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Contests with Entry Fees: Theory and Evidence*

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Abstract

We provide some theory and experimental evidence on contests with entry fees. In our setup, players must simultaneously decide whether or not to pay a fee to enter a contest and the amount they wish to bid should they choose to enter the contest. In a general n-bidder game, we show that the addition of contest entry fees increases the contest designer's expected revenue and that there is a unique revenue maximizing entry fee. In an experimental test of this theory we vary both the entry fee and the number of bidders. We find over-bidding for all entry fees and bidder group sizes, n. We also find under-participation in the contest for low entry fees and over-participation for higher entry fees. In the case of 3 bidders, the revenue maximizing entry fee for the contest designer is found to be significantly greater than the theoretically optimal entry fee. We offer some possible explanations for these departures from theoretical predictions.

Keywords: Contests, Entry Fees, Experimental Economics.

JEL Codes: C72, C92, D72.

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1 Introduction

Contests are games in which participants' effort choices affect their probability of winning a prize. Examples include competitions for promotion among employees, political lobbying, and R&D patent races. While contests need not have entry fees, and the contest literature does not give much attention to such fees, many real-world contests *do* have entry fees. Examples include writing contests, music competitions, photography contests, marathons, dance competitions, and cooking competitions. The organizers of these contests realized a long time ago that the addition of entry fees can increase their expected revenue. Other motivations for such entry fees may include the filtering out of low ability players to increase the quality of contest entries, but here our focus is on seller revenue. Using the model of Fu et al. (2015) we develop a tractable framework for evaluating the designer's revenue and the optimal entry fee for a general n-bidder game. We then design and report on an experiment to investigate whether subjects behave in this game in the manner predicted by the theory when the entry fee changes or the number of bidders is set to $n = 2$ or 3. Our experimental design has both between- and within- subject elements. Between subjects, we hold the group size, n, in a session fixed at either 2 or 3 bidders per round. Within each 2- or 3-bidder session we fix the value of the prize that bidders are attempting to win, $V = 100$, and we vary the contest entry fee, c that bidders face. We consider entry fees in the set: $\{0, 11, 25, 40, 70, 110\}$. In the 2-bidder (3-bidder) case, the theory we develop suggests that the contest designer's expected revenue maximizing choice is to set an entry fee of 25 (11) and that is why we consider those entry fees in addition to three other fees and a 0 entry fee as well. It would be difficult to test how similar groups of bidders react to different entry fees or to evaluate the optimal entry fee prediction using field data; the control of the laboratory enables us to more clearly assess the empirical relevance of the theory, and that is why we chose to evaluate the theory using experimental data.

To preview our experimental results, we have three main findings. First, we find departures from the theoretical equilibrium point predictions for both participation in contests and for the amounts bid across nearly all of the $2 \times 6 = 12$ treatment conditions that we consider. However, the *comparative statics* predictions of the theory work quite well: as the theory predicts, both the frequency of participation in contests and the amount bid tend to decrease, on average, as the entry fee increases. Second, we find that there is under-participation for 0 or low contest entry fees and over-participation for higher contest entry fees. For the lowest entry fees, participation is predicted to be 100% and for the highest entry fee it is predicted to be 0%. Thus, under-participation in the former and over-participation in the latter are not so surprising since in both cases, errors in participation decisions can only go in one direction. However, in 4 of the 5 treatment conditions for which the symmetric equilibrium predicts participation frequencies between 0 and 100% we observe *over*-participation relative to these equilibrium predictions.[1] Similarly, we find that while bids tend to decline ever so slightly as entry fees increase, subjects bid significantly more than equilibrium predictions for all entry fees and both group sizes ($n = 2$, 3). This finding of over-bidding is commonplace in the experimental contest literature where most studies show significant overspending in contest experiments relative to theoretical predictions. See, for example, Morgan et al. (2012), Fallucchi et al. (2013), Sheremeta (2013), Lim et al. (2014), Dechenaux et al. (2015), and Sheremeta (2018). Finally, over-participation for higher entry fees together with over-bidding across all treatments means that the contest designer's revenue is greater than the theoretical prediction. A further implication is that the contest entry fee that is found to maximize the contest designer's

[1]For details see discussion on page 13.

revenue (among the 6 fees that we consider) can be greater than the theoretically optimal entry fee. For instance, in the $n = 3$ case, the empirical, revenue maximizing contest entry fee is found to be $c = 40$ which is much greater than the theoretically optimal fee of $c = 11$ for that same $n = 3$ case. This finding suggests that the theoretically optimally contest entry fees might serve as lower bounds on the choice of entry fees that contest designer's should choose in practice.

As for related literature, there are several papers, Anderson and Stafford (2003), Boosey et al. (2020), and Hammond et al. (2019), that also study contests with entry fees. Anderson and Stafford (2003) test the theoretical predictions of Gradstein (1995) using an experimental design with a variable number of players, cost heterogeneity, and a fixed entry fee. In the first stage, players decide whether to enter the contest and pay a fixed entry fee or not enter. In the second stage, the contestants compete in a Tullock contest. The authors find that, consistent with theoretical predictions, cost heterogeneity and an entry fee decrease participation and effort. Our paper differs from Anderson and Stafford (2003) in two ways. First, our subjects have to make decisions about their participation and effort/bids at the *same time*. Second, and more importantly, we examine how subjects' behavior changes with different entry fees.

Boosey et al. (2020) experimentally test the effect of disclosing the number of active participants in contests with endogenous entry. In the first stage of their experiment, participants choose between entering the contest or receiving an outside option. In the second stage, active participants choose their investment level. The authors manipulate the size of the outside option and the disclosure of the number of entrants at the second stage. They find greater entry for lower outside options, as theory predicts. When the outside option is low, consistent with the theory, disclosing the number of entrants has no effect on aggregate investment. However, when the outside option is high, they find that there is a strong positive correlation between aggregate investment and the disclosure of the number of active players. Our paper is similar to Boosey et al. (2020) in the case where they do not disclose the number of entrants. However, we differ in how we model entry fees: Boosey et al. (2020) have an outside option, and we explicitly use a fee to enter the contest. This important difference can significantly affect the experimental results due to the different framing of entry fees. In addition, we are able to find the entry fee that maximizes total spending or the contest designer's revenue. Anderson and Stafford (2003) and Boosey et al. (2020) do not consider this question.

Finally, Hammond et al. (2019) investigate contests with prize-augmenting entry fees both theoretically and experimentally. Moreover, their model incorporates different abilities of the players (which are their private information) and entry fees increase the winner's prize. They also investigate their theoretical predictions for the two-player case in the experimental laboratory. They set entry fees either at zero, the optimal level (the level that maximizes total effort in theory), or higher than the optimal level (three times the optimal level). They find, consistent with their theoretical predictions, that the optimal entry fee maximizes contest revenue. In contrast, the revenue maximizing entry fee in our experiment is much greater than the theoretical prediction. However, the Hammond et al. (2019) setting is different from our model and experiment; in their setting, the winner's prize depends on the entry fee.

The auction literature has a long history of studying optimal mechanisms including reserve prices and entry fees. Typically, only the auction winner pays the reserve price. Krishna (2002) describes analytical expressions for the optimal reserve price. Both reserve prices and entry fees serve to exclude buyers with low values in auctions. Engelbrecht-Wiggans (1989) and McAfee and McMillan (1987a) provide surveys of this auction literature. A typical theoretical and empirical observation is that the entry fee determines the number of active bidders in the auction. Meyer

(1993) considers first-price private-value auctions with entry fees in the experimental laboratory. He finds that the number of active bidders is inversely related to the size of the entry fee. McAfee and McMillan (1987b) analyze first-price sealed-bid auctions with ex ante identical potential bidders and find that it is optimal for the designer to set an entry fee. Harstad (1990) studies endogenous entry in common-value auctions with entry fees. He assumes that the expected number of bidders always enter the auction. Levin and Smith (1994) consider private-value auctions with risk-neutral bidders. They introduce mixed entry strategies and describe a symmetric equilibrium with a stochastic number of active bidders.

Binmore (2007) discusses a two-bidder sealed-bid auction with an entry fee. He finds a symmetric mixed-strategy equilibrium, where both bidders stay out with a positive probability and randomize their bids if they enter the auction. As in Binmore (2007)'s model, in the equilibrium of our model players also stay out of contests with higher entry fees with a positive probability. However, our active contestants do not randomize their efforts levels in the symmetric equilibrium of the game that we study.

The rest of this paper is organized as follows. First, we present a theoretical model in Section 2. A unique equilibrium is described in which we show how entry fees affect the level of participation and individual efforts in the contest, as well as the expected payoff of the contest designer. Then, in Section 3, we describe our experimental design and predictions. Section 4 presents our main findings. Section 5 concludes.

2 The Model

Consider an $n-$player contest. All players value the prize as $V > 0$. There is a contest entry fee $c \geq 0$.

A strategy of each player i has two parts (p_i, x_i), where $0 \leq p_i \leq 1$ is the contest entry probability of player i and $x_i \geq 0$ is her contest contribution (or bid). We will look for a *symmetric* equilibrium, (p^*, x^*). If player i enters the contest, or $p_i = 1$, then she maximizes her expected payoff:

$$\begin{aligned} E\pi_i\left(p_i=1,x_i\right) = -c + C_0^{n-1}\left(1-p^*\right)^{n-1}\cdot V + \\ +C_1^{n-1}p^*\left(1-p^*\right)^{n-2}\left(\frac{x_i}{x_i+x^*}\right)\cdot V \\ +C_2^{n-1}\left(p^*\right)^2\left(1-p^*\right)^{n-3}\left(\frac{x_i}{x_i+2x^*}\right)\cdot V \\ +...+ \\ +C_{n-1}^{n-1}\left(p^*\right)^{n-1}\left(\frac{x_i}{x_i+(n-1)\,x^*}\right)\cdot V - x_i, \end{aligned} \tag{1}$$

where the first term is the entry fee, the second term is the expected payoff from winning the prize without competition, the third term is the expected payoff from winning the prize in competition with one player and so on, and the last term is the cost of effort.

