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Abstract

Pervasive overbidding represents a well-documented feature of all-pay auctions. Aggregate bids exceed Nash predictions in laboratory experiments, and individuals often submit bids that guarantee negative profits. This paper examines three factors that may reduce pervasive overbidding: (a) repetition (experience), (b) reputation (strangers vs. partners) and (c) active participation. We find that aggregate over-dissipation diminishes but is not eliminated with repetition, and that repetition, in conjunction with active participation generates bids consistent with the static Nash predictions.

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1. Introduction

Many economic situations can be modeled as an all-pay auction (henceforth APA). Consider for example lobbyists' attempts to gain power with political groups or win monopoly licenses, multiple firms engaging in research and development races to release a new product or develop a new drug, or popular concert or sporting event tickets being allocated to those that wait in line the longest (e.g., Baye, Kovenock and de Vries, 1993). In situations like these, participants can put forth costly effort, and those who do not win the auction do not recover their expenditures. These welfare losses can be quite extensive and suggest important policy implications (e.g., Dougan, 1991). Krueger (1974) estimates that losses associated with rent seeking behavior were 7.3% of India's GNP in 1964 and 15% of Turkey's GNP in 1968.

More recently, all-pay auctions are studied as a means of charity fund raising both in theory (Goeree, Maasland, Onderstal and Turner, 2005; Engers and McManus, 2002), lab experiments (Schram and Onderstal, 2007; Orzen, 2005), and field experiments (e.g., Carpenter, Holmes and Matthews, 2007), where they have interesting implications for the revenue of non-profit organizations.

Baye, Kovenock and de Vries (1999) define *aggregate overdissipation* as the sum of all group members' bids being greater than the value of the prize and *individual overdissipation* as a bid by a single player being greater than the value of the prize.

Pervasive aggregate overdissipation represents a well-documented feature of laboratory APA experiments (Davis and Reilly, 1998; Gneezy and Smorodinsky, 2006). This paper reports an experiment conducted to examine some of the factors that may affect overdissipation in all pay auctions (with complete information and more than two players) with a special emphasis on the elimination of overdissipation. We focus on three factors that can contribute to overdissipation: (a) repetition (or experience), (b) reputation (strangers vs. partners), and (c) active participation.

The effects of extensive repetition and the use of a re-matching protocol are currently receiving attention among experimental economists, particularly in the context of oligopoly, public goods, and reciprocity (e.g., Morgan, Orzen and Sefton, 2006; Orzen, 2007; Andreoni and Croson, 2007; Botelho, Harrison, Pinto, and Rutstrom, 2007; McCabe, Rassenti, and Smith, 1996). These studies highlight the importance of matching protocols for the sustainability of cooperation or collusion. Clearly, collusion issues are also relevant in the context of auctions (see Klemperer, 2002).

We think it is natural to study the effects of repetition and matching in the context of an APA. On the one hand, extensive overdissipation observed in the APA diminishes with limited repetition (without disappearing). It is then natural to wonder whether the decreasing trend would continue with extensive repetition: our design involves a time horizon which is significantly longer than in other experimental studies. On the other hand, extensive repetition has no obvious relation to natural APA contexts, since, in contrast with markets, bidders interact in auctions relatively infrequently, and we might expect different groups of bidders to participate in each period in a series of repeated APAs. For this reason, we study a re-matching protocol (strangers protocol) since it has strong parallels to natural contests.

We find that overdissipation is pervasive and persists even with a strangers matching protocol. Since the sustainability of tacit collusion is more difficult with random re-matching, we predict that we will observe lower overdissipation with a partners matching protocol. We find that overdissipation is indeed lower with partners, but not significantly. Thus, we conclude that overdissipation persists over time in both matching treatments.

Our final conjecture of causes of overdissipation is that bidding zero (the minimax strategy) might be perceived as "no active participation" by the subjects (for a similar conjecture see Lei, Noussair and Plott, 2001). Participants might find it unnatural to bid zero and thus will be biased towards positive bids which, in aggregate, causes overdissipation. To test this conjecture, we change the framing of the standard APA to allow negative bids. We find that reputation (partners protocol), in conjunction with active participation (allowing negative bids), generates bidding behavior consistent with the static Nash prediction. This is the only treatment where overdissipation is eliminated.

These findings suggest that overdissipation in laboratory APA is a very robust phenomenon, quite difficult to eradicate. In fact, overdissipation is pronounced not only at the aggregate level but also, more surprisingly, at the individual level.

The paper is organized as follows. Section 2 provides more details on the related literature and highlights the contribution of our paper. Section 3 describes the model and

Section 4 the hypotheses to be tested. The experimental design is described in Section 5. We discuss the experimental results in Section 6 and conclude with Section 7.

2. Related Literature

Most of the experimental studies analyzing APA have focused on auctions with complete information (Potters, de Vries, and van Winden, 1998; Davis and Reilly, 1998; Gneezy and Smorodinsky, 2006). In these studies (with the exception of Potters et al.), it has been shown that agents behave more aggressively than predicted by the Nash equilibrium: the sum of all participants' bids is greater than the value of the prize, i.e., overdissipation is observed.

Davis and Reilly (1998), hereafter DR, conduct a series of experiments to test the theoretical predictions of the complete information APA characterized by Baye, Kovenock, and de Vries (1996). They find a pervasive and significant aggregate overdissipation of rents[1] and they show that aggregate overbidding decreases but does not disappear with experience.[2] DR argue that this phenomenon cannot be explained by risk aversion, which is traditionally used to justify overbidding in the winner-pay auction.[3] Anderson, Goeree, and Holt (1998) develop a theoretical model in which bidding behavior is subject to error, and conjecture that overbidding in APA occurs due to the bounded rationality of subjects. Their model is consistent with the data of DR. An implication of the Anderson et al. model is that aggregate overdissipation should increase with the size of the bidders' group. Gneezy and Smorodinsky (2006), hereafter GS, test this theory directly by conducting a separate study in which they vary group size (four, six, eight, or twelve participants). Their results seem not to be entirely consistent with Anderson et al. since aggregate overdissipation is independent of group size in later periods.

To the best of our knowledge, the only study in which prevalent aggregate overdissipation does not exist is provided by Potters, et al. (1998). Their design has three

[1] Baye, Kovenock, and de Vries (1999) define *aggregate overdissipation* as the sum of all group members' bids being greater than the value of the prize and *individual overdissipation* as a bid by a single player being greater than the value of the prize.

[2] Participants were considered experienced if they had participated in at least one session, but in a different cohort and in many cases in a different design.

[3] In particular, the first price private value winner-pay auction (Cox, Smith, and Walker, 1988).

features (which are not shared by other APA studies) that may attribute to this result. First, their group size is limited to two, where all other studies have four or more participants per group. With only two group members, the Nash equilibrium is unique, while for any group size larger than two, there exists a plethora of mixed strategy equilibria (i.e., the environment is more complex). Second, the endowment that subjects receive in every period only slightly exceeds the value of the prize, which may induce downward pressure on bidding behavior. In other studies subjects receive a one-time large endowment at the beginning of the experiment. Finally, the experiment consisted of 30 periods, which is at least twice as long as other studies, allowing subjects to become more experienced.

Table 1 clarifies how our experiment relates to the existing literature on laboratory all-pay auction.

Table 1. Characteristics of APA Studies with Complete Information

Papers/Design	Number of Periods	Matching Protocol	Group size
Davis and Reilly[4]	15	partners	4
Potters, de Vries, and van Winden	30	strangers	2
Gneezy and Smorodinsky	10	partners	4,6,8,12
Our paper	60	strangers , partners	4

The main innovations of our experiment are a longer time horizon, the comparison of two distinct matching protocols where groups consist of four bidders and a rescaling of the action space. As pointed out in the introduction, we think that the study of these factors sheds light on the phenomenon of overdissipation. We also complement

[4] More precisely, in this paper, APA was only one of the treatments. In each session a group of 5 participants bid against each other in a series of two 15-period auction sequences. Each group is composed by 5 participants since some auctions involved the presence of a rent defending buyer. Under the APA treatment a die was rolled in every period to determine which group member would be inactive for that period (in the event of a six the die was re-rolled). In this sense, the matching protocol is actually a mix of partners and random matching.

existing works by highlighting the presence of individual overdissipation, which we think is an interesting phenomenon which deserves further study.

The following section develops the model underlying our experiment and shows that overdissipation should not occur theoretically.

3. Theoretical Predictions

The model consists of a finitely repeated game, whose stage game is described next. We focus on a first-price APA with four players and complete information, i.e. auctions in which all bidders' valuations for the unit being sold are common knowledge. The value of the prize is taken to be 1000. Each bidder (i = 1, 2, 3, 4) simultaneously submits a sealed bid b_i and the highest bidder gets the prize. In the case of a tie, the prize is equally shared among the highest bidders. All players must pay their bid. Thus, the payoff to a risk-neutral player i in this game is:

$$U_i(b_1,\ldots,b_4) = \begin{cases} -b_i & \text{if } \exists\, j \neq i \text{ such that } b_j > b_i, \\ \dfrac{1000}{m} - b_i & \text{if } i \text{ ties for the highest bid with } (m-1) \text{ others,} \\ 1000 - b_i & \text{if } b_i > b_j \quad \forall j \neq i. \end{cases}$$

Under the assumption of non-negative bids, the full characterization of equilibria for this game is provided by Baye et al. (1996). There exist a continuum of equilibria for this game. The common features of all equilibria are that each point of the interval [0, 1000] is in the support of at least two players, and that the expected payoff to each player is zero.[5] Consequently, the expected sum of the group bids (expected aggregate dissipation) is equal to the value of the prize.[6] We refer to this game as the Standard APA.

