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Slow and deliberate cooperation in the commons

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Slow and Deliberate Cooperation in the Commons

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Abstract

We test how fast and slow thought processes affect cooperation for sustainability by manipulating time pressure in a dynamic common pool resource experiment. Sustainable management of shared resources critically depends on decisions in the current period to leave enough stock so that future generations are able to draw upon the remaining limited natural resources. An intertemporal common pool resource game represents a typical dynamic for social dilemmas involving natural resources. Using one such game, we analyse decisions throughout time. We find that people in this context deplete the common resource to a greater extent under time pressure, which leads to greater likelihood of stock collapse. Preventing resource collapse while managing natural resources requires actively creating decision environments that facilitate the cognitive capacity needed to support sustainable cooperation.

Overextraction of natural resources in the present can lead to negative consequences for society and is at odds with most definitions of sustainable development (1). According to Pearson (2), "the core of the idea of sustainability is the concept that current decisions should not damage prospects for maintaining or improving living standards in the future." Essential for sustainability and important to many aspects of human and animal behaviour (3-6) is cooperation. Societies with imperfect, incomplete, and shared property rights face social dilemmas characterized by conflict between individual and collective interests. Cooperative solutions in social dilemmas require individuals to overcome selfish myopic incentives to achieve better social outcomes. Across many social dilemmas, myopic resource use often yields immediate, tangible, and easy to understand benefits; while long-term cooperative and sustainable stewardship of the resource involves more thought, planning, and coordination, along with benefits that are less certain and harder to calculate (7). Understanding how cognitive pressures influence common pool resource (CPR) outcomes is vital for designing interventions to prevent resource collapse and support sustainable collective decision processes.

Effective stewardship of the commons requires understanding how institutions and cognitive factors contribute to cooperation. An expansive literature considers which institutions can establish cooperation in CPRs and why these institutions work (8-12). While institutions have been rigorously explored in relation to CPRs, less is known about what cognitive factors and decision environments produce sustainable cooperation in CPRs. One particularly salient question is: do fast (intuitive) or slow (deliberative) thought processes better support sustainable use of a common pool resource? We find experimental evidence that groups drawing on a common pool resource are *less* likely to cooperate under time pressure. Instead, a slower, more deliberative, decision process supports cooperation which extends the life of the common pool resource and improves social welfare.

Our experiment uses time pressure manipulation on an intertemporal CPR. While much of the previous experimental work on social dilemmas and cognition has focused on one-shot games, natural resources are often characterized as stock variables (ex. wetlands, fisheries, groundwater) which are not independent of human behaviour in previous periods. These natural assets also cannot be easily regenerated if collapse occurs. By tracking a stock of resources in our experiment we can evaluate when group behaviour causes collapse of the resource which is paramount in understanding sustainable development, the reconciliation of society's goals and the limits of the earth's natural resources (13,14). We have found only one other intertemporal experiment using time pressure which examines intertemporal preferences (15) and no previous experiments involving intertemporal social dilemmas and cognitive manipulations, such as time pressure. The dynamic CPR game we employ allows us to determine how cognitive scarcity, that is present in each decision time frame, impacts the depletion and survival of shared stocks over time. Our experiment further tests whether fast and slow thought processes behave similarly in dynamic CPRs to one-shot social dilemmas.

Common pool resource decisions – and resource decisions in general – are frequently made by individuals who face cognitive constraints. For example, the condition of poverty inhibits farmers' ability to make good decisions due to cognitive resources being consumed by financial concerns, an equivalent of losing 13 IQ points (16). Risks from the natural system, such as weather variability and droughts, also tax mental resources (17). Recent research suggests that scarcities of time and money focus our cognitive system on these particular scarcities, leaving little cognitive bandwidth left to solve other problems (18-20). This may make an escape from poverty more difficult, as the condition of poverty causes poor communities to heavily discount future consequences of extraction behaviour: cognitive scarcities contribute to poverty traps (21). One efficient strategy when faced with cognitive constraints is to apply heuristics, fast and simple rules, which simplify the decision environment. These strategies adopted by subjects in dynamic CPRs under limited cognitive resources could have important implications to the sustainability of natural resources.