2.1 Symmetric Equilibrium

Given (1), the optimal x_i has to satisfy the following first order condition

$$
\begin{gathered}
C_1^{n-1} p^* \left(1-p^*\right)^{n-2} \frac{x^*}{\left(x_i+x^*\right)^2} \cdot V \\
+C_2^{n-1} \left(p^*\right)^2 \left(1-p^*\right)^{n-3} \frac{2x^*}{\left(x_i+2x^*\right)^2} \cdot V \\
+...+ \\
+C_{n-1}^{n-1} \left(p^*\right)^{n-1} \frac{\left(n-1\right) x^*}{\left(x_i+\left(n-1\right) x^*\right)^2} \cdot V = 1.
\end{gathered} \tag{2}
$$

In a symmetric equilibrium, $x_i = x^*$ and $p_i = p^*$. Thus, from the first order condition (2), we get

$$
x^* \left(p^*\right) = V \cdot \sum_{i=1}^{n-1} \frac{i}{\left(i+1\right)^2} C_i^{n-1} \left(p^*\right)^i \left(1-p^*\right)^{n-i-1}. \tag{3}
$$

Plugging (3) back into (1), we obtain

$$
\begin{gathered}
E\pi \left(p_i = 1, x^*\right) = -c + C_0^{n-1} \left(1-p^*\right)^{n-1} \cdot V + \\
+C_1^{n-1} p^* \left(1-p^*\right)^{n-2} \left(\frac{1}{2}\right) \cdot V \\
+C_2^{n-1} \left(p^*\right)^2 \left(1-p^*\right)^{n-3} \left(\frac{1}{3}\right) \cdot V \\
+...+ \\
+C_{n-1}^{n-1} \left(p^*\right)^{n-1} \left(\frac{1}{n}\right) \cdot V - V \cdot \sum_{i=1}^{n-1} \frac{i}{\left(i+1\right)^2} C_i^{n-1} \left(p^*\right)^i \left(1-p^*\right)^{n-i-1} \geq 0.
\end{gathered}
$$

Therefore, if

$$
c \leq \frac{V}{n^2},
$$

then there exists a pure strategy equilibrium with $p^* = 1$ and $x^* = \frac{n-1}{n^2} \cdot V$, where all players get non-negative expected payoffs.

If

$$
c > \frac{V}{n^2},
$$

then all players cannot enter the contest with certainty because their expected payoffs will be negative. Hence, in this case, all players enter the contest with a probability strictly less than one and obtain zero expected payoff, or

$$
E\pi \left(p^*, x^*\right) = 0,
$$

or

$$
V \cdot \sum_{i=0}^{n-1} \frac{1}{\left(i+1\right)^2} C_i^{n-1} \left(p^*\right)^i \left(1-p^*\right)^{n-i-1} = c. \tag{4}
$$

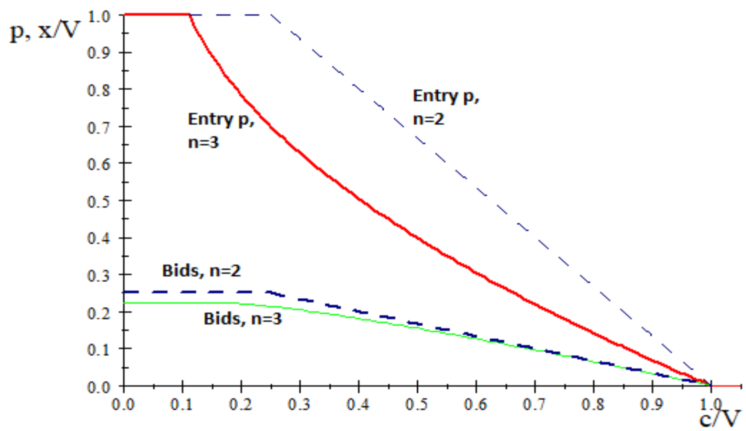

Figure 1: Symmetric equilibrium for $n = 2$ (dashed lines) and $n = 3$ (solid lines)

Proposition 1 *Equation* (4) *has a unique solution* $p^* \in [0, 1]$ *for any* $\frac{c}{V} \in \left[\frac{1}{n^2}, 1\right]$.

See proof in the Appendix.

The next two propositions comprise our main theoretical results.

Proposition 2 *There exists a symmetric equilibrium* $(p^*(n, c), x^*(n, c))$, *where*

$$p^*(n,c) = \begin{cases} 1, & \text{if } 0 \leq c \leq \frac{V}{n^2}, \\ p^*(c), & \text{if } \frac{V}{n^2} < c < V, \\ 0, & \text{if } c \geq V, \end{cases} \tag{5}$$

and

$$x^*(n,c) = \begin{cases} \frac{n-1}{n^2} \cdot V, & \text{if } 0 \leq c \leq \frac{V}{n^2}, \\ x^*(p^*), & \text{if } \frac{V}{n^2} < c < V, \\ 0, & \text{if } c \geq V, \end{cases} \tag{6}$$

where $x^*(p^*)$ *is defined in* (3) *and* $p^*(c)$ *is a unique solution of equation* (4).

In our experiment, we concentrate on the cases where $n = 2$ and $n = 3$ as in those two cases we can derive closed-form solutions for bids and participation probabilities for any entry fee, c. Further, as the equilibrium bids are decreasing in n, the $n = 2$ and $n = 3$ cases provide the greatest amount of contrast for experimental evaluation.

Figure 1 illustrates symmetric equilibrium predictions for both participation and bids for the case of $n = 2$ (dashed lines) and the case of $n = 3$ (solid lines). The horizontal axis measures the normalized cost of entry c/V while the vertical axis measures both the probability of entry p and the normalized bid, x/V. The darker (blue) dashed line represents the bid $x^*(2, c)$ while the thinner (blue) dash line shows the participation probability $p^*(2, c)$ for the $n = 2$ case. The solid thin (green) line depicts the bid $x^*(3, c)$ and the solid thick (red) line shows the participation probability $p^*(3, c)$ for the $n = 3$ case. As Figure 1 reveals, entry costs have to be sufficiently high before they reduce participation and bid amounts. Further, for a given entry cost c, participation probabilities and symmetric bid amounts are generally (though not always lower) as n increases from 2 to 3.

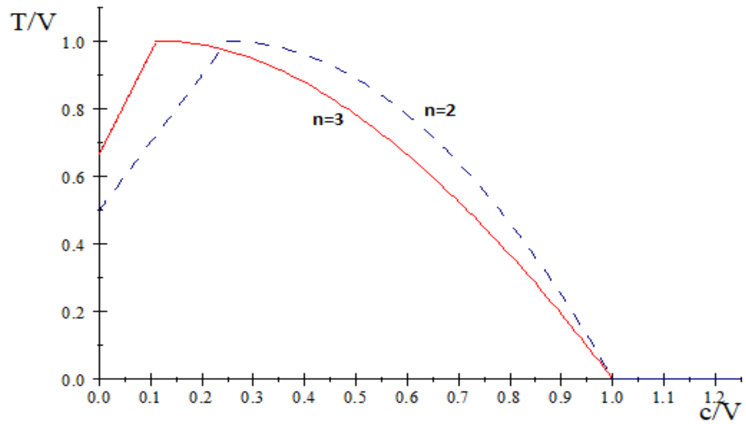

Figure 2: Designer's relative expected payoff, T/V, (vertical axis) as a function of the relative entry cost, c/V (horizontal axis) when $n = 2$ (dashed blue line) and when $n = 3$ (solid red line).

2.2 Designer's Payoff

The expected payoff of the contest designer in the equilibrium is

$$T\left(n,c\right) = np^{*}(x^{*}(n,c)+c)\left[C_{0}^{n-1}(p^{*})^{n-1}+C_{1}^{n-1}(p^{*})^{n-2}(1-p^{*})+...+C_{n-1}^{n-1}(1-p^{*})^{n-1}\right]. \quad (7)$$

Simplifying (7), we get

$$T\left(n,c\right) = np^{*}(x^{*}(n,c)+c). \quad (8)$$

Therefore, using (5) and (6), we get the following result.

Proposition 3 *The designer's expected payoff is*

$$T\left(n,c\right) = \begin{cases} n(\frac{n-1}{n^2}\cdot V+c), & \textit{if } 0\leq c\leq \frac{V}{n^2}, \\ np^{*}(x^{*}\left(p^{*}\right)+c), & \textit{if } \frac{V}{n^2}<c<V, \\ 0, & \textit{if } c\geq V. \end{cases}$$

The designer's expected payoff is maximized at $c^{*} = \frac{V}{n^2}$.

Notice that the designer's expected payoff is maximized by setting the entry fee as high as possible while still ensuring full participation in equilibrium. Prior to reaching the maximum the slope of expected designer revenue is linear and equal to n. Beyond the maximum, the slope is negative but nonlinear as players start to randomize their participation decision, which depends on the cost. These different slopes are revealed in Figure 2 which shows the designer's expected payoff, normalized by the prize value, i.e., $T(n,c)/V$, as a function of the entry cost relative to the prize value (c/V) for the case where $n = 2$ (dashed blue line) and $n = 3$ (solid red line). Given the normalization, the designer's expected payoff in Figure 2 is maximized at $\frac{1}{n^2}$. Notice further that the optimal entry fee induces full rent dissipation since $T(n,c^{*}) = V$.

3 Experimental Design

Our experimental design has two treatment dimensions. First, we consider contests involving groups of size $n = 2$, the "pairs" treatment, or groups of size $n = 3$, the "triples" treatment. The group size aspect of our design is *between subjects*. Second, we vary the contest entry fee that subjects face for each contest. This aspect of our design is *within subjects*. Each subject in the pairs or triples treatment plays a total of 6 different contests. Each contest has a different entry fee as detailed in Table 1. To avoid order effects, we consider two different orders for the six contest entry fees, the baseline ascending fee order and the reverse ascending fee order, as shown in Table 1. This difference in the order of fees is *between subjects*; specifically in one-half of the pairs and one-half of the triples treatment sessions we used the ascending order of fees (our baseline treatment) while in the other half we used the ascending order of fees.

Table 1: Contest Entry Fee in Points for Each of the Six Rounds

	Round/Contest Number					
	1	2	3	4	5	6
Ascending Order of Entry Fees	0	11	25	40	70	110
Descending Order of Entry Fees	110	70	40	25	11	0

The experiment was computerized using the oTree software (Chen et al. (2016)). Subjects entered all choices and received feedback using networked computer terminals.

We report results from 16 sessions, 8 of the pairs treatment and 8 of the triples treatment. Each pairs session consists of $N = 6$ subjects and each triples session consists of $N = 9$ subjects. Thus, we have data from 8×6 or 48 subjects in the pairs treatment and 8×9 or 72 subjects in the triples treatment, or a total of 120 subjects. In each session, all 6 or 9 subjects participated in the same six one-shot contests or "rounds" that differed only in their entry fee, as shown in Table 1.