In addition to the benchmark Standard APA, we consider another game where the strategy space starts at (-1000) rather than at zero. This simply translates the equilibrium randomization interval from [0, 1000] to [-1000, 0], as illustrated by Figure 1. We refer to this second game as the Negative APA.

[5] Therefore, with four players, unlike the two players' case where the equilibrium is unique and symmetric, there exist a continuum of asymmetric equilibria.
[6] However, probabilistically this sum might be both below and above the value of the prize (Baye et al., 1999).

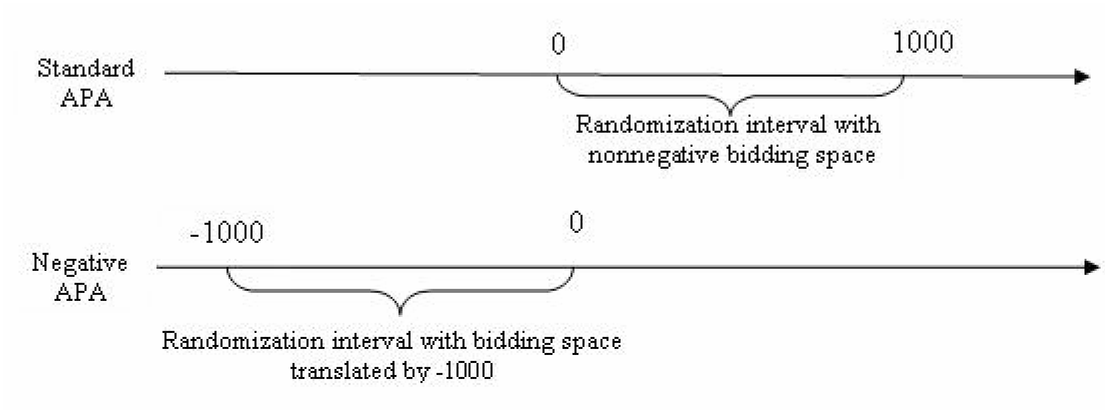

Figure 1. Equilibrium predictions for games under the Standard APA and Negative APA

The features of the theoretical predictions we are interested in are summarized in Table 2. Note that in the Negative APA (Standard APA, respectively), aggregate overdissipation occurs whenever the sum of the bids exceeds -3000 (1000, respectively) and individual overdissipation occurs whenever the individual bid exceeds 0 (1000, respectively).[7] Note also that the game predicts no individual overdissipation: it is a dominated strategy and in fact a bid greater than 1000 in the Standard APA would guarantee a negative payoff. Similarly, a bid greater than 0 in the Negative APA is a dominated strategy (e.g., bidding (-1000) would guarantee a higher payoff). Both phenomena should not occur in equilibrium.

Table 2. Summary of theoretical predictions

Bidding Space	Theoretical Predictions		
	Equilibrium Randomization Interval	Expected per Period Earnings	Expected Sum of Bids
[0,8)	[0,1000]	0	1000
[-1000,8)	[-1000,0]	1000	-3000

[7] Individual overdissipation occurs in both games whenever bid - (minimum bid + prize value) is positive.

3.1. Collusive Equilibria

Theoretically, collusion is not an equilibrium of our finite horizon games, but behaviorally, repeated game effects are possible.[8] Thus, we comment briefly on the existence of subgame perfect equilibria of the infinitely repeated counterpart of our games. Standard Folk Theorem arguments show that bidders may sustain a more favorable outcome than in the one-shot equilibrium. In the APA game we could identify perfect collusion (maximization of joint profit) with all players bidding zero. This collusive equilibrium can be sustained by a trigger strategy. That is, each player colludes until someone fails to collude, which triggers a switch to the noncooperative Nash equilibrium forever after. Note that other feasible payoffs can be obtained in subgame perfect equilibria (for sufficiently high probabilities of continuation). That is, the set of noncooperative equilibria includes cooperative outcomes that are not repetitions of Nash equilibria of the stage game. In our setting, one could not exclude that lower bids could signal willingness to collude.

4. Hypotheses

This section builds on the previous section and on previous experimental studies to formulate hypotheses to be tested.

The extensive overdissipation observed in initial periods of previously reported laboratory APA's tends to diminish with *limited* repetition. In the last few periods of the DR and GS studies there is still a significant level of aggregate overdissipation, but aggregate dissipation decreases over the time horizon.

Inexperience may be a significant factor contributing to aggregate overdissipation.[9] It is then natural to test whether with *extensive* repetition bidders approach Nash equilibrium prediction and thus no overdissipation.

If subjects participate in a longer APA that allows them to acquire a sufficient level of experience, deviations from Nash predictions may decrease over time and eventually disappear.

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[8] Note that the time horizon of sixty periods in the experiment may be long enough to make repeated game effects possible.

[9] As pointed out in Section 2, APA involving groups of more than two may considerably increase the complexity of the experimental setting. As a result, in a setting with four bidders, subjects may require additional experience to overcome potential confusion.

Hypothesis 1: As subjects gain experience, the level of average aggregate overdissipation decreases over time across treatments.

To test this hypothesis, we construct all our treatments to have a time horizon of 60 periods, which is at least four times as long as any previous study with four players that we are aware of.

Theoretically, collusion is not an equilibrium of our finite horizon game, but, as discussed in Section 3.1, behaviorally repeated game effects are possible.[10]

There is experimental evidence that in market games it is more difficult to sustain tacit collusion under a random matching protocol than under a partners' one (e.g., Orzen, 2007). We conjecture that a partners protocol facilitates the organization of tacit collusion also in an APA game, leading to lower bids, thus contributing to the reduction of aggregate overdissipation.

Hypothesis 2: Regarding the strangers and partners matching protocols:
2a) Collusion is higher under a partners matching protocol than under a strangers matching protocol;
2b) Aggregate overdissipation is lower under a partners matching protocol than under a strangers matching protocol.

To test for this hypothesis, the subjects' matching protocol is one of our treatment variables. In particular, we hold the makeup of the groups fixed in some sessions (partners matching protocol), while in others the composition is changed randomly in every period (strangers matching protocol).[11] Note that a study of a re-matching protocol is interesting in itself since it bears strong parallels to natural contests, where (as opposed to certain market environments) rent-seeking auctions may involve groups of different sets of bidders.

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[10] The time horizon of 60 periods in the experiment may be long enough to make repeated game effects possible. Experimental evidence suggests that this is the case in prisoner's dilemma games (e.g., Selten and Stoecker, 1986; Normann and Wallace, 2006).

[11] To our knowledge, Potters et al. (1998) is the only other study to implement a strangers matching protocol. Once again, in their study agents are randomly and bilaterally matched implying a simpler environment.

In the typical APA game bidders are allowed to place nonnegative bids. Note that an individual bidder can guarantee to himself the minimax payoff of zero by bidding zero. Here, we have a behavioral conjecture based on a previous experimental study. We conjecture that subjects find it unnatural to bid zero and are biased towards positive bids that in the aggregate lead to overdissipation. This conjecture is reminiscent of the active participation hypothesis formulated in a different environment (asset markets) by Lei et al., 2001.

Hypothesis 3*:* Rescaling the Standard APA design to allow for negative bids (Negative APA):

3a) increases the proportion of maximin bids;[12] and

3b) decreases the aggregate overdissipation level.

In order to test for the active participation hypothesis, we rescale the bidding space of the Standard APA by (-1000). That is, the strategy space starts at (-1000) rather than at zero. This translates the equilibrium randomization interval from [0, 1000] to [-1000, 0], as pointed out in Section 3 and illustrated by Figure 1. We would like to highlight that alternative designs could have been used to explore the active participation hypothesis. For instance, we could have translated the strategy space by a different constant. However, since overdissipation is a very persistent phenomenon, we allowed for negative bids to give the design its best shot at overdissipation reduction. We discuss this further in Section 6 where we present the experimental results.

The next hypothesis deals directly with individual overdissipation and it is a straightforward implication of the model (e.g., in the standard APA placing a bid exceeding the value of the prize is a dominated strategy).

Hypothesis 4*:* Individual overdissipation is not observed in any of the treatments.

[12] A maximin bid is the zero bid in the Standard APA and (-1000) in the Negative APA.