It is common for experimenters to use time pressure to shine a light on the innate thought processes of individuals. As a cognitive constraint, time pressure is used to distinguish between fast instinctive strategies and slow deliberative strategies in the dual process theory of cognition (22-26). Through applying time pressure to participants' decisions we can determine if fast, instinctive strategies are more sustainable than slow, deliberative ones.

There are two types of cooperation in a game theoretic setting: pure cooperation, which is cooperation when defection strictly maximizes payoffs (ex. one-shot social dilemma games), and strategic cooperation, which is cooperation that can be long-run payoff maximizing (ex. coordination games). Previous studies find evidence of increased cooperation under time pressure in one-shot social dilemmas (27-30). This increased cooperation can be explained by a dual process theory of cognition called the Social Heuristics Hypothesis (SHH) (5,6,31). SHH predicts that deliberation can undermine pure cooperation but may support strategic cooperation if the context is sensitive for intuitive thought processes (31,32). A recent meta-study (30) finds evidence for the prediction of increased cooperation in social dilemmas when people rely more on intuitive thought processes and finds no effects on cooperation of cognitive manipulation (ex. time pressure or cognitive load) in games with the potential of future benefits. Though, there is a recent study finding decreased cooperation under time pressure which is attributed to confusion (33). According to SHH, deliberation would either have no effect or increase cooperation in our setting because cooperation can be payoff maximizing over the life of the common pool resource, similar to a coordination game. Since none of the time pressure studies to date include intertemporal games our experiment adds new evidence of cooperative behaviour of individuals subjected to cognitive scarcities.

Utilizing a between-subject comparison test (between participants under time pressure and participants without a time constraint) we find participants behave more myopically when limited by time constraints, which is consistent with SHH. Thus, common pool resources have a higher probability of failure when managed by people under cognitive scarcities, a finding which contrasts the findings from previous time pressure experiments. We explore three potential reasons for this result which include: errors in judgment (34,35), slow adjustment of extraction strategies during the game (36), and intuitive heuristics for myopic extraction (5,6,31). Our results highlight the benefits of examining intertemporal dynamics over one-shot games to understand how cognition and cooperation unfolds to promote sustainable development.

Dynamic CPR Model

There are numerous economic experiments with dynamic CPRs that investigate different institutions which propagate cooperation (37,38). Our experiment uses a dynamic CPR model used by Kimbrough and Vostroknutov (39). This model considers an inexhaustible private resource and an exhaustible shared resource. Socially optimal resource exploitation in this game requires drawing heavily from the shared resource early and preserving it as time passes. In each period, n players simultaneously remove tokens from an inexhaustible private account and a shared exhaustible group account with the constraint that only 60 tokens in total can be taken in a period. Tokens from the group account are worth twice as much as tokens from the individual account. Each group member i chooses the number of tokens to extract, e_{it}, from the group account at time *t*. The sum of the group members extraction is $E_t = \sum_{i=1}^{n} e_{it}$. The group account acts as the stock of a common pool resource in the experiment and the private account acts as the opportunity cost of extraction.

The group account replenishes at a rate, β, each period, multiplied by the difference between the remaining group account balance and a maximum size of the group account, $\overline{w}$. Thus the group account, w_t, evolves over time according to the following formula: $w_t = w_{t-1} - E_{t-1} + \beta(\overline{w} - w_{t-1} - E_{t-1})$. The size of the group account in the present period directly depends on the size of the group account in the past round and the decisions made by group members in that round. To realize regrowth of the group account, groups must maintain a group account level above a threshold, τ. Whenever the group account is reduced below this threshold there ceases to be any regrowth in the group account and the resource collapses. In our experiment β was set at 0.25, the minimum threshold, τ, was set equal to 30 tokens, and $\overline{w}$ was set to 360 tokens.

We parameterize a relatively small regrowth rate in our experiment so that the symmetrical Subgame Perfect Nash Equilibrium (SPNE) is to exhaust the resource as fast as possible though gains for the group can be higher if they do not exhaust the resource. The socially optimal strategy in this game is to maintain the group account indefinitely to prevent the collapse of the group account. The path of the socially optimal extraction depends on the parameters of the experiment and consists of a set of group account dependent choice rules, detailed in the Methods section.

This model describes situations where societies discover a virgin resource, extract much of it, and then attempt to jointly conserve the remaining resource. The presence of a threshold, below which the stock will not regenerate, is also a pillar of ecological theory (40) and is descriptive of many real-world common pool resource dilemmas.