At the start of each and every one of these six rounds, subjects were randomly and anonymously matched in groups to play each contest. In each pairs treatment session, the 6 subjects were randomly matched to form groups of size $n = 2$ (3 pairs total). In each triples treatment session, the 9 subjects were randomly matched to form groups of size $n = 3$ (3 triples total). Subjects always knew the number of subjects in their group (2 or 3), though the identities of these subjects were not known and the composition of each subject's group was likely to change from round to the next as the groups were randomly re-determined each round.

The prize for each contest/round was fixed across all sessions at $V = 100$ points. Prior to each contest/round $k = 1, 2, ..., 6$, subjects were shown the entry fee for that contest/round, c_k, also in points. Further, at the start of each and every round, they were given an endowment of $120 + c_k$ points for the round. With this information, subjects had to simultaneously decide whether or not to give up c_k points from their endowment to enter contest k.

If a subject chose *not* to enter contest k, then their payoff for the round was their endowment of $120 + c_k$ points. If a subject chose to enter contest k then they gave up the c_k points associated with entering that contest k and had to then choose how much to bid for the prize of $V = 100$ points out of their remaining endowment of 120 points. Note that the remaining endowment of points available to a subject who paid the entry fee to enter a contest was always the same, and, at 120 points, enabled a contest entrant to bid in excess of the constant prize value $V = 100$ if they so chose. Bids by contest entrants were always constrained to lie between 0 and 120 points and were made without knowledge of the number of other contest entrants or those other entrants' bids. If a subject was the only entrant (a fact they would not know in advance of bidding), then they would win the contest with any bid. If there was more than one contest entrant in a round, then subject i's probability of winning the 100 point prize was $x_i / \sum_{j=1}^{n} x_j$, where the numerator is subject i's bid and the denominator is the sum of the bids of all players (including i) where we assume that the bid of a non-entering player is 0. Thus, the point earnings of subject i in round/contest k can be summarized as follows:

$$\pi_i^k = 120 + \begin{cases} c_k, & \text{if } i \text{ did not enter,} \\ 100 - x_i, & \text{if } i \text{ entered and is the winner of his } n\text{-player group,} \\ -x_i, & \text{otherwise.} \end{cases}$$

After each round, subjects learned the number of subjects in their group of size $n = 2$ or 3 who chose to enter, the amount that each entrant bid and each entrant's probability of winning. To convey that information, entrants were assigned a temporary label as participant 1, 2 or 3 in each contest they chose to enter.

After all 6 rounds were played, subjects answered four cognitive reflection test (CRT) questions for which there was no additional payment. They then completed a brief demographic survey including a question about their willingness to take risks.

Subjects were given written instructions that were read aloud at the start of the experiment. They had to correctly answer a number of comprehension instructions before moving on to the main experiment. The experimental instructions, CRT and demographic survey questions along with example screenshots of the computer program used to collect the data can be found in the Appendix.

After the CRT and survey questions were completed, the program randomly chose one of the 6 rounds for payment. The round chosen was the same for all participants in a given session, but the round chosen for payment differed from session to session; subjects did not know in advance which of the 6 rounds would be chosen for payment and so they were incentivized to do their best in all 6 contests (rounds).

Each subject's point earnings from the randomly chosen round were converted into U.S. dollars at the known rate of 1 point = \$0.10. In addition, subjects earned a \$7 show-up payment. The subject's total earnings, including the \$7 show-up payment, averaged \$22.82 for a 1-hour study.

The subjects were 120 undergraduate students from the University of California, Irvine from various major programs of study. No subject participated in more than one session. The sessions were conducted in person in the UC Irvine Experimental Social Science Laboratory Subjects were recruited using the Sona system software. Details on the 16 sessions conducted and subjects' average earnings per session are given in Table 2.

4 Results

Details on the subject population are reported in Table 3. There we observe that our sample was 59% female, the average age was 20.2 years, the median CRT score was 2 (out of 4) and the median risk measure was 6 on the 11 point (0 - 10) Likert scale, where 0 means the subject is "completely unwilling to take risks" and 10 means the subject is "very willing to take risks."

In reviewing the major results from our experiment, we will first consider subjects' decisions to participate in the various contests, and the amounts they bid conditional on entry. Then we will

Table 2: Experimental Session Details and Average Subject Earnings

Session No.	No. Subjects	Group Size, n	Fee order	Avg Earnings
1	6	2	Ascending	$17.78
2	9	3	Ascending	$20.16
3	9	3	Ascending	$20.44
4	6	2	Ascending	$23.27
5	6	2	Ascending	$23.18
6	6	2	Ascending	$25.08
7	9	3	Ascending	$23.67
8	9	3	Ascending	$26.83
9	6	2	Descending	$30.00
10	6	2	Descending	$23.17
11	6	2	Descending	$19.68
12	6	2	Descending	$21.00
13	9	3	Descending	$17.27
14	9	3	Descending	$22.09
15	9	3	Descending	$22.23
16	9	3	Descending	$29.33
Total	120		Average	$22.82

Table 3: Descriptive Statistics on Subjects

	Female	Age	CRT Score	Risk
Mean	.592	20.158	2.108	5.525
SD	.494	2.609	1.471	1.931
Median	1	20	2	6
Min	0	18	0	1
Max	1	40	4	10

Table 4: Mean Participation Probabilities, Bids and Designer Payoffs Compared to Equilibrium (Eq). Top panel $n = 2$ treatment; bottom panel $n = 3$ treatment

Entry Fee	Mean Participation Probability	Eq Participation Probability	Mean Bid	Eq Bid	Mean Designer Payoff	Eq Designer's Exp. Payoff
			$\boldsymbol{n = 2}$			
0	0.90	1.00	43.52	25.00	77.97	50.00
11	0.88	1.00	46.86	25.00	101.26	72.00
25	0.73	1.00	43.41	25.00	99.77	100.00
40	0.60	0.80	43.28	20.00	100.63	96.00
70	0.50	0.40	39.44	10.00	109.44	64.00
110	0.19	0.00	53.70	0.00	61.39	0.00
			$\boldsymbol{n = 3}$			
0	0.82	1.00	41.62	22.00	102.31	66.00
11	0.81	1.00	44.06	22.00	133.07	99.00
25	0.71	0.70	42.40	21.38	143.24	97.40
40	0.69	0.50	39.15	18.13	164.90	87.20
70	0.44	0.22	36.10	9.64	141.47	52.56
110	0.18	0.00	42.55	0.00	82.63	0.00

explore group size and entry fee effects. Finally, we will consider the designer's actual revenue in relation to theoretical predictions.

Looking first at participation decisions, we find that 4 out of 120 subjects (3.3%) never submitted a bid in any contest (all 4 were in the $n = 3$ treatment) even when entry was free. Considering only contests with positive entry fees, 10 out of 120 subjects (8.3 %) never paid a fee to enter a contest, and so they never bid in such contests. On the other hand, 7 out of 120 subjects (5.8%) bid in all 6 contests and so they always paid the contest entry fees. Thus, the large majority of our subjects, 99/120 (91%) participated in the various contests with frequencies in the interval $(0, 1)$.

Mean participation rates by entry fee and group size are shown in Table 4 and in Figure 3 along with equilibrium predictions. In the first columns of Tables 5-7 under the heading "Participation in Contest" we report estimates from random effects probit regressions of the *binary* decision to enter a contest as a function of entry costs, c, and other potential explanatory factors. Note that the baseline specification is these regressions is an entry fee of 0.

From these tables and figures we observe that, consistent with the theory for both the $n = 2$ and $n = 3$ treatments, contest entry is monotonically decreasing as the entry fee rises. The first columns of Table 5 reporting on probit regressions using the combined data sample reveal that participation is significantly decreasing as the entry cost rises. However, there are departures from the equilibrium *point* predictions for these participation frequencies as revealed in Table 4 and Figure 3. In particular for low entry fees, where entry is predicted to be 100% (fees less than 40 when $n = 2$ and fees less than 25 when $n = 3$). Table 4 reveals that there is, on average, *under*-participation. This result may not be so surprising, since in the case when full participation is predicted, the errors can only be in one direction (i.e., less than predicted). At the other extreme, when the entry fee is 110 and 0 entry is predicted, we see again in Table 4 that there is *over*-participation on average, but this is again owing to the fact that errors can only go in that direction. More interestingly, in the 5 treatment conditions where contest participation is predicted

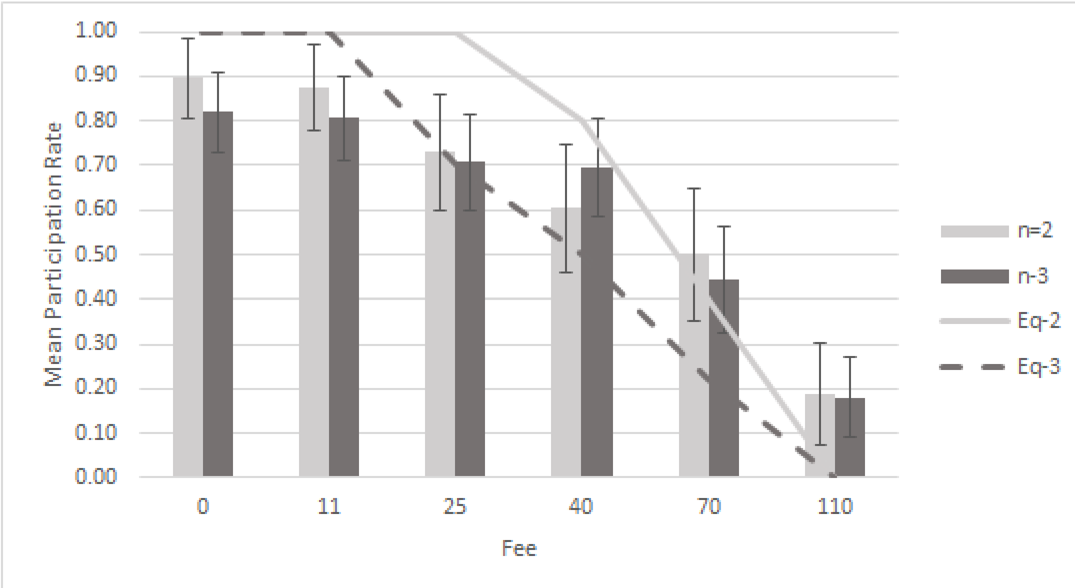

Figure 3: Mean participation frequencies (vertical axis) by contest fee (horizontal axis) and group size. Light bars are for $n = 2$ and dark bars are for $n = 3$. The whiskers indicate 95% confidence intervals. Symmetric equilibrium predictions are indicated by solid lines for $n = 2$ and dashed lines for $n = 3$

to lie between 0 and 100% (fees of 40 and 70 in the $n = 2$ treatment and fees of 25, 40 and 70 in the $n = 3$ treatment) we generally find significant *over*-participation relative to theoretical predictions, with the exception of the $n = 2$, $c = 40$ treatment where mean participation is lower than predicted. Indeed, for these five cases we can reject the null of no difference from theoretical predictions based on the 95% confidence intervals shown in Figure 3 for all but the treatment where $n = 3$ and $c = 25$, where we cannot reject the null. We summarize these findings as follows.