5. The Experiment

The experiment consisted of nine sessions conducted at the University of Canterbury, Christchurch, New Zealand in 2004. Each session consisted of 16 subjects for a total of 144 subjects recruited from undergraduate economics and mathematics courses. Although some of the subjects may have participated in previous economics experiments, none had any experience in auction experiments. Each subject participated in only a single session of the study. The experiment was computerized and used the Ztree software package, developed at the University of Zurich, Institute for Empirical Research in Economics.[13] The currency used for decision making within the experiment was called francs. Subjects' earnings were paid in New Zealand dollars at the end of the experiment according to a predetermined and publicly known conversion rate between francs and dollars. The conversion rate differed between sessions, but was always identical for all subjects within a given session. On average, a session lasted 90 minutes including initial instruction period and the payment of subjects. Subjects earned an average of $17.56NZ.[14]

The design of the experiment consists of three treatments (S, P and P-neg) and employs two treatment variables (matching protocol and bidding space). The features distinguishing the different treatments are summarized in Table 3. The endowment is different in P-neg to make sure that the total expected payoff would be the same as in the other games. In treatments P and P-neg, a partner matching protocol was implemented in which the computer network separated the subjects into groups, and it was common information that these group assignments remained constant for the entire session. A stranger matching protocol was implemented in treatment S such that subjects were re-matched each period into new groups of four. It was common knowledge that each subject had zero probability of being matched with the same group member for two consecutive periods and a very low probability that they will be matched with the same group member in period $t + 2$.[15] For our second treatment variable, we varied the feasible

[13] See Fischbacher (1999) for a discussion of the Ztree software package.
[14] The minimum wage in New Zealand was $9.00NZ per hour at the time that the experiments were conducted.
[15] Note that our stranger matching protocol differs from random matching in that players are guaranteed that they will never play with the same group member for two consecutive periods. Even though our

bidding space. Treatments P and S are the Standard APA in which bidders were only allowed to place non-negative bids. The P-neg treatment is a Negative APA. As discussed in Section 3, it is exactly the same as the Standard APA except for the translation of the strategy space by (-1000). That is, any bid greater than or equal to (-1000) was permitted. Our treatments are motivated by overdissipation reduction, thus we did not run any S-neg session.

Table 3. Summary of treatments

Session Number	Treatment	Matching Protocol	Endowment	Bidding Space	Theoretical Predictions		
					Randomization Interval	Expected per Period Earnings	Total Expected Payoff
1-3	S	Strangers	65000	[0,8)	[0,1000]	0	65000
4-6	P	Partners	65000	[0,8)	[0,1000]	0	65000
7-9	P-neg	Partners	5000[16]	[-1000,8)	[-1000,0]	1000	65000

At the beginning of each session, the experimenter read the instructions aloud.[17] The subjects were encouraged to follow along with their own copy of the instructions and to ask any questions relating to the interface and rules at any time.[18] In order to limit the effects of confusion, in all treatments subjects completed a questionnaire (included in Appendix 1) before the experiment started, which tested their comprehension of the instructions. There was no communication allowed between subjects at any time during the experiment. All interaction took place via the computer terminal and all decisions were anonymous.

Each session consisted of 60 plays of the same first-price APA. In each session we had four groups of four participants who played the role of bidders. We refer to each play of the auction as a period. The total number of periods in a session and the fact that the rules in each period were identical was common knowledge. In each period, there

stranger matching protocol does not completely eliminate the possibility for strategic behavior, it makes it more difficult.

[16] The endowment in P-neg is adjusted to keep the same Total Expected Payoff as in the other games.

[17] The instructions for each treatment are provided in the appendix.

[18] The experimenter addressed questions privately to ensure that other subjects were not biased by potential normative statements/questions.

was a single fictitious prize auctioned to each group of four bidders. It was common knowledge that the valuation of the prize was identical across all bidders and equal to 1000 francs. In each period, bidders simultaneously placed bids for the single prize offered for sale in that period.[19] The bidder with the highest bid won the auction and her earnings equaled the 1000 franc reservation value minus the bid offered for the prize. In the event of a tie for the highest bid, the 1000 francs was split equally among all tied highest bidders.[20]

All bidders had their bid subtracted from their earnings regardless of whether they won the auction or not. In treatments P and S, every bidder with a non-winning bid incurred losses for the period equal to the amount of their bid. In order to cover these potential losses and insure that the subjects were not income constrained in any period, subjects in treatments P and S received an initial participation fee of 65000 francs. It was announced at the beginning of the experiment that this money was theirs to keep and any earnings or losses incurred would be added or subtracted from this participation fee.[21]

Note that in the P-neg setting, subtracting a negative bid from their period earnings translated into positive earnings for the period equal to the amount of their bid. If their bid was the highest bid and thus won the auction, then their period earnings equaled the 1000 franc reservation value minus their bid. For example, if the highest bid were (-10) then the winner's period earnings would equal 1000-(-10)=1010.[22] In equilibrium, there should only be non-negative earnings each period. In order to make the overall expected payoffs equivalent across treatments and insure that the subjects were not income constrained in any period, 5000 francs were provided as an initial endowment to participants in the P-neg treatment.[23]

[19] In order to approximate a continuous bidding space, bidders were allowed to place bids up to the 4th decimal place.
[20] Puzzello (2007) shows that in some environments a sharing tie breaking rule might facilitate coordination.
[21] Given the nature of an APA, it is possible for a subject to have negative overall earnings. That is, a sum of potential losses each period is greater than the 65000 franc initial endowment. However, this did not occur in any of our sessions. The lowest residual endowment observed in any period of the P and S designs was 39539 francs.
[22] In order to deal with possible confusion, subjects filled a questionnaire (included in Appendix 1) in all treatments. The choice of allowing negative bids is discussed in Section 6.
[23] The lowest residual endowment observed in any period of the P-neg design was 3950 francs.

At the end of every period, the subjects were provided with a summary screen that displayed all four group members' bids, their own bid, the highest (winning) bid and their period earnings. This information was available for the current period, and also a history from all previous auctions in the session. To present all four group members' bids on the summary screen, each group member was assigned an identifier of letters A through D. In treatments P and P-neg, the bidder identifiers remained constant for the entire session, and thus it was possible to associate bidding behavior with a particular bidder over time. In treatment S, not only were the group assignments changed every period, but also the ordering of the bidder identifiers. Therefore, it was very difficult to trace individual behavior, which greatly increased the difficulty of strategic behavior in the repeated game.

6. Experimental results

We begin our review of the results from the experimental sessions by focusing on aggregate behavior. Average aggregate dissipation levels for all treatments in each 10 period segment of the experiment are represented in Figure 2.[24] Let us initially focus on the first 10 periods in order to compare our data to previous studies.[25] As in Davis and Reilly (1998) and Gneezy and Smorodinsky (2006), there is persistent overdissipation of rents. During this interval, the incidence of aggregate overdissipation is 88% in S, 74% in P and 68% in P-neg, where the incidence is given by the proportion of observations exhibiting aggregate overdissipation.[26] The levels of average aggregate overdissipation are 115%, 77% and 63%, respectively (as can be roughly inferred from Figure 2). The numbers we obtained under the P treatment are comparable with the numbers that GS obtain in the sessions with groups of four agents each, namely 84% for the incidence of aggregate overdissipation and 94% for the level of average aggregate overdissipation.

However as the number of periods increases, the average levels of aggregate dissipation decrease across all treatments, and thus provide support for Hypothesis 1a.

[24] In order to make the average aggregate dissipation levels comparable across treatments, we added 1000 to the P-neg bid values. Also, pooling the data across different time intervals (5 or 20 periods) does not affect the qualitative results.

[25] The study of Gneezy and Smorodinsky consists of 10 periods.

[26] The theoretically predicted range of the incidence of aggregate overdissipation for symmetric equilibria with 2, 3, and 4 players is between 44% and 50%, while the theoretically predicted level of aggregate dissipation is 100% for all types of equilibria (see Baye et. al., 1999).

By the last 10 period segments, the incidence of aggregate overdissipation decreases to 58% in S, 51% in P, and 43% in P-neg, while the level of average aggregate overdissipation decreases to 25%, 16%, and 0% respectively. The downward trend in dissipation levels suggests that participants may in fact alter their behavior as they become more familiar with the auction process and gain experience with bidding strategies. Nonetheless, aggregate overdissipation is eliminated only in P-neg.

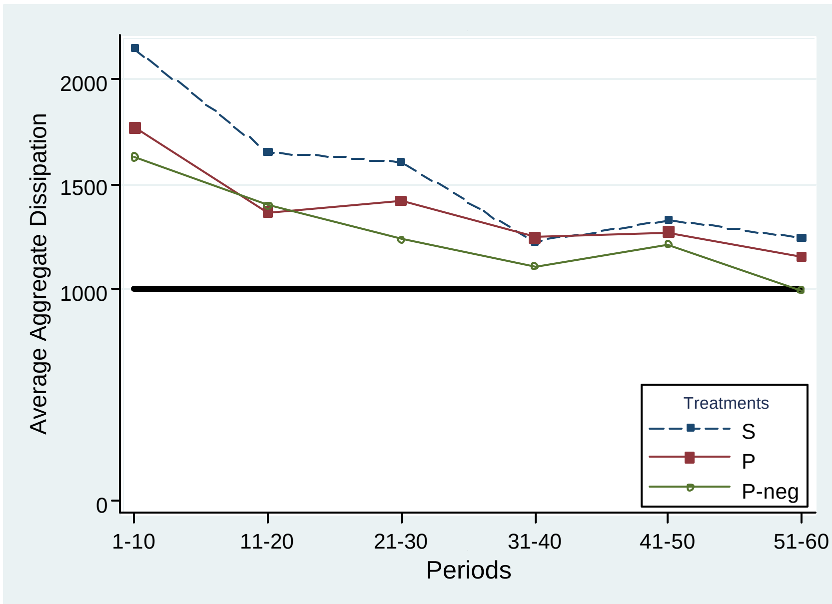


Figure 2: Average aggregate dissipation across treatments

Result 1: The level of average aggregate dissipation decreases with experience in all treatments.

Support for result 1: Table 4 lists average dissipation differences and provides results from Wilcoxon signed-rank tests on average aggregate dissipation over 20 period intervals. As a robustness check, we include the corresponding statistics for 10 period intervals in Appendix 2: the results are not qualitatively different. The unit of observation is the group average for P and P-neg (N = 12 for each time interval within a given treatment) and the session average for S (N = 3 for each time interval).