Results

Figure 1 shows the evolution of the average group account (stock) size for time pressure and non-time pressure groups. The lower stock path of time pressure groups indicates greater extraction and lower survival rates of group accounts in the time pressure treatments as compared to those under no time pressure. This suggests that time pressure leads to less cooperation and shorter survival of the common resource.

We use a Cox proportional hazard model to estimate the treatment effect of time pressure on the probability of failure of the group account. This method of survival analysis is commonly employed in medical research to measure causal effects on the probability of an event, such as death or relapse, and in economics and political science to evaluate duration data (41-44). The model is appropriate to analyse the event of failure of the group account in our experiment since the timing of collapse is a type of duration data.

Analysis at the individual level in Table 1 suggests an effect from the imposition of time pressure (group level analysis is provided in Supplementary Table 1). We find that individuals exposed to time pressure face an increased rate of failure of 101.3% ($2.013 = e^{0.700},\ p < 0.01$) over the control group in Table 1, column 2. This is sometimes referred to as the hazard ratio in survival analysis studies. A similar pattern is present for individual differences in Cognitive Reflection Test (CRT). An increase in correctly answered CRT questions reduced the rate of group account failure by 79% (p<0.05). The coefficient on the percentage of CRT questions answered correctly indicates that participants who do not repress their intuitive thought process induce a greater probability of failure of the group account. This finding is also consistent with the average treatment effects of time pressure. The rate of increase in hazard ratio is roughly equivalent across time periods with the difference in hazard ratios being proportional, which is an important assumption in the Cox proportional hazards model. The results suggest that time pressure significantly increases the failure rate of the group account in the intertemporal CPR game which adds a different finding from much of the existing literature on cooperation and intuitive decisions in one-shot social dilemmas.

Extraction Behaviour

We also explain the effect of time pressure on the deviation of observed extraction from the optimal extraction behaviour ($Socially\ Optimal\ Extraction - Observed\ Extraction$). We analyse this difference in extraction behaviour because the socially optimal extraction path is group account dependent and incorporates the level of the group account as a decision making variable that is nonlinearly related to extraction decisions. Using a simpler extraction measure, like the number of group tokens extracted, may be misleading as participants adjust to changing group account levels across rounds of the game. In the following analysis we only include rounds of the game before exhaustion of the group account since the observed behaviour after exhaustion is trivial.

In Table 2 we find that time pressure induces greater extraction of the resource. A negative coefficient indicates the variable increases extraction relative to the social optimal, which in turn would increase the relative risk of collapse of the resource. The treatment effect is statistically weak without any controls, which suggests the time within game is important to the size of the treatment effect. As a robustness check, the SI reports results including subjects and groups who violated the time limit to test whether results are explained by systematic differences between the participants who meet the time constraint versus those who do not (Supplementary Table 3). In some one-shot games there is a loss of support for intuitive cooperation when including these participants. We find attenuated estimates of our treatment effect with the inclusion of subjects who violate the time limit. We also take a further look at round differences in Supplementary Table 4. The coefficient on time pressure is negative though the coefficient on CRT score is not statistically significant. Combined with our survival analyses (Table 1) and Supplementary Tables 2, 3, and 4, this gives us some confidence that the cognitive scarcities in the dynamic common pool resource game induce less cooperative behaviour and increase the risk of group account failure through greater myopic extraction.

Discussion

Our results indicate one domain in which intuitive judgment under limited cognitive resources leads to more myopic behaviour, to the detriment of the individual and group welfare. We find in an intertemporal social dilemma game, participants with cognitive scarcities have a propensity to extract more from a shared resource stock. This result provides empirical evidence of when individuals are deliberatively cooperative, which has previously drawn almost exclusively on static social dilemma experiments (5,27,28). In an intertemporal setting, individuals require the cognitive bandwidth for sustainable management of the resource, and deliberation supports cooperation in this setting.

Since many common pool resource situations are intertemporal in nature, our results are more germane to these contexts than those of traditional one-shot games (27,28). Such one-shot games are limited in their ability to capture the development of intertemporal dynamics, which can have large impacts on sustainable development. In one-shot games the logical action is to extract as much as possible. However, in intertemporal games with repeated interactions cooperating in maintaining the resource becomes a more viable strategy (45); a phenomenon which helps explain the success of some common pool resource management programs (46). So it is interesting that the imposition of time pressure decreases the probability of survival of group accounts in our experiment, which suggests these CPR success stories were in spite of intuitively myopic behaviour.