Result 1 *Participation: Contest participation generally decreases significantly as the entry fee rises in line with theoretical predictions. Relative to Nash equilibrium point predictions, there is generally under-participation when entry fees are low and over-participation when entry fees are high.*

We next consider bidding behavior across our different treatment conditions. Mean bids are shown for each treatment condition in Table 4 and Figure 4. Figures 5 - 6 show jittered scatterplots of *all* bids made for each entry fee, c, for the $n = 2$ and $n = 3$ treatments respectively along with the prediction of a non-parametric LOWESS filter and the equilibrium bid amount. Finally, the last columns 6-9 of Tables 5 - 7 (under the heading "Bid Amount Conditional on Participation") report on random effects linear regressions of bid amounts on entry costs, c, and other potential explanatory variables.

Table 4 reveals that mean bids do not decrease or change very much as the entry fee increases. The two exceptions to this observation are found in the two extreme fee cases, an entry fee of 0 and an entry fee of 110. The increase in mean bids as the entry fee increases from 0 to 11 is due to the small bids made by those who enter only when the fee is 0 but who select not to enter when

Table 5: Random Effects Regression Analysis of Contest Participation and Bids, All Data

	Participation in Contest				Bid Amount Conditional on Participation			
	All Data	All+Demo	CRT>2	Risk<6	All Data	All+Demo	CRT>2	Risk<6
Constant	1.265***	1.076**	1.274***	1.222***	39.355***	19.203	37.083***	37.189***
	(0.256)	(0.425)	(0.352)	(0.353)	(5.265)	(20.120)	(4.080)	(8.978)
Fee=11	-0.093	-0.087	-0.038	-0.139	1.029	0.929	0.159	-1.584
	(0.278)	(0.277)	(0.392)	(0.419)	(2.446)	(2.490)	(4.161)	(4.404)
Fee=25	-0.571*	-0.570*	-0.154	-0.934**	-2.513	-2.566	-4.463	-5.743
	(0.295)	(0.295)	(0.414)	(0.465)	(2.844)	(2.893)	(2.936)	(3.885)
Fee=40	-0.786***	-0.778***	-0.858**	-1.347***	-4.566	-4.933	-10.127**	-13.343***
	(0.299)	(0.300)	(0.375)	(0.386)	(4.096)	(3.939)	(3.946)	(4.103)
Fee=70	-1.390***	-1.378***	-1.524***	-1.877***	-10.398**	-11.116**	-27.465***	-16.640***
	(0.238)	(0.240)	(0.304)	(0.395)	(5.045)	(4.833)	(3.633)	(6.065)
Fee=110	-2.384***	-2.371***	-2.485***	-3.101***	-3.604	-5.253	-4.112	-5.948
	(0.329)	(0.330)	(0.421)	(0.599)	(6.587)	(6.257)	(15.617)	(13.420)
$n=3$	-0.111	-0.051	-0.250	-0.077	-0.175	0.498	3.946	3.804
	(0.149)	(0.086)	(0.279)	(0.269)	(4.347)	(3.793)	(4.289)	(8.425)
Order Desc.	0.160	0.048	-0.230	0.176	8.034**	4.194	0.517	0.551
	(0.154)	(0.133)	(0.286)	(0.306)	(4.062)	(4.074)	(4.171)	(7.262)
Female		-0.152				4.524		
		(0.165)				(4.423)		
Age		-0.034				0.149		
		(0.021)				(0.828)		
CRT Score		-0.091				-3.587*		
		(0.084)				(1.885)		
Risk		0.210***				4.141**		
		(0.045)				(1.645)		
Observations	720	720	324	324	445	445	180	167
Pseudo R^2	0.215	0.248	0.650	0.662	0.02	0.15	0.05	0.04

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Random effects estimation with robust standard errors clustered at the session level in parentheses using 16 sessions/clusters. The participation decision analysis (columns 2-5) uses a Probit regression specification while the bid analysis (conditional on contest entry, columns 6-9) uses a linear regression specification.

the fee is 11. The mean bids of these subjects in the fee=0 treatment are 11.46 when $n = 2$ and 20.86 when $n = 3$. The lack of entry by these low bidders when the entry fee increases to 11 works to raise the mean bid in that contest relative to the 0 entry fee contest. If we consider only the 37/48 (77%) subjects who entered both the lowest fee contests in the $n = 2$ treatment, their mean bids *fall* from 48.72 to 46.54 as the fee increases from 0 to 11. Similarly, if we look at the 52/72 (72%) subjects who entered both the lowest fee contests in the $n = 3$ treatment, their mean bids *fall* from 44.41 to 43.32 as the fee increases from 0 to 11.

The story is similar but slightly more mixed for the increase in bids as the entry fee increases from 70 to 110. First, in the $n = 2$ treatment, the increase in bids in the higher fee contest is owing only *in part* to the lower bids made by the 16/48 (33%) of subjects who only entered when the

Table 6: Random Effects Regression Analysis of Contest Participation and Bids, $n = 2$ treatment

	Participation in Contest $n = 2$				Bid Conditional on Participation $n = 2$			
	All Data	All+Demo	CRT>2	Risk<6	All Data	All+Demo	CRT>2	Risk<6
Constant	1.641***	0.361	1.737***	1.995*	38.238***	-1.130	34.567***	41.207***
	(0.495)	(1.695)	(0.576)	(1.033)	(8.051)	(47.382)	(4.791)	(11.678)
Fee=11	-0.129	-0.109	-0.306	-0.462	0.860	-0.107	4.775	-5.506
	(0.684)	(0.688)	(0.811)	(1.102)	(3.594)	(3.021)	(4.574)	(8.267)
Fee=25	-0.832	-0.826	-0.437	-1.596	-4.011	-5.059	-0.232	-6.652
	(0.560)	(0.559)	(0.742)	(1.097)	(4.945)	(4.577)	(3.901)	(8.791)
Fee=40	-1.347**	-1.350**	-1.169	-2.189*	-3.797	-5.162	-11.815**	-15.850***
	(0.584)	(0.579)	(0.781)	(1.174)	(10.414)	(9.561)	(5.260)	(5.997)
Fee=70	-1.715***	-1.706***	-1.486***	-2.401**	-11.138	-13.025	-25.163***	-9.652
	(0.473)	(0.472)	(0.516)	(1.214)	(10.133)	(9.120)	(6.866)	(9.360)
Fee=110	-2.964***	-2.956***	-2.634***	-4.751***	-7.610	-11.832	3.392	24.006***
	(0.562)	(0.558)	(0.550)	(1.529)	(11.236)	(9.855)	(33.360)	(4.173)
Order Desc.	0.141	0.187*	-0.847***	-0.141	12.192	9.767*	4.341	-7.144
	(0.216)	(0.108)	(0.322)	(0.429)	(8.304)	(5.340)	(7.754)	(16.054)
Female		-0.478				3.403		
		(0.328)				(6.606)		
Age		0.024				0.594		
		(0.076)				(2.257)		
CRT Score		-0.155				-4.094**		
		(0.178)				(1.803)		
Risk		0.239***				6.177***		
		(0.086)				(2.336)		
Observations	288	282	120	126	182	181	71	66
Pseudo R^2	0.27	0.30	0.68	0.71	0.04	0.20	0.15	0.08

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Random effects estimation with robust standard errors clustered at the session level in parentheses using 8 sessions/clusters. The participation decision analysis (columns 2-5) uses a Probit regression specification while the bid analysis (conditional on contest entry, columns 6-9) uses a linear regression specification.

Table 7: Random Effects Regression Analysis of Contest Participation and Bids, $n = 3$ treatment

	Participation in Contest $n = 3$				Bid Conditional on Participation $n = 3$			
	All Data	All+Demo	CRT>2	Risk<6	All Data	All+Demo	CRT>2	Risk<6
Constant	0.985***	0.982*	0.772**	0.812**	39.781***	25.376	41.142***	38.106***
	(0.278)	(0.502)	(0.390)	(0.364)	(3.472)	(24.304)	(6.542)	(4.523)
Fee=11	-0.072	-0.075	0.102	0.021	1.421	1.548	-1.411	1.238
	(0.291)	(0.289)	(0.454)	(0.418)	(3.642)	(3.833)	(6.421)	(4.587)
Fee=25	-0.441	-0.446	0.004	-0.616	-1.071	-0.891	-5.209	-4.844
	(0.358)	(0.358)	(0.539)	(0.513)	(3.637)	(3.776)	(4.533)	(2.960)
Fee=40	-0.489	-0.478	-0.686	-0.954***	-4.586	-4.721	-6.686	-11.005**
	(0.337)	(0.337)	(0.437)	(0.346)	(2.944)	(3.010)	(5.583)	(4.971)
Fee=70	-1.246***	-1.237***	-1.564***	-1.668***	-9.158*	-9.673*	-25.360***	-22.475***
	(0.281)	(0.284)	(0.402)	(0.355)	(5.296)	(5.229)	(5.093)	(7.707)
Fee=110	-2.126***	-2.117***	-2.405***	-2.532***	1.172	-0.113	-3.688	-13.128
	(0.408)	(0.411)	(0.610)	(0.599)	(8.424)	(7.974)	(15.693)	(13.068)
Order Desc.	0.179	0.009	0.152	0.320	5.344	0.636	-0.415	5.466
	(0.221)	(0.237)	(0.413)	(0.434)	(4.131)	(5.299)	(5.426)	(6.142)
Female		-0.051				4.348		
		(0.196)				(6.650)		
Age		-0.041**				0.257		
		(0.021)				(0.789)		
CRT Score		-0.065				-3.816		
		(0.074)				(3.277)		
Risk		0.199***				3.027		
		(0.043)				(2.527)		
Observations	432	432	204	198	263	263	109	101
Pseudo R^2	0.19	0.23	0.64	0.64	0.01	0.12	0.02	0.07

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Random effects estimation with robust standard errors clustered at the session level in parentheses using 8 sessions/clusters. The participation decision analysis (columns 2-5) uses a Probit regression specification while the bid analysis (conditional on contest entry, columns 6-9) uses a linear regression specification.