In the partners matching protocol treatments (P and P-neg), average aggregate dissipation significantly decreases from the first 20 period segment to the last 20 periods. In P, the average is not significantly different between the first and second 20 period intervals. This finding suggests that even a 40 period interval is not sufficient to capture the full effect of learning in the Standard APA design. However in P-neg, the first and second 20 period intervals do have significantly different averages. This might be due to the additional confusion that subjects may have experienced in the initial periods from not being accustomed to placing negative bids.[27] The z-statistic is positive in all comparisons of S, which indicates a decrease in the aggregate dissipation over time. The fact that it is not statistically significant reflects the extremely low number of observations rather than lack of statistical evidence.[28] This is fairly evident from Figure 2 in which the average aggregate dissipation level in S experiences the sharpest decrease over the entire time horizon compared to P and P-neg.

Furthermore, average aggregate overdissipation is eliminated only in the last 10 periods of P-neg. ?

Table 4. Differences in average aggregate dissipation across time

	Comparison of 20 period intervals		
	21-40 to 1-20	**41-60 to 21-40**	**41-60 to 1-20**
P-neg	-683**	-136	-819**
P	-469	-237	-706***
S	-776	-127	-903

Wilcoxon signed-rank test:
**** 5% significance level,**
***** 1% significance level.**

Next, we test for Hypothesis 2, i.e., whether aggregate overdissipation is more widespread under strangers than under partners. We test for collusion attempts (Result 2a) and we compare levels of aggregate overdissipation (Result 2b) across treatments.

In the formulation of Hypothesis 2, we conjectured that partners matching protocols facilitate the organization of tacit collusion. To test this conjecture, we interpret 0 bids as attempts of tacit collusion.[29] We classify bidders into behavioral types according

[27] See also Table A1 in Appendix 2, where comparisons among the first ten periods and other 10 period increments are all significant. That is not the case for comparisons involving intermediate periods.
[28] Since we only have 3 observations, the theoretical maximum for this test is z = 1.60, which is not significant at the 10% level.
[29] This identification is not arbitrary. Perfect tacit collusion (maximization of joint profit) would be achieved if all subjects submitted a zero bid. Also, a deeper look at the data suggests that subjects were indeed trying to use zero bids as signals. For instance, some subjects would bid zero a few periods in a row. Nonetheless, collusion was very difficult to sustain since it involved the coordination of four subjects and a very rich strategy space (subjects could place bids up to four decimal places).

to the number of zero bids that they placed. As illustrated in Table 5, we find evidence suggesting that more subjects are willing to collude under partners than under strangers.

Table 5. Proportion of individuals who place maximin bid at least *T* times

T	Average proportion in			Mann-Whitney rank-sum test	
	Strangers	Partners	P-neg	Partners vs. Strangers	P-neg vs. Partners
5	69%	81%	90%	2.3**	1.68*
10	50%	67%	77%	1.62	1.51
15	40%	54%	69%	1.21	1.89**
20	23%	35%	60%	0.68	2.48**

*** 10% significance level**
**** 5% significance level.**

Result 2a: The proportion of subjects who attempted to collude is higher under Partners than under Strangers.

Support for result 2a: A two-sample Mann-Whitney test supports result 2a (Table 6). The unit of observation is the group proportion of subjects for P (N = 12 for each time interval within a given treatment) and the session proportion for S (N = 3 for each time interval). From Table 5, we can see that the proportion of (perfectly) "colluding" types is consistently higher under partners than under strangers. However, this difference is statistically significant only when T = 5. This is in part due to the low number of observations under the S treatment.

In addition, it was difficult to sustain collusion in our environment even under Partners. Indeed, recall that our groups consisted of four subjects and the strategy space was very rich.[30] Note also, that some subjects attempted to collude by placing few zero bids in a row but reverted to nonzero bids after seeing that their attempts were unsuccessful. ?

Even though a partners matching protocol facilitates collusion, the effect at the aggregate level is not significant, except for the first ten periods.

[30] In the context of experimental markets, several studies suggest that collusion is more difficult to sustain as the group size increases or the divisibility of the strategy space increases (e.g., Huck et al., 2004; Puzzello, 2007).

Table 6. Comparison of average dissipation levels across treatments

Periods	Average dissipation levels			Mann-Whitney rank-sum test	
	Strangers	Partners	P-neg	Partners vs. Strangers	P-neg vs. Partners
1-10	2146	1769	1631	-1.9*	-0.9
11-20	1652	1368	1400	-0.4	-0.5
21-30	1607	1421	1237	-0.7	-0.8
31-40	1228	1247	1110	0.1	-1.1
41-50	1331	1273	1214	-0.7	-1.2
51-60	1248	1158	998	-0.3	-1.9*
overall	1535	1373	1265	-0.9	-1.7*

Two-sample Mann-Whitney test:
*** 10% significance level.**

Result 2b: The level of aggregate overdissipation under the Partners matching protocol is significantly lower than under the Strangers matching protocol only in the first ten periods.

Support for result 2b: A Mann-Whitney rank-sum test of the difference between aggregate overdissipation under partners and strangers, using each session as the unit of observation shows that this difference is significant in the first ten periods (see Table 6). Thus, as shown in Table 6 and Figure 2, overdissipation tends to be lower under partners than under strangers, but this is significant only in the first 10 periods. ?

Result 3: The Negative APA design has:

a) higher proportion of maximin bids;[31] and

b) lower aggregate overdissipation level.

Support for result 3: Figure 2 indicates that P-neg has a lower average aggregate dissipation than P in five out of six 10-period intervals, and Table 7 provides the proportion of maximin bids across treatments. A Mann-Whitney test comparing P-neg to P across the entire time horizon, using individual groups as the unit of observation (N = 12 for each treatment), rejects the hypothesis that:

a) the proportion of maximin bids is the same in P-neg as in P ($z = -3.0$; $p = 0.003$).

[31] A maximin bid is the zero bid in the Standard APA and (-1000) in the Negative APA.

b) the average aggregate overdissipation is the same in P-neg as in P (z = -1.7; p = 0.09). That is, the proportion of maximin bids is significantly higher under P-neg than under P (a look at Table 5 suggests that this is the case also for the proportion of subjects who submit maximin bids), and the average aggregate dissipation over all periods is significantly lower. One interpretation of these results is that our P-neg treatment is successful in eliciting maximin bids. ?

Table 7. Proportion of maximin bids across treatments

Periods	Proportion of Maximin Bids			Mann-Whitney rank-sum test	
	Strangers	Partners	P-neg	Partners vs. Strangers	P-neg vs. Partners
1-10	23%	31%	41%	1.6	1.9*
11-20	24%	30%	47%	1.3	2.5**
21-30	23%	33%	47%	1.1	2.3**
31-40	26%	31%	48%	0.6	3.0***
41-50	22%	31%	41%	1.3	2.1**
51-60	23%	30%	43%	1.3	1.9*
overall	24%	31%	44%	1.4	3.0***

Two-sample Mann-Whitney test:
*** 10% significance level.**

Overall, although the level of average aggregate dissipation decreases in all three treatments, overdissipation is only eliminated under the Negative APA (P-neg) design. In the last 10 periods of P-neg, the average aggregate dissipation level is 998 compared to 1158 in P.

Here, some remarks are in order. On the one hand, alternative designs could have been employed to address our active participation hypothesis (e.g., a rescaling of the strategy space by a positive constant). On the other hand, since aggregate overdissipation is a very persistent phenomenon, we developed the Negative APA design to give its best shot at overdissipation reduction (recall that by placing a negative bid subjects were guaranteed a gain equal to their bid). Even though, according to our theoretical predictions, allowing for negative bids should not make a difference in terms of overdissipation, we thought that behaviorally this would matter by biasing bids towards the lowest one.

Although the result of overdissipation elimination may have controversial interpretations we think it is interesting. Even though the result of overdissipation elimination seems encouraging, one may find surprising that aggregate dissipation is not reduced even further under the Negative APA.

On the other hand, if one accepts this result, then further questions can be asked regarding the robustness of this result to a different rescaling of the strategy space. The investigation of this question is left for further research.

We believe the main message of these results is that aggregate overdissipation in the All-Pay Auction is a very robust phenomenon. What's more, as shown in the next result, individual overdissipation is also robust.

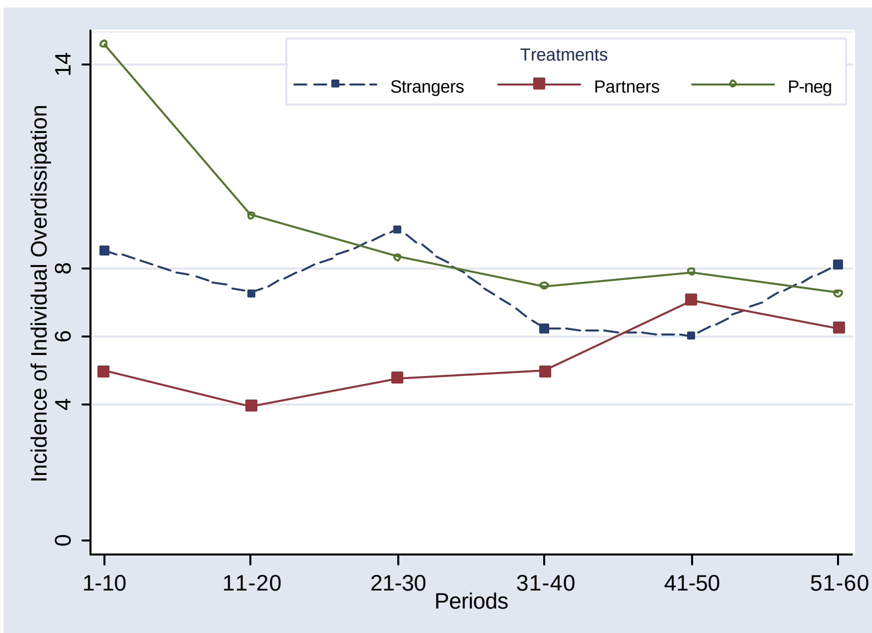


Figure 3. Incidence of individual overdissipation

Result 4. Individual overdissipation is observed in the experimental lab.