We explore three potential reasons for the contrast between our results and those of prior static non-cooperative games. The first possibility is that people make more mistakes when confronted with a difficult problem under time pressure (34, 35). Such stochastic mistakes may increase the variance in play from participants and the group account may be inadvertently exhausted. To evaluate the variation in extraction behaviour we compare the absolute value of the deviation of extraction decisions between rounds ($Absolute\ Deviation = |\ e_{i,t} - e_{i,t-1}|$) in Supplementary Figure 1. A greater value of the absolute deviation from the time pressure treatment would indicate that stochastic behaviour, or random mistakes, may play some role in additional failure of groups in the survival analysis. Our results suggest that stochasticity in choice is similar between time pressure treatments. This however does not suggest that other mean shifting errors in extraction do not exist.

A second explanation for the departure from past one-shot game results is that the design of the game encourages large extraction decisions at the beginning of the game and cooperation requires restraining extraction behaviour once the group account nears the threshold for failure. The initial extraction behaviour could induce inertia in participants under time pressure leading to a slower adaptation to optimal levels of extraction. Alós-Ferrer et al. (36) found that inertia as an automatic process conflicts with a more rational deliberative one, consistent with the dual process view of decision making. We can use the change in extraction behaviour to analyse inertia as well as variance in individual extraction behaviour. A smaller absolute value of the difference in extraction decisions indicates greater inertia in extraction decisions. We find no difference in inertia between time pressure treatments, which puts serious doubts on inertia as an explanation for increased extraction and greater failure of CPRs (Supplementary Figure 1).

A third explanation, the main hypothesis for interpretation of these results, is that the dynamic aspect of the game affects intuitive cooperation among subjects. The data from our experiment supports the proposition of quick and fast myopic behaviour in the commons. Our finding is consistent with the SHH (5,6), wherein deliberation can sometimes increase cooperation in settings where cooperating can be a long run payoff-maximizing strategy. Such an increase in cooperation can be favored by natural selection or learning – and thus is expected to occur – if cooperation is typically long-run advantageous and intuition is sufficiently sensitive to context (31), or if most interactions are one-shot and the distribution of deliberation costs satisfies certain conditions (32). Deliberation promotes cooperation when it leads people to attend to the features of the dynamic CPR which realize cooperation as a more efficient strategy. If people only really confront the nature of the collapsing resource when they have time, deliberation would override myopic impulses.

Many decisions in our society can be characterized as dynamic choices under cognitive scarcities. Our research provides insights into instinctive human behaviour, enabling us to shed light on whether humans behave more myopically under temporally dynamic common pool resource scenarios with quick and fast decision processes. This may well mean that cooperation in the commons is more difficult to sustain because of intuitively myopic behaviour and the use of policy tools becomes even more important to combat over-extraction in the commons. It is also unclear how to provide the cognitive bandwidth necessary to support cooperative behaviour since it can be presented through a combination of factors, though efforts to mitigate these stressors for individuals operating in a common pool resource context could provide an important support tool to sustainable collective management.

The results also highlight the implications of generalizing results of one-shot games to situations that involve intertemporal trade-offs, or repeat interactions, when considering sustainability. One-shot games are poor substitutes for dynamic games when exploring cognitive processes of human behaviour and sustainability. To evaluate the importance of deliberation in thought processes to cooperation in common pool resources more aspects of these games need to be explored. Specifically, there is a need to investigate how group size, uncertainty in natural systems, and institutions affect the cognitive thought processes and cooperation to support sustainable management.

Methods

Data

A total of 120 undergraduate students were recruited at a public university in the northeastern United States and paid based on their performance in the game. Participants played three cycles of the intertemporal CPR game in the Spring and Fall of 2016, a cycle is one set of rounds of the same CPR game with the same group. In each cycle, a participant extracted tokens from a group account shared with 3 other anonymous participants (a representative decision screen is shown in Supplementary Figure 4). The last round (decision period) in each game was randomly predetermined and not communicated to the participants to avoid last round effects. Participants were randomly and anonymously regrouped after each cycle into a new group.