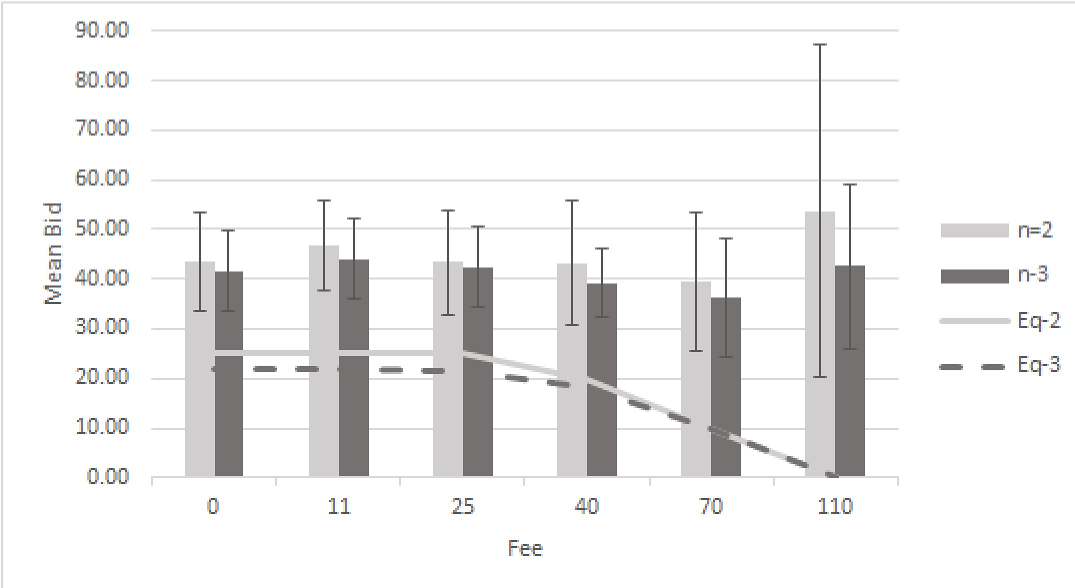

Figure 4: Mean bid amounts (vertical axis) by contest fee (horizontal axis) and group size. Light bars are for $n = 2$ and dark bars are for $n = 3$. The whiskers indicate 95% confidence intervals. Symmetric equilibrium predictions are indicated by solid lines for $n = 2$ and dashed lines for $n = 3$

fee is 70 (mean bid of 35.30). Still, among the few, 8/48 (17%) subjects who enter both high fee contests, the mean bid *d*oes increase from 47.70 to 60.28 as the fee increases from 70 to 110, but these are small numbers of subjects. In the $n = 3$ treatment, the increase in the mean bids as the fee increases from 70 to 110 is entirely due to the 25/72 (35%) who enter only when the fee is 70; those subjects bid lower amounts (mean bid of 32.82) than do those who enter both of the highest fee contests. Among the few 7/72 (10%) subjects who enter both of these contests in the $n = 3$ treatment, the mean decreases from 47.81 to 42.90 as the fee increases from 70 to 110.

However, as Table 4, Figures 4 - 6 and Tables 5 - 7 all reveal, the response of bids as entry costs increase is small and not statistically significant. Relative to the Nash equilibrium point predictions, mean bids are, in all cases *greater* than predicted and this difference *is* statistically significant, using the 95% confidence intervals shown in Figure 4 in all treatment conditions. That is, we can easily reject the null of no difference between Nash equilibrium bids and bids in our experiment at the 5% level in favor of the alternative that observed mean bids are always significantly greater. We summarize these findings as follows.

Result 2 *Overbidding: Mean bids do not change much in response to entry fees and are significantly higher than Nash equilibrium bids for all entry fees and regardless of whether $n = 2$ or 3.*

While this over-bidding phenomenon might seem surprising, it is, in fact quite common in the experimental contest literature, see e.g., Sheremeta (2013). This paper differs by adding contest entry fees which, in theory, should reduce the amounts bid relative to the no-entry-fee case and in the process, possibly curtail the over-bidding phenomenon. However, as our results indicate, overbidding persists even with the addition of contest entry fees.

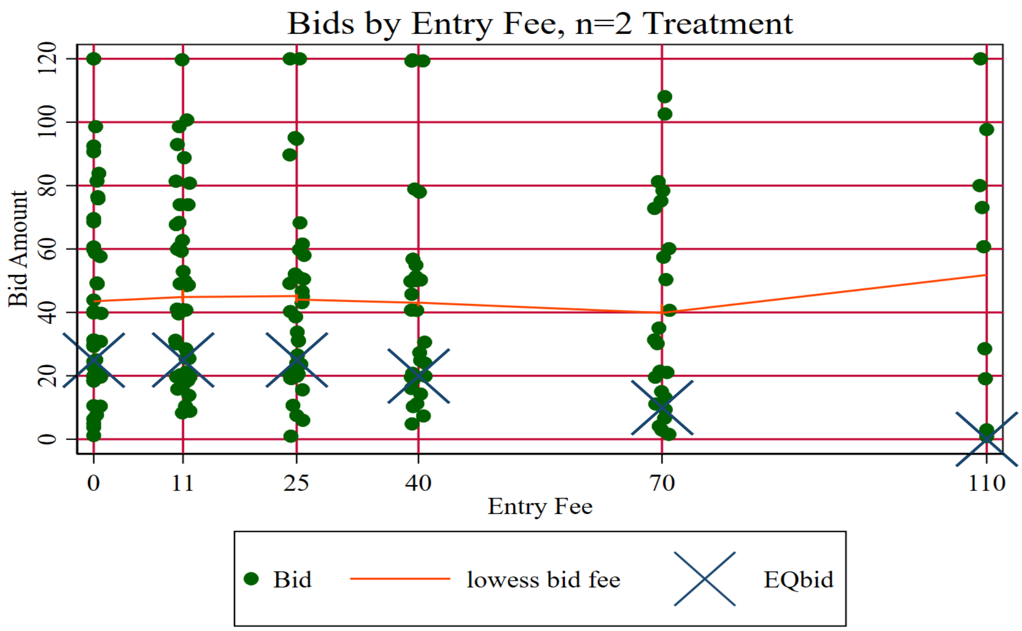

Figure 5: Jittered scatter plots of bids by entry fee (dots) along with Lowess filter prediction (red line) and equilibrium predictions (cross) $n = 2$ treatment

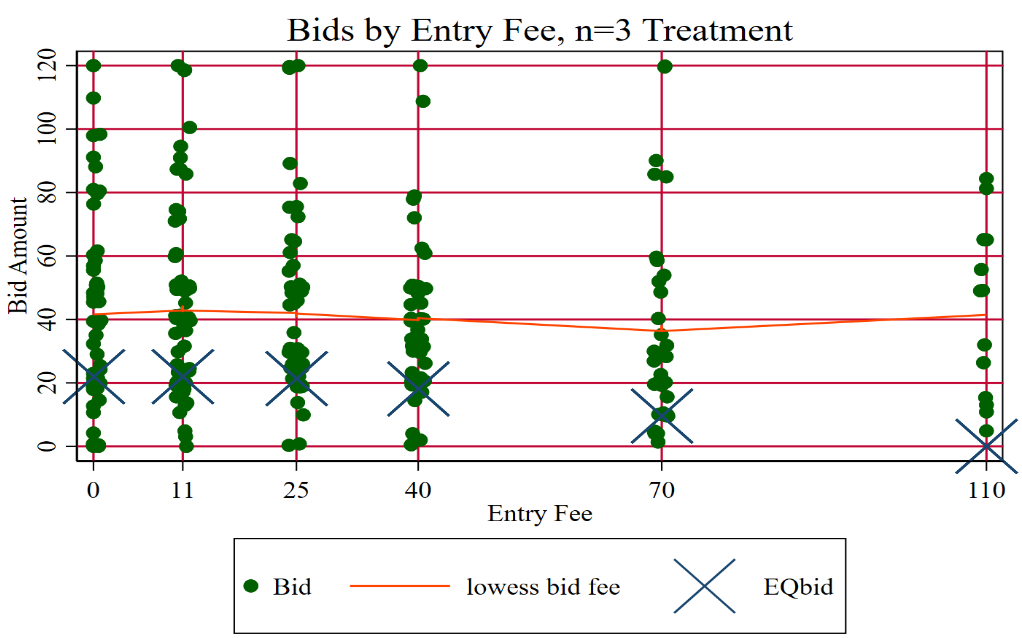

Figure 6: Jittered scatter plots of bids by entry fee (dots) along with Lowess filter prediction (red line) and equilibrium predictions (cross) $n = 3$ treatment

Having considered mean participation and bids across all treatments, we now focus more precisely on treatment effects, in particular on the effects of increasing the group size, the entry fee and the interactions between these two treatment variables.

We first consider the difference in behavior between groups of 2 and 3 bidders. According to the theory (Proposition 2) in the symmetric equilibrium, both $p^*(n, c)$ and $x^*(n, c)$ decline as n and c increase. Equilibrium participation rates and bids for the $n = 2$, 3 cases are illustrated in Figure 1 and the precise equilibrium point predictions for the participation probabilities and bids for our experimental treatments are shown in Table 4. Notice that while there is generally good separation in the equilibrium participation rates as n increases from 2 to 3, the differences in equilibrium bids are comparatively smaller, making these differences harder to detect with our sample size.

The experimental data means also reported in Table 4 generally support the comparative statics prediction of the theory that, for a given contest entry fee, a higher number of bidders (3 versus 2) reduces the probability of participating in that contest. In particular, notice in Table 4 that the mean participation probabilities in the $n = 3$ treatment for each entry fee $c = 0$, 11, 25, 40, 70 and 110 are always lower than the corresponding $n = 2$ version of the same entry fee value with the sole exception of the $c = 40$ treatment. Similarly, but without exceptions, mean bids in the $n = 3$ treatment for each entry fee $c = 0$, 11, 25, 40, 70 and 110 are always lower the corresponding $n = 2$ treatment for the same entry fee value. Nevertheless these group size differences are small, and as Figures 3 - 4 and Table 5 reveal, the differences in participation and entry between 3- and 2- player groups of bidders for given entry fees are not statistically significant. Note in particular that the $n = 3$ dummy variable in the regressions characterizing both participation and bidding behavior as reported in Table 5 generally has a negative sign, but statistically the coefficient on this $n = 3$ group size indicator is not significantly different from 0.