Support for result 4: Figure 3 indicates that individual overdissipation is a persistent phenomenon. For both Partners and P-neg,[32] a sign rank test shows that the incidence of individual overdissipation is statistically different from zero at 5% significance level in every ten period interval (N = 12 for each treatment in every ten period interval).

[32] In P-neg individual overdissipation is identified with positive bids.

For Strangers, a sign rank test shows that the incidence of individual overdissipation is different from zero at 11% level in every ten period interval (which is the minimum possible level of significance for N=3 observations). ?

Individual overdissipation is observed in other studies as well. For instance, a look at the data of GS shows that in their experiment the incidence of individual overdissipation is 10%. In their case, those subjects who overdissipated placed a bid higher than the value of the prize in only one period out of the ten periods and always in the first half of the experiment (in the first five periods). Thus, one could reasonably think that individual overdissipation is a sporadic phenomenon. Result 4 shows that this is not the case.

The individual overdissipation phenomenon is surprising since a subject who overbids is choosing a dominated strategy, and in fact is guaranteed a loss in the standard APA. We think that this might be due to a variety of reasons such as other regarding preferences, competitive preferences, fairness considerations, and we leave a deeper study of individual overdissipation for future research.

7. Conclusions

This paper studies aggregate overdissipation in common value APA with complete information. Previous studies exhibit pervasive aggregate overdissipation throughout the entire time horizon of their experiments. In this study, we identify three factors that appear to be critical in reducing aggregate overdissipation, i.e., extensive repetition, fixed groups and allowing for negative bids. When all of these factors are addressed, aggregate overdissipation is eliminated. Nonetheless, we interpret our results as suggesting that aggregate overdissipation and, more surprisingly, individual overdissipation are robust phenomena.

We conjecture that longer time horizons than GS and DR studies (10 and 15 periods respectively), can provide enough time for the subjects to fully understand the game and to eliminate systematic deviations from Nash predictions. To allow subjects sufficient time to gain experience and overcome confusion, our experiments consists of 60 periods. Over the first 15 periods of our experiments, the bidding behavior is consistent with DR and GS, i.e. an initial very high level of aggregate overdissipation that decreases over time. However just as in their studies, by period 15 the extent of aggregate overdissipation is still substantially greater than the Nash predictions. Over the next 45 periods, aggregate overdissipation continues to decrease across all three treatments. Ultimately, aggregate overdissipation is eliminated in the P-neg treatment under the Negative APA design and partner matching protocol. Furthermore, we also observe individual overdissipation in all treatments.

We believe that the main message of this study is that both aggregate overdissipation and individual overdissipation are very robust phenomena. Our post-experiment survey suggests that other regarding behavior, such as spite, revenge, fairness, and tournament play are likely candidates in the explanation of overbidding. We leave the exploration of these factors to future research.

References

Anderson S., J. Goeree, and C. Holt (1998). "Rent Seeking with Bounded Rationality: An Analysis of the All Pay Auction," *Journal of Political Economy*, 828-853.

J. Andreoni and R. Croson (2007). "Partners versus Strangers: The Effect of Random Rematching in Public Goods Experiments," forthcoming in Handbook of Experimental Economics Results, Plott & Smith eds.

Baye, M., D. Kovenock and C. de Vries (1993). "Rigging the Lobbying Process: An Application of the All Pay Auction," *American Economic Review* 83, 289-294.

Baye, M., D. Kovenock and C. de Vries (1996). "The All Pay Auction with Complete Information," *Economic Theory* 8, 291-305.

Baye, M., D. Kovenock, and C. de Vries (1999). "The Incidence of Overdissipation in Rent-Seeking Contests," *Public Choice* 99, 439-454.

Botelho, A., G. Harrison, L. Pinto, and E. E. Rutstrom (2007). "Testing Static Game Theory with Dynamics Experiments: a Case Study of Public Goods," mimeo.

Carpenter, J., J. Holmes, and P. H. Matthews (2007). "Charity Auctions: A Field Experiment," *Economic Journal*, forthcoming.

Cox, J., V. Smith, and J. Walker (1988). "Theory and Individual Behavior of First Price Auctions," *Journal of Risk and Uncertainty* 1, 61-99.

Davis D. and R. Reilly (1998). “Do too many cooks always spoil the stew? An experimental analysis of rent-seeking and the role of a strategic buyer,” *Public Choice,* 95, 89-115.

Dougan, W. R. (1991). “The Cost of Rent Seeking: is GNP Negative?” *Journal of Political Economy* 99, 660-664.

Engers, M., and B. McManus (2002). “Charity Auctions,” mimeo.

Fischbacher, U. (1999). “Z-Tree - Zurich Toolbox for Readymade Economic Experiments - Experimenter’s Manual” Working Paper #21, Institute for Empirical Research in Economics, University of Zurich.

Goeree, J.K., Maasland, E., Onderstal, S., and J. L. Turner (2005). “How (Not) to Raise Money,” *Journal of Political Economy,* 113(4), 897-917.

Gneezy and Smorodinsky (2006). “All-Pay Auctions: An Experimental Study,” *Journal of Economic Behavior and Organization*, 61(2), 255-275.

Huck, H.-T. Normann and J. Oechssler, (2004). “Two are few and four are many: number effects in experimental oligopolies,” *Journal of Economic Behavior and Organization* 53, 435–446.

P. Klemperer (2002). “How (Not) to Run Auctions: The European 3G Telecom Auctions,” *European Economic Review*, 46, 829-845.

Krueger, A. (1974). “The Political Economy of the Rent-Seeking Society,” *American Economic Review*, 64(3), 291-303.

Lei, V., C. Noussair, and C. Plott (2001). “Nonspeculative Bubbles in Experimental Asset Markets: Lack of Common Knowledge of Rationality vs. Actual Irrationality,” *Econometrica*, 69(4), 831-859.

McCabe , K. A., S. J. Rassenti, and V. L. Smith (1996). “Game Theory and Reciprocity in Some Extensive Form Experimental Games,” *Proc. Natl. Acad. Sci. USA* 93, p. 13421-13428, November 1996 Economic Sciences.

Morgan, J., H. Orzen and M. Sefton (2006). “An Experimental Study of Price Dispersion,” *Games and Economic Behavior* 54, 134-158.

Normann, H. T., and B. Wallace (2006). “The Impact of the Termination Rule on Cooperation in a Prisoner’s Dilemma Experiment,” *Working Paper*, Royal Holloway and UCL.

Orzen, H. (2005). “Fundraising through Competition: Evidence from the Lab.” CeDEx Working paper 2005-04.

Orzen, H. (2007). "Counterintuitive Number Effects in Experimental Oligopolies," mimeo.

Potters, J., C. de Vries and F. van Winden (1998). "An Experimental Examination of Rational Rent-Seeking," *European Journal of Political Economy* 14, 783-800.

D. Puzzello (2007). "Tie-breaking Rules and Divisibility in Experimental Duopoly Markets," *Journal of Economic Behavior and Organization*, doi:10.1016/j.jebo.2006.09.002 .

Schelling, T.C. (1960). *The Strategy of Conflict*, Harvard University Press, Cambridge MA.

Schram, A.J.H.C. and Onderstal, S. (2008). "Bidding to Give: An Experimental Comparison of Auctions for Charity," *International Economic Review*, forthcoming.

Selten, R., and R. Stoecker (1986). "End Behavior in Sequences of Finite Prisoner's Dilemma Supergames-A Learning Theory Approach," *Journal of Economic Behavior and Organization* 7, 47-70.

Tullock, G. (1980). "Efficient Rent-Seeking" In: Buchanan, J, Tollison, R. and G. Tullock (Eds.), *Toward a Theory of Rent-Seeking Society*, 97-112. College Station, Texas A&M University Press, TX.

Appendix 1

Instructions for Experiment (*For Treatment P-neg)*

General Instructions:

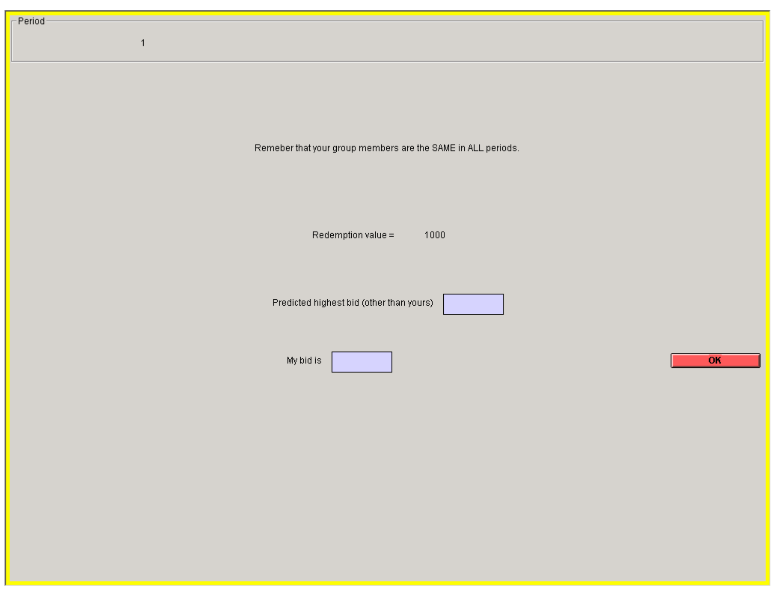
This is an experiment in the economics of decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash. The experiment will consist of 60 periods in which you will be bidding in a series of auctions for units of a good called X.