Participants received a show-up fee of $10 and the average payout at the end of the game was $18.70. The payout was based on each individual token taken from the private account yielding a return of 0.8 cents while the tokens taken from the public account yielded 1.6 cents each. The economic experiment software Z-tree (47) was used to run the experiment. There were three cycles in the experiment with a predetermined fixed length; the first cycle lasted 12 rounds, the second cycle lasted 15 rounds, and the third cycle lasted 8 rounds. Participants were not told how many rounds to expect or that there would be multiple cycles during the experiment.

Prior to the game, participants answered a three question Cognitive Reflection Test (CRT) (shown in Supplementary Figure 3) under a 90 second time constraint (48). The Cognitive Reflection Test can determine whether participants can suppress an intuitive answer which uses little conscious deliberation (“System 1” spontaneous, intuitive thinking) and employ a slower and more reflective cognitive process (“System 2” processes requiring mental effort and reasoning) when making decisions. If a subject did not answer all three of the CRT questions before the end of the 90 seconds then they were recorded as having not finished the CRT and as having answered none of the questions correct.

In addition to the CRT, participants answered demographic questions (as shown in Supplementary Figure 2). Next participants were given instructions about the dynamic CPR game (a representative copy of these instructions is provided in the Supplementary Information). The experimenter read the instructions to the participants, who were required to correctly answer 3 comprehension questions to confirm their understanding of the game. Experience with other economic experiments, time to complete the comprehension questions, CRT scores, gender ratios, and areas of study of the subjects were similar between treatment and control groups. Indicators for whether a participant was majoring in environmental economics or biology were included because of the potential for effects from their educational program of choice on their decisions.

The participants in half of the experimental sessions were exposed to time pressure constraints with a 7-second per round decision time limit. This constraint was chosen because the decision times of subjects within sessions without time pressure indicated that it would be a binding constraint for the majority of them. There was a clock visible to subjects counting down the time and the decision screen disappeared after the 7-second limit was reached. Time pressure was instituted by requiring participants to make extraction decisions within 7-seconds, and if the time constraint was violated then the participants earned zero tokens (public or private) for that round. When subjects violate the 7-second time limit no tokens are taken from the group account for that subject. To ensure differences in extraction decisions are active choices rather than inaction, 31 out of 2,440 observations where subjects do not make a decision within the time constraint are excluded in the analysis. Similarly, 16 out of 90 groups with a subject who did not enter an extraction decision within the time constraint are excluded from the survival analysis so that any interdependency between that zero-extraction observation and overall survival is not biased. Most participants in sessions without a time constraint took longer to make a decision than the time constraint would have permitted (indicating the 7-second time constraint was binding on average); we find the difference in mean decision time between treatment and control groups is statistically significant at the 1% level using a Mann-Whitney two sample statistic test.

We employ a series of statistical tests to estimate the treatment effect of time pressure and the effect of greater CRT scores on cooperative behaviour to understand the cognitive underpinnings of cooperation in a dynamic CPR.

In the model for the dynamic game, the size of the group account (stock) in the present period directly depends on the size of the group stock in the past period and the decisions made by group members in the past period. In our experiment β was set at 0.25 and, τ, was set at a stock size of 30 tokens (if the stock size fell below 30 tokens, the group account would not regenerate lost tokens).

