an increase in social efficiency in our experiment. Perhaps uncertainty may have a larger positive effect in an environment where no-volunteer outcomes are more common, but that positive effect has to outweigh the social wastefulness that occurs when more than one person volunteers in a given round (resulting in redundant costs).

The role of preference types demonstrates the presence of a bystander effect and the experimental data show this effect to be more prevalent in larger groups than in smaller ones. All else constant, a larger group is more likely to have a greater quantity of volunteers, but also a greater percentage of weak and strong free-riders. Despite the additional number of free-riders, larger groups are still able to provide the public good more frequently due to the greater likelihood that at least one person in the group will volunteer.

Our findings contribute to the development of accurate models of volunteer behavior and to our understanding of how individuals respond to changes in the relative cost to volunteer, as well as when we face uncertainty regarding the abilities other potential volunteers nearby. In circumstances where increasing the rate of volunteering could improve social welfare, understanding the motives behind when and why individuals volunteer allows for the opportunity to design institutions that create the incentives needed to produce greater volunteerism.

## Appendix

### Instructions [language variations by treatment indicated in brackets]

This is an experiment in decision-making. Various research agencies have provided funds for the conduct of this research. The instructions are simple and if you follow them carefully and make good decisions, you may earn a considerable amount of money that will be paid to you in cash at the end of the experiment. What you earn depends partly on your decisions and partly on the decisions of other participants in this experiment. It is in your best interest to fully understand the instructions, so please feel free to ask any questions at any time. It is important that you do not talk or discuss your information with other participants in the room during the experiment.

In this experiment, you will be interacting with the other participants in a sequence of 24 rounds. In each round, you will be matched with one other person selected at random from the other participants. You will be randomly re-matched with a new person in each round. The decisions that you and the other person make will determine your earnings.

[When  $N = 2$ : Both you and the other person will decide whether to pay a cost to undertake an action that benefits both of you.] [When  $N = 6$ : Both you and the other people will decide whether to pay a cost to undertake an action that benefits all of you.] You will not be able to see the others' decision while choosing yours and vice versa. The full benefit from this action is available to all if at least one person undertakes the costly action. No additional benefits are given if more than one person chooses to pay this cost.

In each round, you will decide whether to make a costly decision, which is referred to as an investment. If you decide to **invest**, you will pay a cost of either \$0.20 or \$0.60, each with an equal probability. This is the same as saying that, in each round, your cost is decided by a coin flip where heads gives you a cost of \$0.20 and tails gives you a cost of \$0.60. [Full information treatment: You will be able to see both your cost and the cost of the other person/people in each round before making your investment decision.] [Incomplete information treatment: You will be able to see your cost in each round before making your investment decision, but you will not know the cost of the other person/people.] If your decision is to **not invest**, your cost is \$0.

If at least one person decides to invest, each person will receive \$1.00, whether or not he or she invested in that round. For example, if at least one participant invests, then the participant who invests with a cost of \$0.20 will earn  $\$1.00 - \$0.20 = \$0.80$  and a participant who doesn't invest earns \$1.00. If nobody invests, you both earn \$0.

Again, there will be 24 rounds total, and in each round you will be randomly re-matched with another participant. You will need to keep track of your investment decision, cost, and your earnings for every round. If you have a question now, please raise your hand.

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