Result 3 *Group size effect: As the group size n increases from 2 to 3, participation rates and bids are only slightly lower as the contest entry fee, c, increases and these group size differences are not statistically significant.*

There appear to be two qualifications to Result 3. First, using all data Table 5 reveals that participation rates are significantly lower than the baseline case of no entry fee only when the entry fee rises to 25 or more. However, a comparison of Tables 6 - 7, which redo the regression analysis of Table 5 separately by group size ($n = 2$ or $n = 3$), suggests that the reduction in participation for low contest entry fees, particularly a fee of 40, is largely coming from groups of size $n = 2$ rather than from groups of size $n = 3$. Similarly, as Table 5 reports, bids are significantly lower than the baseline case of no entry fee only when the entry fee is 70.[2] However, a comparison with Tables 6 - 7, which disaggregate Table 5 by group size $n = 2$ or $n = 3$, suggests that this effect is largely coming from groups of size $n = 3$.

We next consider the effect of adding contest entry fees for the contest designer's revenue and in particular the revenue-maximizing fee. Recall that the designer's expected payoff is given by $p \times n(x + c)$. Here instead of calculating ex-ante expected revenue we report on the actual, ex-post revenue earned by the contest designer as we have such revenue information from our experimental data. As Figure 2 revealed, in theory the designer's expected revenue should be maximized at an entry fee of $c = 25$ in the $n = 2$ treatment and at an entry fee of $c = 11$ in the $n = 3$ treatment.

[2]Recall from the theory (see Table 4) that NE bids do not really start declining until the fee increases to 40 and the first large change in the NE bid occurs when the fee rises to 70.

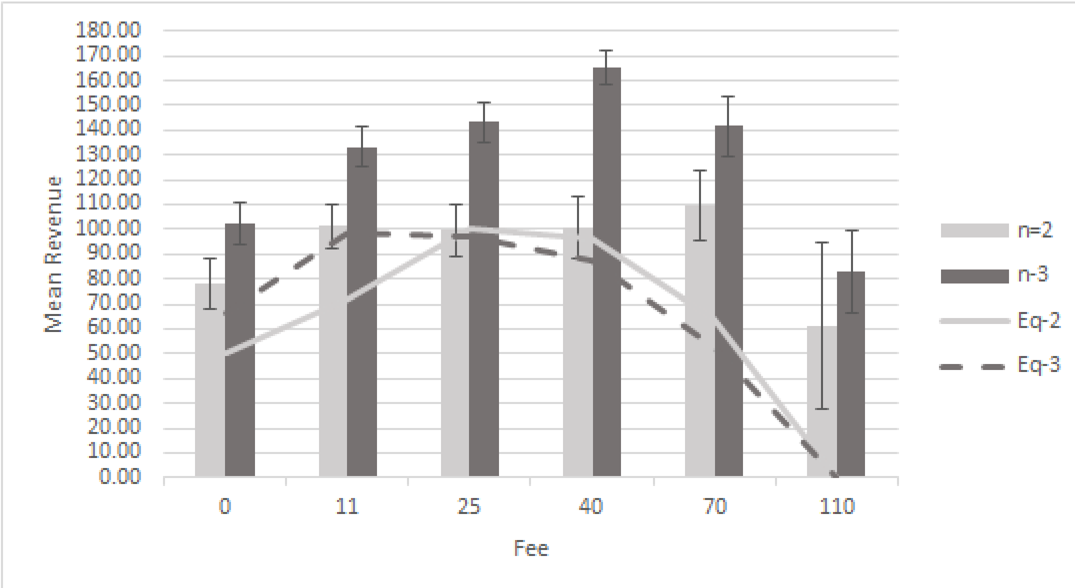

Figure 7: Mean revenue generated (vertical axis) for each contest fee (horizontal axis) and group size n. Light bars are for $n = 2$ and dark bars are for $n = 3$. The whiskers indicate 95% confidence intervals. Symmetric equilibrium predictions are indicated by solid lines for $n = 2$ and dashed lines for $n = 3$

However, as Table 4 and Figure 7 reveal, when $n = 2$ the actual contest designer's mean revenue is greatest when the fee is 70, though statistically this revenue amount is not significantly different than revenues generated by fees of 11, 25 or 40. However, when $n = 3$ the actual contest designer's revenue is greatest, and significantly so when the fee is 40 which is higher than the predicted payoff maximizing fee of 11. Thus, for both group size treatments, the entry fee yielding the greatest revenue is higher than the Nash prediction, though only significantly so in the $n = 3$ treatment. This result follows directly from the significant overbidding observed at all entry fee levels in combination with significant over-participation for intermediate and higher entry fee levels, as noted earlier in Results 1 and 2.

For the $n = 2$ case, Figure 7 reveals that the contest designer's revenue is significantly higher than theoretical predictions when the entry fees are 0, 70 or 110 and insignificantly different from theoretical predictions in the three intermediate fee cases (fees of 11, 25 and 40). However, in the $n = 3$ case the contest designer's revenue is significantly higher than theoretical predictions for all 6 entry fee values. We summarize these observations as follows.

Result 4 *Designer's revenue: The contest designer's revenue is often significantly greater than theoretical predictions. The entry fees generating the highest designer's revenue are greater than theoretical predictions, and significantly so in the $n = 3$ treatment.*

Table 4 and Figure 7 further reveal that the mean designer's revenue is not only frequently in excess of theoretical predictions, but also significantly exceeds the $V = 100$ point value of the prize. This *overdissipation* result occurs in 4 out of the 6 fee treatments for the $n = 3$ case. It is due to our addition of entry fees and is a new finding in the contest literature; Lim et al. (2014) found that overdissipation might take place with at least $n = 4$ players in contests without entry fees.

Finally, we explore some possible behavioral explanations for our experimental findings. Recall that we asked each subject to complete four CRT questions. Each such question has an immediate simplistic answer that is incorrect; the correct answer requires somewhat more thought and deliberation. Frederick (2005) has shown that the number of correct answers to such CRT questions is positively correlated with various measures of cognitive ability (or intelligence). Since there were four such questions (see the Appendix for these questions and answers) a perfect CRT score is 4. As Table 3 reveals the median CRT score in our sample was 2 out of 4 correct. We use each subjects' score (minimum 0, maximum 4) as a proxy for their cognitive abilities.

We also elicited each subject's tolerance for risk by asking them: "In general, how willing are you to take risks?" Answers were recorded on an 11 point Likert scale, where 0 means "completely unwilling to take risks" and 10 means very willing to take risks." Hence a higher number indicates a greater risk tolerance. This simple risk elicitation question has been shown to generate responses that correlate strongly with measures of risk attitudes derived from more traditional and incentivized paired lottery choices (see, e.g., Dohmen et al. (2011)). As Table 3 reveals the median risk self-assessment was 6. Finally, we collected other potential explanatory data, e.g., on gender, age, and on whether the order of the contests played, ascending or descending in terms of the entry fees, mattered for subjects' decisions. Using this subject specific data we have the following results.

Result 5 *CRT Scores: Subjects with high CRT scores are less prone to over-bidding in the contests they choose to enter.*

Support for Result 5 can be found in Tables 5 - 7. See also additional regression tables in Appendix E. As Table 5 reveals (in the regression specification All+Demographic data), overall CRT scores don't matter for participation decisions, but subjects with higher CRT scores are found to bid significantly less on average in the baseline 0 entry fee case. If we restrict attention to subjects with CRT scores that are greater than the median score of 2, as in the regressions under the heading "CRT > 2" we observe a more significant effect of entry fees on bidding behavior, particularly for entry fees of 40 and 70, with no change in participation behavior. Comparable regressions with subjects having CRT scores ≤ 2, as reported in the Tables found in Appendix E show that for these low CRT score subjects, bidding is not significantly lower for entry fees of 40 or 70.

Regarding self-elicited risk preferences, we have the following result.

Result 6 *Risk preferences: Increases in subjects' self-reported risk tolerance lead to higher bids and greater contest participation. Subjects who assess their own risk taking to be below the median of 6 (i.e. those who are less risk tolerant) are less prone to over-bidding compared with those who are more risk tolerant (reporting a risk tolerance ≥ 6).*

Support for Result 6 is also found in Tables 5 -7. See also additional regression tables in the Appendix. In the regression specification All+Demographic ("All+Demo") of these tables we see that for the baseline 0-entry fee case, subjects with greater self-reported risk tolerance, as captured by the variable Risk, are more likely to participate in contests and to bid higher amounts. When we focus only on subjects whose risk assessments are *below* the median of 6 ("Risk < 6") we observe that these more risk averse subjects reduce their bids significantly more as fees increase from 25 to 40 to 70 as compared with the more risk tolerant subjects – for a direct comparison with the latter subject group, see additional Tables in the Appendix.

Finally, we note that we do not find strong evidence for any age or gender effects or order effects. The female dummy variable is not significant in any of our regressions. The age variable is significantly positive only for the $n = 3$ treatment and not using the combined data set. The dummy variable labeled 'Order Desc.', equal to 1 if the fees followed the descending order starting at 110 and decreasing to 0, is significantly positive in Table 5 for bid amounts without demographic data, but it is no longer significant when we break the dataset down by group size as is done in Tables 6 - 7.

5 Conclusions

Many contests do not have entry fees, though some do. The recognition that entry fees could increase a contest designer's revenue has not gone unnoticed. For one example, the Eyelands short story contest did not have an entry fee prior to 2016 and now they have one. Other contests, such as the John Lennon Songwriting contest, have always had an entry fee (currently $30 per song). Our analysis seeks to rationalize the presence of such fees for entering contests.

We demonstrate that the addition of moderate entry fees can indeed increase a contest designer's revenues without having large effects on contest participation, depending on the number of potential participants. Moreover, in equilibrium we show there is a theoretically optimal contest entry fee depending on the number of potential entrants and that this entry fee is non-zero. In an experimental test of the theory we develop, we find mixed support for our theoretical predictions. While participation and bids do decline as contest entry fees increase, the decline is not as rapid, or as monotonic as the theory predicts. We observe both over-bidding in contests with entry fees and over participation for larger entry fees. In the case of 3 bidders, over-participation and over-bidding yield the outcome that the entry fee that generates the greatest revenue is significantly greater than the theoretically optimal entry fee.

Taking the behavior from our experiment into account, we conclude that contest designers will want to consider adding entry fees to their contests and consider the possibility that the entry fee that is revenue maximizing may be even larger than the one predicted by the rational actor model.