There exists a myopic strategy in this game which is the Subgame Perfect Nash Equilibrium (SPNE), wherein each player extracts the maximum amount until the group account is depleted. In the SPNE, forward-looking individual agents consider the trade-off between assured present benefits and uncertain future benefits (measured in terms of tokens extracted from the group account). This SPNE depends on the parameters of the experiment, primarily the relative values of β, τ, and n. Specifically, when $\beta < \frac{\tau(n-1)}{\bar{w}-\tau}$, or regrowth of the resource is relatively small, there is an SPNE where it is optimal for individuals to exhaust the resource, which is established in the Supplementary Information. Here we demonstrate the SPNEs for our specific parameterization. The level of effort, e_{it}, exerted by individual *i* at time *t* is equivalent to the number of group tokens extracted in the experiment. The maximum effort, $\bar{e}$, is the total amount of effort the participant has available to extract from the group account. If $\beta > \frac{\tau(n-1)}{\bar{w}-\tau}$ and $\tau \leq \bar{e}$ the SPNE decision rule is such that we retrieve a set of decision rules that are dependent on the size of the stock in the previous round. The set of decision rules are: choose $e_{it} = \bar{e}$ if the resource stock is $w_{t-1} \geq n\bar{e} + \tau$; $e_{it} = \frac{w_{t-1}-\tau}{n}$ if $w_{t-1} \in [\tau, n\bar{e} + \tau)$; $e_{it} = \frac{w_{t-1}}{n}$ if $w_{t-1} < \tau$; $e_{it} = \min\left\{\bar{e}, \frac{w_{t-1}}{n}\right\}$ if $w_{t-1} < n\bar{e} + \tau$. These results indicate the symmetric stock specific extraction paths by all participants of a group and mimic the social planner's extraction path. These rules indicate that when the regrowth rate of the stock is relatively high, participants have an incentive to maintain the resource in order to reap the benefits of future periods of the stock and the growth of that stock. When the regrowth rate is relatively small and $\beta < \frac{\tau(n-1)}{\bar{w}-\tau}$ and $\tau \leq \bar{e}$ then the optimal decision rule is to extract $e_{it} = \min\{\bar{e}, \frac{w}{n}\}$. This extraction path drives the stock to extinction and is similar to the Nash Equilibrium in the prisoner's dilemma game. The proof of the optimal decision rule for our experiment can be found in the Supplementary Notes of our SI. In our parameterization, with a low regrowth rate of the stock, the SPNE decision rule is to extract $e_{it} = \min\{\bar{e}, \frac{w}{n}\}$. Though multiple equilibria can exist, invoking the Folk Theorem (41), if subjects are sufficiently patient the SPNE can coincide with the social optimal path of extraction. Through the lens of SHH, the Folk Theorem could operationalize strategic cooperation because individuals can maximize their own payoffs through cooperation. This is true if individuals are patient and expect future gains in later time periods provided others cooperate, as current period cooperative decisions are more likely to sustain later cooperation. For certain values of the parameters $\beta, \tau,$ and n the selfish SPNE could also coincide with the socially optimal strategy. For instance, when regrowth of the group account is relatively high the private benefits from cooperating with group members can outweigh the private benefits from extracting the resource to collapse, therefore creating a game where social cooperation and the SPNE are equivalent.

In our experiment, the group account starts with 360 tokens in it and each group token extracted is subtracted from the total amount of tokens in the account. After each round of decision making, the resource stock grows according to the formula (360 - X)/4 tokens, where X is the stock of group tokens. Therefore, at the beginning of the next period, there will be X + (360 - X)/4 tokens in the group account. If the total number of tokens in the group account ever falls to fewer than 30 tokens, the threshold τ, the group account will cease to replenish.

Econometric Methodology

Survival analysis is the appropriate tool to analyse the time to exhaustion of the group account. Ordinary linear regression would require that the group exhaustion times be transformed to account for their strictly positive values and for the censoring of the data. Therefore, survival analysis is more appropriate in our context rather than ordinary linear regression (44).

The semi-parametric Cox proportional hazards regression describes the dependence of failure risk at any time, *t*, on the covariates in the regression (41). The Cox model is popular, flexible, and does not assume specific probability distributions until events occur, leading to the advantage of not needing to parameterize time dependency (43). The Cox proportional hazards model is the most commonly used modeling procedure for survival/censored data and covariates.

In the Cox proportional hazards model, $F(t)$ is the survivor function, $F(t) = Pr(t \leq T)$ and $\lambda(t)$ is the hazard at time *t*, where $\lambda(t) = \lim_{\Delta t \to \infty} \frac{\Pr(t \leq T < t + \Delta t | T \leq t)}{\Delta t} = f(X\beta)$. We can use a set of *k* covariates in *X* and recover the coefficients of vector β which tell us about the hazard of failure for a specific covariate. The hazard rate is $\lambda(t|X) = \lambda_0(t)e^{X\beta}$, where β is a *px1* vector of unknown coefficients and $\lambda_0(t)$ is an unknown function for the baseline cumulative hazard function when *X=0*. The hazard ratio is thus $\lambda(t)/\lambda_0(t)$ and $ln\left(\frac{\lambda(t)}{\lambda_0(t)}\right) = \beta X$. This holds for all individuals so that $ln\frac{\lambda_i(t)}{\lambda_j(t)} = \beta(X_j - X_i)$ for individuals *i* and *j*.