These instructions are solely for your private information. **It is prohibited to communicate with the other participants during the experiment.** Should you have any questions, please ask me. If you violate this rule, I shall have to exclude you from the experiment and from all payments.

The currency used in this market is "francs". All bidding in the auctions will be in terms of francs. Your final payoff will be in terms of dollars. The conversion rate is _____ francs to 1 dollar. You will be paid at the end of the experiment.

Detailed Instructions:

The experiment consists of 60 periods. In each period the participants are divided into groups of four. You will therefore be in a group with 3 other participants. These groupings will remain **constant** for the **entire experiment**. That is, the participants of your group will be the **same** throughout **all periods**. There will be 1 unit of X sold to each group each period. If you happen to buy a unit of X in a period, you will receive 1000 francs.

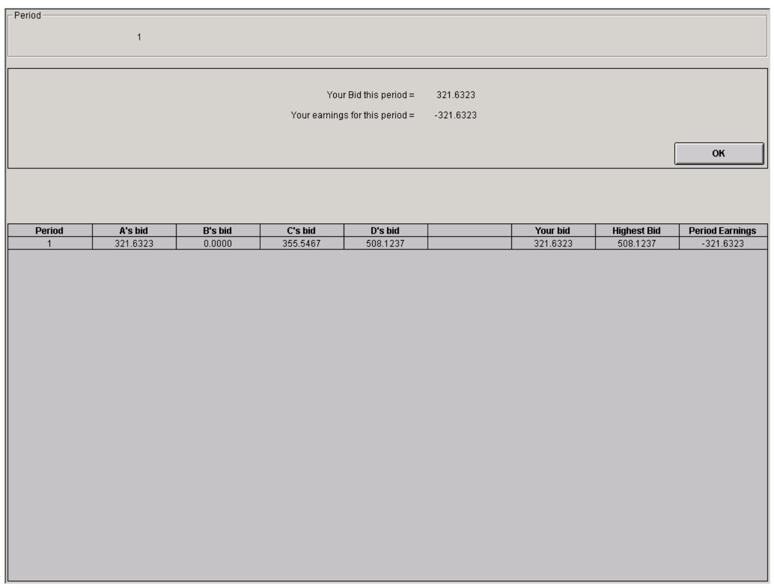


The figure above is an example of the bidding screen for a given period. In the top left corner, the current period is displayed. The REDEMPTION VALUE indicates how many francs you will receive if you are able to buy a unit of X in the auction. Remember that each participant has the same redemption value of 1000 francs. In the space provided next to MY BID IS, you may submit a bid for one unit of X. Your bid can be any amount greater than or equal to negative one thousand -1000 and may be a decimal (up to 4 decimal places). In the space provided next to PREDICTED HIGHEST BID (OTHER THAN YOURS), please enter what you believe will be the highest bid in your group for that period other than your own bid. Once you have entered a bid and prediction, please click on the OK button.

Notice that all the participants of your group make their bids simultaneously without knowing the bid of your group members.

In each period, all of the bids will be ordered from highest to lowest for each group. The highest bid in each group will be accepted and the bidder who made the bid will receive the unit of X. If there is a tie for the highest bid, then 1000 francs will be divided evenly between all the highest bidders.

IN THIS AUCTION, THE AMOUNT THAT YOU BID WILL BE SUBSTRACTED FROM YOUR EARNINGS REGARDLESS OF WHETHER YOU RECEIVE A UNIT OR NOT.



The figure above is an example of a summary screen for fictitious period 1. Once everyone has entered his/her bid for the period, you will be shown a summary screen that presents the decisions of all group members for all completed periods. The first column in the table labeled PERIOD lists the periods that have been completed in the experiment. The columns labeled A's BID, B's BID, C's BID and D's BID list the bids of all group members for the corresponding period. The column labeled YOUR BID lists your bid for each period. The column labeled HIGHEST BID lists the highest bid per period. The column labeled PERIOD EARNINGS lists your earnings for each period. When you are finished viewing the information, please click the OK button. Once everyone clicks the OK button, the program will proceed to the next period.

Determining Your Earnings:

You will receive an initial endowment of 5000 francs at the beginning of the experiment. The amount of your bid each period will be subtracted from your earnings regardless of whether you receive a unit of X or not. If you are the highest bidder and thus purchase a unit of X, your period earnings are 1000 francs minus the amount of your bid. If you are not the highest bidder and bid between -1000 and 0, you will earn 0 minus the amount of your bid. If you are not the highest bidder and bid greater than zero, you will earn negative profit for the period. If you bid more than 1000, you are guaranteed to make negative profit for the period. Your earnings for the entire experiment are the sum of your period earnings plus the initial endowment of 5000 francs.

You earnings each period are calculated as:

If your bid is the highest bid, then your payoff = - your bid + 1000 francs
If your bid is not the highest bid, then your payoff = - your bid

The computer will calculate the earnings for you each period.

The three following examples may be helpful in explaining the calculations.

Example 1: Suppose for example that your Redemption Value is 1000 and you submit a bid for 800. Suppose your bid is the highest so that you receive the unit of X being sold. Your earnings for the period equal 1000 - 800 = 200.

Example 2: Suppose that your Redemption Value is 1000 and you submit a bid for 355.89. Suppose your bid is not the highest so that you do not receive the unit being sold. Then your payoff for the period equals 0 - 355.89 = -355.89. You incur losses of 355.89 for the period.

Example 3: Suppose for example that your Redemption Value is 1000 and you submit a bid for -800. Suppose your bid is not the highest so that you do not receive the unit of X being sold. Your earnings for the period equal 0 – (-800) = 800.

Example 4: Suppose for example that your Redemption Value is 1000 and you submit a bid for -800. Suppose your bid is the highest so that you receive the unit of X being sold. Your earnings for the period equal 1000 – (-800) = 1800.

Example 5: Suppose that your Redemption Value is 1000 and you submit a bid for 1200. Suppose your bid is the highest so that you do receive the unit being sold. Then your payoff for the period equals 1000 – 1200 = -200. Even though you have submitted the highest bid and purchase the unit, you still incur losses of 200 for the period.

Quiz: To check your understanding of the experiment, please answer the following questions:

1. Assume that in the first period your bid is 700. Suppose your bid is the highest so that you receive the unit of X being sold.
   a) You earn +300 in the first period.
   b) You earn +700 in the first period.
   c) You earn +1000 in the first period.
   d) You earn +1700 in the first period.
   e) You earn -700 in the first period.

2. Assume that in the first period your bid is 20.751. Suppose your bid is not the highest so that you do not receive the unit of X being sold.
   a) You earn -20.751 in the first period.
   b) You earn 979.249 in the first period.
   c) You earn 1020.751 in the first period.
   d) You earn 1000 in the first period.
   e) None of the above

3. Assume that in the first period your bid is 0. Suppose your bid is not the highest so that you do not receive the unit of X being sold.
   a) You earn -1000 in the first period.
   b) You earn 1000 in the first period.
   c) You earn 0 in the first period.
   d) Bidding 0 is not allowed
   e) None of the above

4. Assume that in the first period your bid is 1100. Suppose your bid is the highest so that you receive the unit of X being sold.
   a) You earn 1100 in the first period.
   b) You earn 1000 in the first period.
   c) You earn -1100 in the first period.
   d) You earn -100 in the first period.
   e) None of the above

5. Assume that in the first period your bid is -700. Suppose your bid is not the highest so that you do not receive the unit of X being sold.
   a) You earn +300 in the first period.
   b) You earn +700 in the first period.
   c) You earn +1000 in the first period.
   d) You earn +1700 in the first period.
   e) You earn -700 in the first period.

6. Assume that in the first period you bid is -700. Suppose your bid is the highest so that you do receive the unit of X being sold.
   a) You earn +300 in the first period.
   b) You earn +700 in the first period.
   c) You earn +1000 in the first period.
   d) You earn +1700 in the first period.
   e) You earn -700 in the first period.

7. Will you ever make a profit if you bid greater than 1000?
   a) Depends on what others bid.
   b) Yes, since it guarantees that I purchase the unit of X.
   c) No, since someone might have still bid more than me.
   d) No, since the redemption value for X is 1000.
   e) None of the above.