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Appendix

A Proof of Proposition 1

Proof. Consider the following differentiable function

$$f(x) = \sum_{i=0}^{n-1} \frac{1}{(i+1)^2} C_i^{n-1} (x)^i (1-x)^{n-i-1}.$$

It is straightforward to check that

$$f(0) = 1$$

and

$$f(1) = \frac{1}{n^2}.$$

Note that

$$f'(x) = \sum_{i=1}^{n-1} \left[\frac{i^2 - (i+1)^2}{i(i+1)^2} \right] \frac{(n-1)!}{i!(n-i-1)!} (x)^{i-1} (1-x)^{n-i-1} < 0 \text{ for } x \in (0,1).$$

Therefore, function $f(x)$ is monotonically decreasing on the interval $[0,1]$ and the range of function f is $\left[\frac{1}{n^2}, 1\right]$. Hence, equation (4) has a unique solution $p^* \in [0,1]$ for any $\frac{c}{V} \in \left[\frac{1}{n^2}, 1\right]$. ■

B Experimental Instructions

Here we present the instructions for the pairs treatment. The instructions for the triples treatment are similar.

Welcome to this experiment in the economics of decision-making. You are guaranteed $7 for showing up and completing this study. These instructions explain how you can earn additional earnings from the choices you make. Please silence any mobile devices and refrain from talking with others for the duration of this study. If you have any questions, please raise your hand.

Today's study involves 6 rounds of decision-making and the completion of a questionnaire.

Decisions

Prior to the start of *each* of the 6 decision rounds, you will be randomly matched with one other participant in the room. Thus, the participant you are matched with will likely change from one round to the next. In each round you will be randomly assigned the role of "participant 1" or "participant 2". This labeling helps in identifying each person's choices in the round but otherwise it makes no difference. You will not know the identity of the other participant you are matched with in each decision round – "your match" – nor will they know your identity even after the study is over.

For each decision round, you and your match for that round have to simultaneously make one or two decisions.

The first decision is whether you want to enter a contest with the other participant. The contest always yields a prize of 100 points to the winner and 0 to the loser. In order to enter the contest, you have to pay an entry fee in points which will be shown on your decision screen. The entry fee will be the same for you and your match.

Let us denote the fee to enter decision contest number $k = 1, 2, ..., 6$ by f_k points. The actual entry fee will differ from round to round so *pay careful attention to the fee in each decision round.* A fee of 0 points means there is no entry fee, but in that case you still have to choose to pay that fee to enter the contest.

Prior to deciding whether you want to enter contest k, both you and your match for that contest will each be given $120 + f_k$ total points.

If you choose "Don't Enter" then you keep and earn the $120 + f_k$ points you were given for decision round k.

If you choose "Pay the Fee and Enter the Contest," then you give up f_k points and you have to decide how many of your remaining 120 points you want to bid toward winning contest round k.

Specifically, on the first screen for each round you will see this information:

The **prize** to the winner of the contest is: **100.0** points
The **fee** for entering the contest this round is: $\mathbf{f_k}$ points
You are given **120.0** points plus the fee of $\mathbf{f_k}$ points for a total of $\mathbf{120.0 + f_k}$ points this round.
Do you want to pay the fee and enter the contest?

Below this you click on either the "Don't Enter" button or the "Pay the Fee and Enter" button. Then click the Next button to confirm your decision. You can change your mind anytime prior to clicking the Next button.

If you choose to Pay the Fee and Enter the contest then you give up f_k points and on the next screen, you make a second decision: how many of your remaining 120 points you want to *bid* toward winning the contest you have entered. You make this second decision by moving a slider on your screen between 0 and 120 or by entering the number of points you want to bid between 0 and 120 in an input box. Once you have made your bid, click the Next button. You can change your mind anytime prior to clicking the Next button.

If you choose Don't Enter then you will see a "Please Wait" screen.

In either case, you will *NOT* know when making your own decisions whether your matched participant has chosen to Pay the Fee and Enter the Contest or has chosen Don't Enter. You also don't know the bid that your match makes if they do choose to enter the contest until after the round is over.

Decision Outcomes

There are several possible outcomes for each decision round (contest):

1. Both you and the other participant chose to pay the fee and enter the contest. In this case you each give up the entry fee of f_k points. Your probability of winning the contest is calculated as:
$$\text{Your Probability of Winning} = \frac{\text{Your Bid}}{\text{Your Bid} + \text{Other Participant's Bid}}$$
The other participant's probability of winning is calculated in the same manner and is equal to 1-your probability of winning.[3] Using these two probabilities, the computer program determines the winner in a manner such that the participant with the higher (lower) probability of winning is more (less) likely, though *not certain* to win the contest. For example, suppose in a round that you are participant 1 and based on the points bid, your probability of winning is .60 (60%) and your match (participant 2) has a probability of winning equal to $1 - .60 = .40$ (40%). In this case the computer program draws a number randomly from the interval $[1, 100]$. If the number drawn is 60 or less, than you are declared the contest winner, while if the number drawn is greater than 60, then the other player is declared the contest winner.

   If you are the winner, then your payoff in points for the round is
$$120 - \text{Your bid} + 100$$
   If you are not the winner, then your payoff in points for the round is:
$$120 - \text{Your bid}$$
   These payoff consequences are symmetric for the other participant in the contest.

2. You enter the contest but the other participant does not enter. In this case, you automatically win the contest with any bid that you make but, of course, you don't know in advance whether the other participant entered the contest or not. Your payoff in points for the round in this case is:
$$120 - \text{Your bid} + 100$$
   The other participant earns $120 + f_k$ points for the round where f_k is the contest entry fee.

[3] In the event that you and the other participant both enter a bid of 0, then your probability of winning and that of the other participant are the same.

3. You do not enter the contest and the other participant does. In this case the other participant automatically wins the contest with any bid. Your payoff in points for the round in this case is:
$$120 + f_k$$
where f_k is again the contest entry fee in points. The other participant's payoff in points for the round in this case is 120 - Other Participant's Bid + 100.

4. You and the other participant both Don't Enter the contest. In this case, there is no winner of the contest. The points earned by both you and the other participant for the round in this case are:
$$120 + f_k$$
where f_k is again the contest entry fee in points.

Feedback

At the end of each round, you learn what the other participant chose to do and the outcome of the round. If one or both of you chose to enter the contest, then you will learn what was bid by each participant (1 and 2) and your probability and/or the other participant's probability of winning. You will learn who (if anyone) won the prize of 100 points for that round. Finally, you will see your total earnings in points for the round which you can write down. When you have viewed this information click the Next button.

Earnings

Following completion of all 6 rounds, the computer program will choose one of the six decision-rounds randomly. All six rounds have an equal chance of being chosen. Your points from the one chosen round will be converted into dollars at the exchange rate of 1 point = 10 cents ($0.10 USD).

Questionnaire

To finish the study, you must complete an online questionnaire. Following completion of the questionnaire, you will be awarded your earnings from the experiment plus your $7 show-up payment on a final screen that also shows your unique subject ID number. **Please leave this screen open for verification purposes.**

Questions?

Now is the time for questions. If you have a question, please raise your hand.

Comprehension Quiz

The following questions are intended to check your understanding of the instructions. Please answer all parts of all 6 questions. If you make a mistake you will be asked to re-do your answer until you get it right.

1. Circle One: True or False: I will be matched with the same other participant in all 6 rounds.

2. Suppose in round k, the contest entry fee, $f_k = 30$ points.

   a. How many points will you earn for the round if you *do not enter* the contest?

   b. If you *do enter* the contest, how many points can you bid toward winning the prize?

   c. Suppose you enter the contest, you bid 20 points but you *do not* win the prize. What are your earnings in points for the round?

   d. Suppose you enter the contest, you bid 20 points and you *do* win the prize. What are your earnings in points for the round?

3. Suppose in round k, the contest entry fee $f_k = 80$ points.

   a. How many points will you earn for the round if you *do not enter* the contest?

   b. If you *do* enter the contest, how many points can you bid toward winning the prize?

   c. Suppose you enter the contest, you bid 50 points but you *do not* win the prize. What are your earnings in points for the round?

   d. Suppose you enter the contest, you bid 50 points and you *do* win the prize. What are your earnings in points for the round?

4. Circle One: True or False: Paying the fee and entering a contest will always result in more points earned in a round than choosing not to enter the contest.

5. Circle the correct answer. If both participants enter a contest and both make positive bids then:

   a. Whoever bids the most is guaranteed to win the prize.

   b. Whoever bids the most has a greater chance of winning but either participant can win.

   c. The probability that each participant wins the prize can never be the same.

6. Circle One: True or False: After playing 6 decision rounds, one round will be randomly chosen and the points you earned in that round will be converted into money earnings a the rate of 1 point = $0.10 (10 cents).