In the Cox model, baseline hazard rates vary over time, but the hazards for different covariate values are assumed to be proportional or constant over time. The proportions are also assumed to hold for all periods of *t* and between all individuals (42). The Cox proportional hazards model implies that an independent variable shifts the hazard by a factor of proportionality. This time invariant proportionality assumption implies that the size of that effect remains the same irrespective of when it occurs. If this assumption is violated, the outcomes can be significantly biased coefficient estimates (and reduced power from significance tests, leading to inefficient estimates) and therefore overestimated or underestimated variable impacts (42). We test for proportionality using Schoenfeld and Deviance residuals and find that for our data the proportionality assumption holds.

We use the Breslow approximation to handle ties in event times. It is the simplest approximation to the probability that an individual had an event, given that an event occurred at that time. While it is the simplest, it also the most conservatively biased (it estimates coefficients too close to zero) and was chosen for such (44). In addition, we cluster standard errors in our analysis by the unit of observation. Observations at the individual subject level can have errors which are correlated and therefore clustering is a common technique for statistical inference of the significance of the recovered coefficients.

In Table 2 we present ordinary linear regressions of the deviation of extraction decisions to the social optimal extraction decision, including a series of controls. The dependent variable is constructed to compare the observed extraction to a stock dependent decision which is deemed cooperative and socially optimal. We define this difference as $Diff_{it} = Social\ Optimal\ Extraction_{it} - Observed\ Extraction_{it}$. This is then used in equation (1) to evaluate the coefficient on the treatment effect of time pressure.

$$Diff_{it} = \beta_0 + \beta_1 Pressure_i + \beta_{2\ldots k} X_{it,2\ldots k} + \varepsilon_{it} \quad (1)$$

Equation 1 includes k covariates to control for other factors that affect decisions such as round in the experiment, gender of the participant, cycle, the experience with economic experiments of participants, undergraduate major, and CRT score. We cluster standard errors in our analysis by subject to adjust for correlation of observations by subject in the experiment. The interpretation of negative coefficient of time pressure is that the effect of the time pressure treatment increased extraction from the group account and participants behaved more selfishly compared to the control group.

Data Availability

The experimental data and code are freely available and have been deposited in figshare at https://doi.org/10.6084/m9.figshare.5965462.v1.

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Ethics

All experiments were conducted at the University of Rhode Island. All procedures, including recruitment, consenting, and testing of human subjects were reviewed and approved by the University of Rhode Island's Institutional Review Board (protocol 476535-6).

Author contributions

All authors contributed to the writing of the manuscript. T. Guilfoos and C. Brozyna designed the experiment and analysed the data.

Competing interests

The authors declare no competing financial interests.

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Table 1: Survival Analysis

	Dependent variable:		
	Failure of Group Account		
	(1)	(2)	(3)
Pressure	0.539^{***}	0.700^{***}	0.788^{***}
	(0.134)	(0.149)	(0.171)
Female		0.214	0.334^{**}
		(0.133)	(0.164)
# of previous experiments		-0.005	0.011
		(0.084)	(0.085)
UG major: biology		-0.412^{**}	-0.423^{*}
		(0.180)	(0.220)
UG major: environmental economics		-0.001	-0.109
		(0.179)	(0.209)
Cycle 2		-0.164	-0.158
		(0.165)	(0.198)
Cycle 3		-0.540^{***}	-0.530^{**}
		(0.181)	(0.209)
% CRT Correct			-0.583^{*}
			(0.299)
Observations	2,148	2,148	1,545
Log pseudolikelihood	-1,000	-993	-688

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$. Cox proportional hazard model results, with stock failure as the event of interest. Clustered standard errors by participant, cycle, and session are in parentheses. Column (1) and (2) contain the full sample of all individuals while column (3) restricts the sample to include only individuals with a CRT score. "UG major:" indicates the participant's area of study.