Instructions for Experiment (*For Treatment P*)

General Instructions:

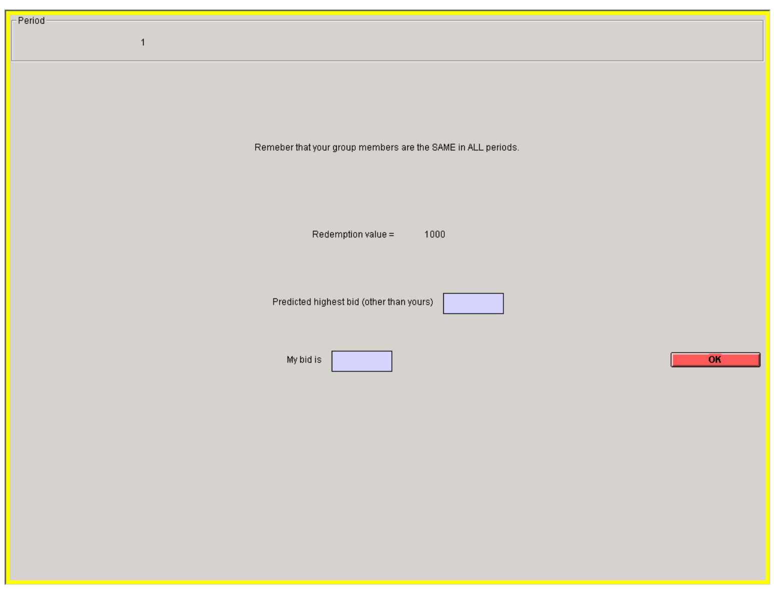
This is an experiment in the economics of decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash. The experiment will consist of 60 periods in which you will be bidding in a series of auctions for units of a good called X.

These instructions are solely for your private information. **It is prohibited to communicate with the other participants during the experiment.** Should you have any questions, please ask me. If you violate this rule, I shall have to exclude you from the experiment and from all payments.

The currency used in this market is "francs". All bidding in the auctions will be in terms of francs. Your final payoff will be in terms of dollars. The conversion rate is 5275 francs to 1 dollar. You will be paid at the end of the experiment.

Detailed Instructions:

The experiment consists of 60 periods. In each period the participants are divided into groups of four. You will therefore be in a group with 3 other participants. These groupings will remain **constant** for the **entire experiment**. That is, the participants of your group will be the **same** throughout **all periods**. There will be 1 unit of X sold to each group each period. If you happen to buy a unit of X in a period, you will receive 1000 francs.

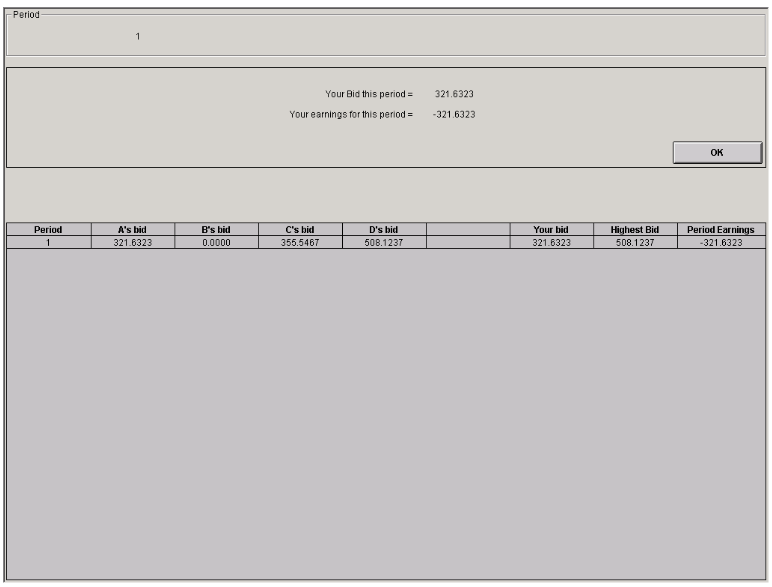


The figure above is an example of the bidding screen for a given period. In the top left corner, the current period is displayed. The REDEMPTION VALUE indicates how many francs you will receive if you are able to buy a unit of X in the auction. Remember that each participant has the same redemption value of 1000 francs. In the space provided next to MY BID IS, you may submit a bid for one unit of X by entering a non-negative bid. Your bid can be any amount greater than or equal to zero and may be a decimal (up to 4 decimal places). In the space provided next to PREDICTED HIGHEST BID (OTHER THAN YOURS), please enter what you believe will be the highest bid in your group for that period other than your own bid. Once you have entered a bid and prediction, please click on the OK button.

Notice that all the participants of your group make their bids simultaneously without knowing the bid of your group members.

In each period, all of the bids will be ordered from highest to lowest for each group. The highest bid in each group will be accepted and the bidder who made the bid will receive the unit of X. If there is a tie for the highest bid, then 1000 francs will be divided evenly between all the highest bidders.

IN THIS AUCTION, YOU MUST PAY THE AMOUNT THAT YOU BID REGARDLESS OF WHETHER YOU RECEIVE A UNIT OR NOT.



The figure above is an example of a summary screen for fictitious period 1. Once everyone has entered his/her bid for the period, you will be shown a summary screen that presents the decisions of all group members for all completed periods. The first column in the table labeled PERIOD lists the periods that have been completed in the experiment. The columns labeled A’s BID, B’s BID, C’s BID and D’s BID list the bids of all group members for the corresponding period. The column labeled YOUR BID lists your bid for each period. The column labeled HIGHEST BID lists the highest bid per period. The column labeled PERIOD EARNINGS lists your earnings for each period. When you are finished viewing the information, please click the OK button. Once everyone clicks the OK button, the program will proceed to the next period.

Determining Your Earnings:

You will receive an initial endowment of 65000 francs at the beginning of the experiment. You must pay the amount of your bid each period regardless of whether you receive a unit of X or not. If you are the highest bidder and thus purchase a unit of X, your period earnings are 1000 francs minus the amount of your bid. If you are not the highest bidder, you will earn zero or negative profit for the period (zero if you bid zero, and negative if you bid greater than zero). If you bid more than 1000 francs, you are guaranteed to make negative profit for the period. Your earnings for the entire experiment are the sum of your period earnings plus the initial endowment of 65000 francs.

You earnings each period are calculated as:

If your bid is the highest bid, then your payoff = - your bid + 1000 francs
If your bid is not the highest bid, then your payoff = - your bid

The computer will calculate the earnings for you each period.

The three following examples may be helpful in explaining the calculations.

Example 1: Suppose for example that your Redemption Value is 1000 and you submit a bid for 800. Suppose your bid is the highest so that you receive the unit of X being sold. Your earnings for the period equal 1000 - 800 = 200.

Example 2: Suppose that your Redemption Value is 1000 and you submit a bid for 355.89. Suppose your bid is not the highest so that you do not receive the unit being sold. Then your payoff for the period equals 0 - 355.89 = -355.89. You incur losses of 355.89 for the period.

Example 3: Suppose that your Redemption Value is 1000 and you submit a bid for 1200. Suppose your bid is the highest so that you do receive the unit being sold. Then your payoff for the period equals 1000 – 1200 = -200. Even though you have submitted the highest bid and purchase the unit, you still incur losses of 200 for the period.

Quiz: To check your understanding of the experiment, please answer the following questions:

1. Assume that in the first period your bid is 700. Suppose your bid is the highest so that you receive the unit of X being sold.
    a. You earn +300 in the first period.
    b. You earn +700 in the first period.
    c. You earn +1000 in the first period.
    d. You earn -300 in the first period.
    e. You earn -700 in the first period.

2. Assume that in the first period your bid is 20.751. Suppose your bid is not the highest so that you do not receive the unit of X being sold.
    a. You earn -20.751 in the first period.
    b. You earn 979.249 in the first period.
    c. You earn 1020.751 in the first period.
    d. You earn 1000 in the first period.
    e. None of the above

3. Assume that in the first period your bid is 0. Suppose your bid is not the highest so that you do not receive the unit of X being sold.
    a. You earn -1000 in the first period.
    b. You earn 1000 in the first period.
    c. You earn 0 in the first period.
    d. Bidding 0 is not allowed
    e. None of the above

4. Assume that in the first period your bid is 1100. Suppose your bid is the highest so that you receive the unit of X being sold.
    a. You earn 1100 in the first period.
    b. You earn 1000 in the first period.
    c. You earn -1100 in the first period.
    d. You earn -100 in the first period.
    e. None of the above

5. Will you ever make a profit if you bid greater than 1000?
    a. Depends on what others bid.
    b. Yes, since it guarantees that I purchase the unit of X.
    c. No, since someone might have still bid more than me.
    d. No, since the redemption value for X is 1000.
    e. None of the above.

Instructions for Experiment (*For Treatment S*)

General Instructions:

This is an experiment in the economics of decision-making. The instructions are simple, and if you follow them carefully and make good decisions, you might earn a considerable amount of money which will be paid to you in cash. The experiment will consist of 60 periods in which you will be bidding in a series of auctions for units of a good called X.

These instructions are solely for your private information. **It is prohibited to communicate with the other participants during the experiment.** Should you have any questions, please ask me. If you violate this rule, I shall have to exclude you from the experiment and from all payments.

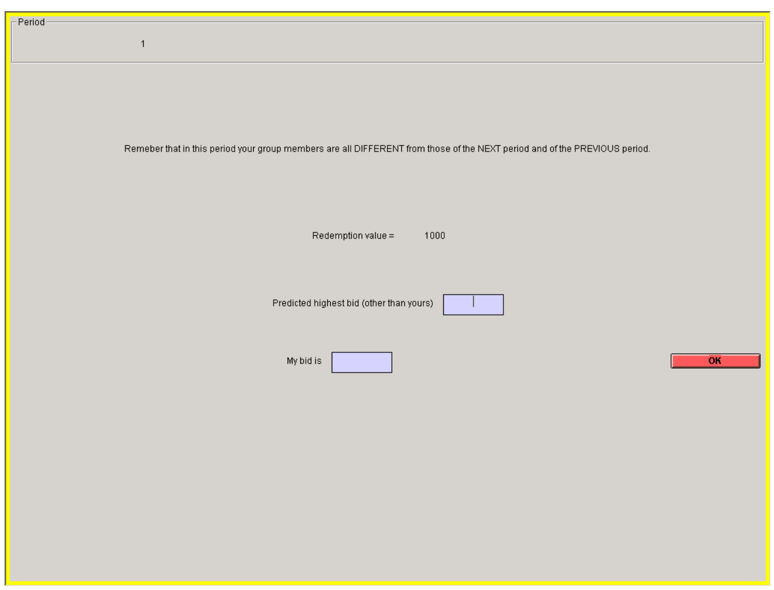
The currency used in this market is "francs". All bidding in the auctions will be in terms of francs. Your final payoff will be in terms of dollars. The conversion rate is _____ francs to 1 dollar. You will be paid at the end of the experiment.

Detailed Instructions :

The experiment consists of 60 periods. In each period the participants are divided into groups of four. You will therefore be in a group with 3 other participants. The composition of your group will be changing **every** period. After every period you will be **reassigned** to a **new group** of 4 participants. The probability that you will play with the same group member in two consecutive periods is zero, and the probability that you will play with the same group member in the third following period is very low.

THAT IS, YOU WILL NOT BE MATCHED WITH ANY OF THE SAME GROUP MEMBERS IN ANY TWO CONSECUTIVE PERIODS.

There will be 1 unit of X sold to each group each period. If you happen to buy a unit of X in a period, you will receive 1000 francs.

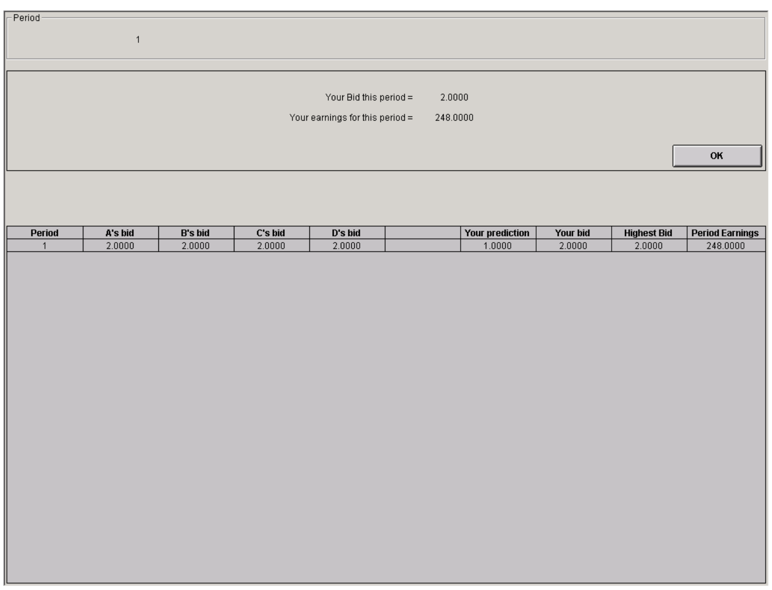


The figure above is an example of the bidding screen for a given period. In the top left corner, the current period is displayed. The REDEMPTION VALUE indicates how many francs you will receive if you are able to buy a unit of X in the auction. Remember that each participant has the same redemption value of 1000 francs. In the space provided next to MY BID IS, you may submit a bid for one unit of X by entering a non-negative bid. Your bid can be any amount greater than or equal to zero and may be a decimal (up to 4 decimal places). In the space provided next to PREDICED HIGHEST BID (OTHER THAN YOURS), please enter what you believe will be the highest bid in your group for that period other than your own bid. Once you have entered a bid and prediction, please click on the OK button.

Notice that all the participants of your group make their bids simultaneously without knowing the bid of your group members.

In each period, all of the bids will be ordered from highest to lowest for each group. The highest bid in each group will be accepted and the bidder who made the bid will receive the unit of X. If there is a tie for the highest bid, then 1000 francs will be divided evenly between all the highest bidders.

IN THIS AUCTION, YOU MUST PAY THE AMOUNT THAT YOU BID REGARDLESS OF WHETHER YOU RECEIVE A UNIT OR NOT.



The figure above is an example of a summary screen for fictitious period 1. Once everyone has entered his/her bid for the period, you will be shown a summary screen that presents the decisions of all group members for all completed periods. The first column in the table labeled PERIOD lists the periods that have been completed in the experiment. The columns labeled A's BID, B's BID, C's BID and D's BID list the bids of all group members for the corresponding period. Your bid for the period will always be in the columns A's BID and YOUR BID. The column labeled HIGHEST BID lists the highest bid per period. The column labeled PERIOD EARNINGS lists your earnings for each period. When you are finished viewing the information, please click the OK button. Once everyone clicks the OK button, the program will proceed to the next period.

Determining Your Earnings:

You will receive an initial endowment of 65000 francs at the beginning of the experiment. You must pay the amount of your bid each period regardless of whether you receive a unit of X or not. If you are the highest bidder and thus purchase a unit of X, your period earnings are 1000 francs minus the amount of your bid. If you are not the highest bidder, you will earn zero or negative profit for the period (zero if you bid zero, and negative if you bid greater than zero). If you bid more than 1000 francs, you are guaranteed to make negative profit for the period. Your earnings for the entire experiment are the sum of your period earnings plus the initial endowment of 65000 francs.

You earnings each period are calculated as:

If your bid is the highest bid, then your payoff = - your bid + 1000 francs
If your bid is not the highest bid, then your payoff = - your bid

The computer will calculate the earnings for you each period.

The three following examples may be helpful in explaining the calculations.

Example 1: Suppose for example that your Redemption Value is 1000 and you submit a bid for 800. Suppose your bid is the highest so that you receive the unit of X being sold. Your earnings for the period equal 1000 - 800 = 200.

Example 2: Suppose that your Redemption Value is 1000 and you submit a bid for 355.89. Suppose your bid is not the highest so that you do not receive the unit being sold. Then your payoff for the period equals 0 - 355.89 = -355.89. You incur losses of 355.89 for the period.

Example 3: Suppose that your Redemption Value is 1000 and you submit a bid for 1200. Suppose your bid is the highest so that you do receive the unit being sold. Then your payoff for the period equals 1000 – 1200 = -200. Even though you have submitted the highest bid and purchase the unit, you still incur losses of 200 for the period.

Quiz: To check your understanding of the experiment, please answer the following questions:

1. Assume that in the first period your bid is 700. Suppose your bid is the highest so that you receive the unit of X being sold.
    a. You earn +300 in the first period.
    b. You earn +700 in the first period.
    c. You earn +1000 in the first period.
    d. You earn -300 in the first period.
    e. You earn -700 in the first period.

2. Assume that in the first period your bid is 20.751. Suppose your bid is not the highest so that you do not receive the unit of X being sold.
    a. You earn -20.751 in the first period.
    b. You earn 979.249 in the first period.
    c. You earn 1020.751 in the first period.
    d. You earn 1000 in the first period.
    e. None of the above

3. Assume that in the first period your bid is 0. Suppose your bid is not the highest so that you do not receive the unit of X being sold.
    a. You earn -1000 in the first period.
    b. You earn 1000 in the first period.
    c. You earn 0 in the first period.
    d. Bidding 0 is not allowed
    e. None of the above

4. Assume that in the first period your bid is 1100. Suppose your bid is the highest so that you receive the unit of X being sold.
    a. You earn 1100 in the first period.
    b. You earn 1000 in the first period.
    c. You earn -1100 in the first period.
    d. You earn -100 in the first period.
    e. None of the above

5. Will you ever make a profit if you bid greater than 1000?
    a. Depends on what others bid.
    b. Yes, since it guarantees that I purchase the unit of X.
    c. No, since someone might have still bid more than me.
    d. No, since the redemption value for X is 1000.
    e. None of the above.

Record Sheet (*Used for all Treatments)*

Period	Earnings	Period	Earnings
1		31	
2		32	
3		33	
4		34	
5		35	
6		36	
7		37	
8		38	
9		39	
10		40	
11		41	
12		42	
13		43	
14		44	
15		45	
16		46	
17		47	
18		48	
19		49	
20		50	
21		51	
22		52	
23		53	
24		54	
25		55	
26		56	
27		57	
28		58	
29		59	
30		60	
		Total Earnings Calculation	
		5000	(Endowment)
	+	______	(Sum period earnings)
		______	(Total Earnings)

Appendix 2

Table A1: Wilcoxon Signed-Rank Test Statistics Comparing Average Aggregate Dissipation across Periods

	Treatment									
	P					S				
Later Periods \ Earlier Periods	1-10	11-20	21-30	31-40	41-50	1-10	11-20	21-30	31-40	41-50
11-20	-401					-438				
21-30	-348	53				-426	12			
31-40	-522**	-121	-174			-788	-350	-361		
41-50	-496***	-94	-148	27		-731	-293	-304	57	
51-60	-612***	-210	-264	-89	-116	-611	-173	-184	177	119
	Treatment									
	P-neg									
Later Periods \ Earlier Periods	1-10	11-20	21-30	31-40	41-50					
11-20	-230**									
21-30	-393**	-163								
31-40	-520***	-290*	-127							
41-50	-417*	-187	-24	103*						
51-60	-632***	-402**	-239*	-112	-215***					