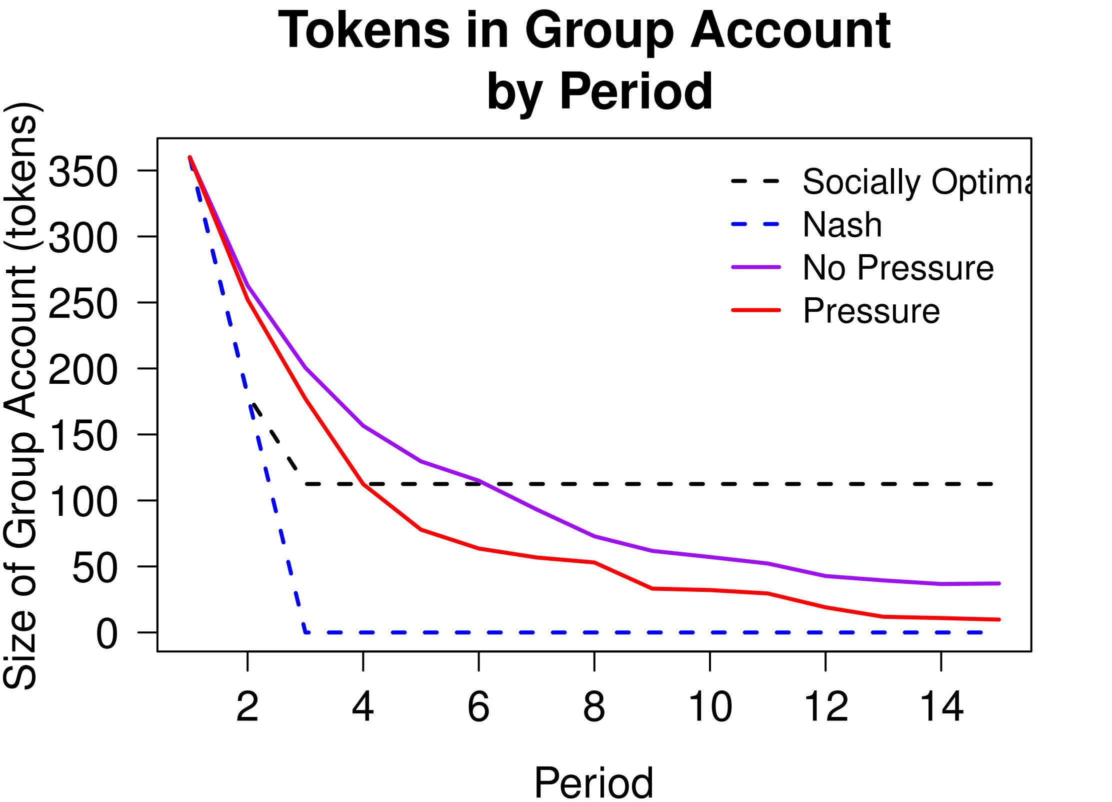
Table 2: Extraction Behaviour

	Dependent variable: (SO Extraction – Observed Extraction)		
	(1)	(2)	(3)
Pressure	-1.079	-4.973*	-6.695**
	(2.502)	(2.831)	(3.088)
Female		-3.431	-6.163*
		(2.781)	(3.311)
# of previous experiments		1.633	1.627
		(1.633)	(1.555)
UG major: biology		2.269	3.509
		(2.665)	(3.045)
UG major: environmental economics		-4.078	-5.184
		(3.883)	(4.578)
Cycle 2		2.432	2.105
		(1.626)	(1.799)
Cycle 3		2.979*	2.443
		(1.720)	(2.052)
Round		-1.781***	-1.731***
		(0.196)	(0.231)
% CRT Correct			-0.087
			(6.841)
Observations	1,952	1,952	1,400
R-squared	0.000	0.107	0.126

Note: *p<0.1; **p<0.05; ***p<0.01. Ordinary least squares regression. Clustered standard errors by participant are in parentheses. Groups with participants who do not enter a decision within the time constraint are excluded from the analysis. Column (1) and (2) contains the full sample of all individuals while column (3) restricts the sample to include only individuals with a CRT score. "UG major:" indicates the participant's area of study.

Figure 1 Legend

Fig. 1: A graph showing the average size of the group account (n=168 for no time pressure treatment and n=116 for the time pressure treatment) at the beginning of each period (the stock size left after the previous period with the addition of regrown stock). The black dashed line indicates the predicted stock sizes were the groups behaving as a social planner would. The blue dashed line indicates the stock path if all the participants are in a competitive Subgame Perfect Nash Equilibrium.



Tokens in Group Account
by Period
Size of Group Account (tokens)
350
300
250
200
150
100
50
0
2
4
6
8
10
12
14
Period
Socially Optima
Nash
No Pressure
Pressure