C Screenshots

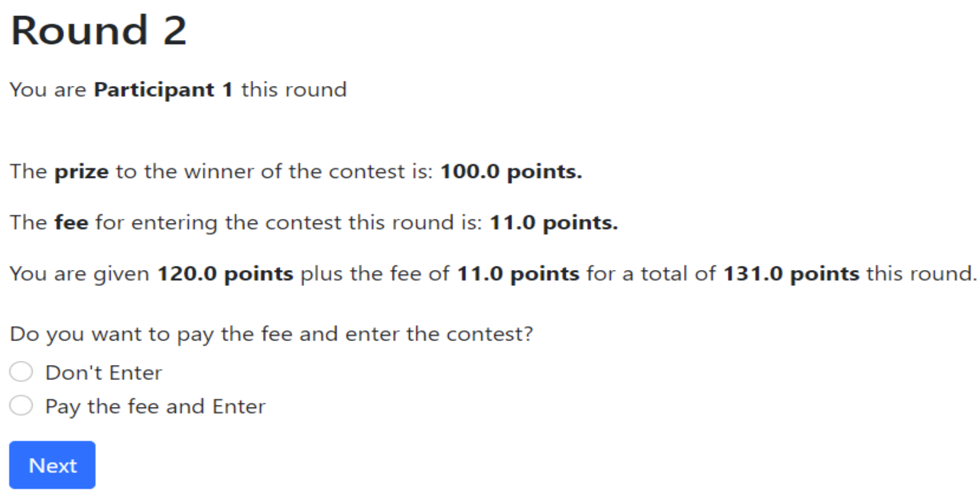


Figure C1: First Entry choice Screen in Round

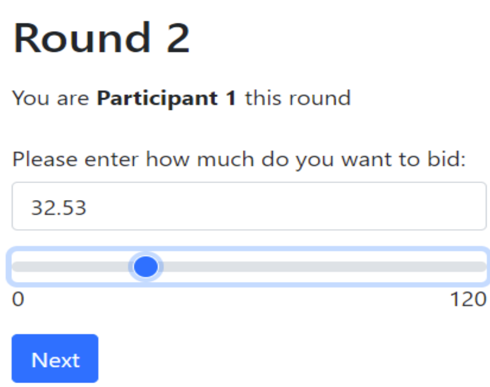
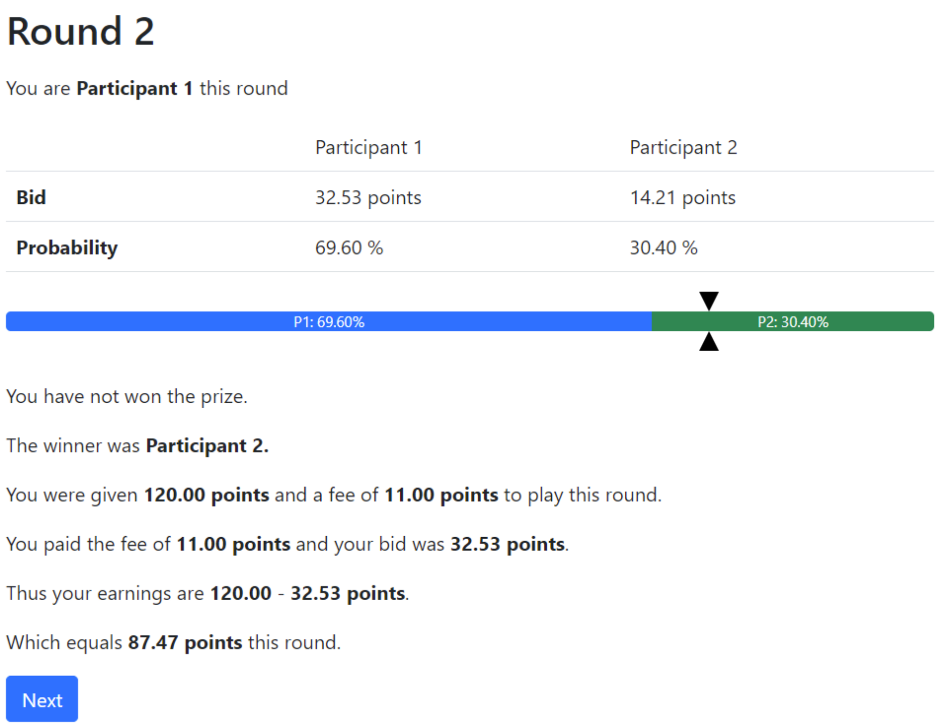


Figure C2: Screen with Bid Slider if Entered Contest



Round 2

You are **Participant 1** this round

	Participant 1	Participant 2
Bid	32.53 points	14.21 points
Probability	69.60 %	30.40 %

You have not won the prize.

The winner was **Participant 2.**

You were given **120.00 points** and a fee of **11.00 points** to play this round.

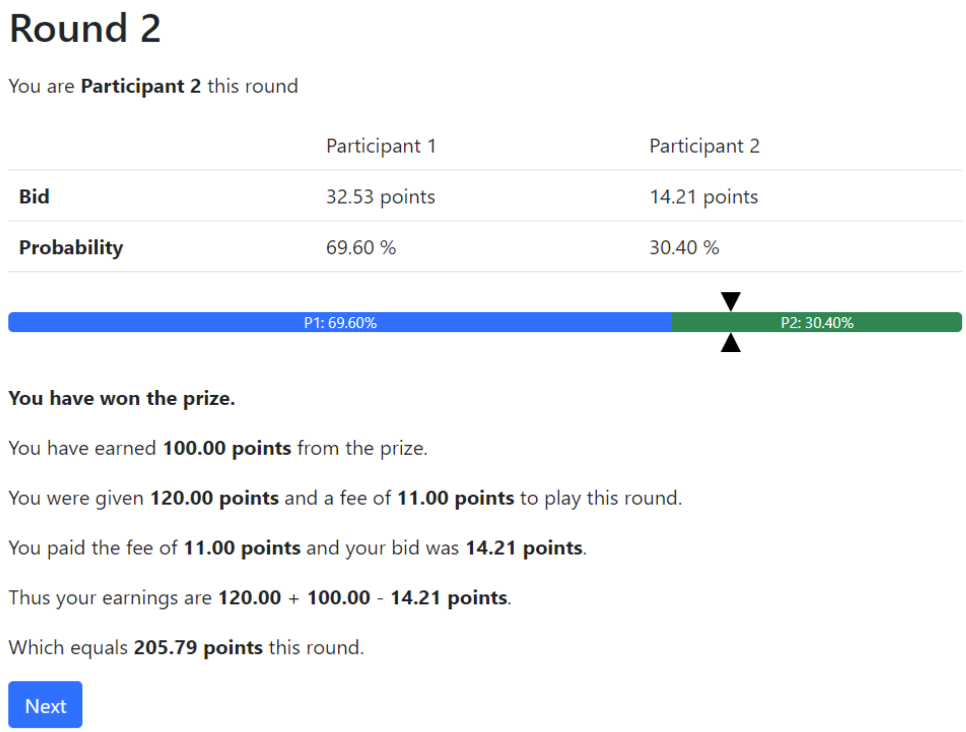
You paid the fee of **11.00 points** and your bid was **32.53 points**.

Thus your earnings are **120.00** - **32.53 points**.

Which equals **87.47 points** this round.

Next

Figure C3: Contest Results Screen, Participant 1



Round 2

You are **Participant 2** this round

	Participant 1	Participant 2
Bid	32.53 points	14.21 points
Probability	69.60 %	30.40 %

You have won the prize.

You have earned **100.00 points** from the prize.

You were given **120.00 points** and a fee of **11.00 points** to play this round.

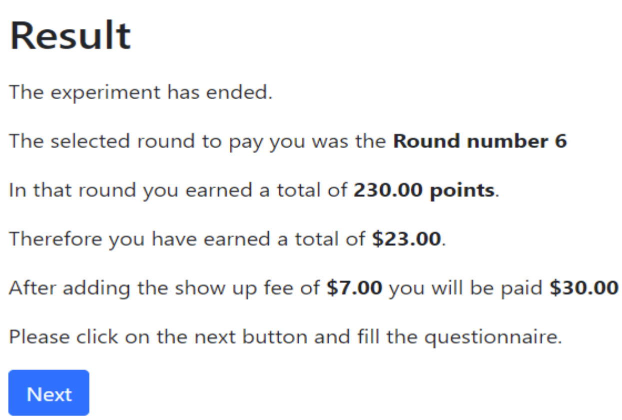
You paid the fee of **11.00 points** and your bid was **14.21 points**.

Thus your earnings are **120.00** + **100.00** - **14.21 points**.

Which equals **205.79 points** this round.

Next

Figure C4: Contest Results Screen, Participant 2



Result

The experiment has ended.

The selected round to pay you was the **Round number 6**

In that round you earned a total of **230.00 points**.

Therefore you have earned a total of **$23.00**.

After adding the show up fee of **$7.00** you will be paid **$30.00**

Please click on the next button and fill the questionnaire.

Next

Figure C5: Final Payoff Screen

D CRT and Demographic Questions

CRT Questions

The CRT questions we used differ from Frederick (2005) (which are already well known) and are taken from Toplak et al. (2014)

1. The ages of Anna and Barbara add up to 30 years. Anna is 20 years older than Barbara. How old is Barbara? [Correct Answer 5; Intuitive Wrong Answer 10]
2. If it takes 2 nurses 2 minutes to check 2 patients, how many minutes does it take 40 nurses to check 40 patients? [Correct Answer 2; Intuitive Wrong Answer 40]
3. On a loaf of bread, there is a patch of mold. Every day, the patch doubles in size. If it takes 24 days for the patch to cover the entire loaf of bread, how many days would it take for the patch to cover half of the loaf of bread? [Correct Answer 23; Intuitive Wrong Answer 12]
4. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how many days would it take them to drink one barrel of water together? [Correct Answer 4; Intuitive Wrong Answer 8]

Demographic Questions

1. What is your age?
2. What is your gender? Choices: Male, Female, Non-binary
3. What is your university major?
4. What is your grade point average (GPA)?
5. In general, how willing are you to take risks? Please use a scale from 0 to 10, where 0 means you are "completely unwilling to take risks" and a 10 means you are "very willing to take risks."

E Additional Tables

Table E1: Random Effects Regression Analysis of Contest Participation and Bids, All Data, Comparison of Specifications Involving Different Cut-off Values for CRT Scores and Risk Tolerance

	Participation in Contest				Bid Conditional on Participation			
	CRT>2	$CRT \leq 2$	Risk<6	Risk≥ 6	CRT>2	$CRT \leq 2$	Risk<6	Risk≥ 6
Constant	1.274***	1.303***	1.222***	1.293***	37.083***	42.189***	37.189***	41.075***
	(0.352)	(0.313)	(0.353)	(0.247)	(4.080)	(7.396)	(8.978)	(4.828)
Fee=11	-0.038	-0.162	-0.139	-0.022	0.159	1.635	-1.584	2.626
	(0.392)	(0.320)	(0.419)	(0.280)	(4.161)	(3.556)	(4.404)	(3.834)
Fee=25	-0.154	-0.912***	-0.934**	-0.279	-4.463	-1.014	-5.743	-0.633
	(0.414)	(0.336)	(0.465)	(0.254)	(2.936)	(4.026)	(3.885)	(4.329)
Fee=40	-0.858**	-0.759**	-1.347***	-0.343	-10.127**	-1.105	-13.343***	-0.328
	(0.375)	(0.351)	(0.386)	(0.329)	(3.946)	(5.931)	(4.103)	(5.417)
Fee=70	-1.524***	-1.336***	-1.877***	-1.036***	-27.465***	-1.955	-16.640***	-7.392
	(0.304)	(0.368)	(0.395)	(0.278)	(3.633)	(5.977)	(6.065)	(6.769)
Fee=110	-2.485***	-2.364***	-3.101***	-1.922***	-4.112	-3.125	-5.948	-2.820
	(0.421)	(0.358)	(0.599)	(0.307)	(15.617)	(7.037)	(13.420)	(8.833)
$n = 3$	-0.250	-0.001	-0.077	-0.100	3.946	-3.212	3.804	-2.271
	(0.279)	(0.227)	(0.269)	(0.100)	(4.289)	(6.241)	(8.425)	(4.878)
Order Desc.	-0.230	0.391*	0.176	0.010	0.517	10.659*	0.551	11.534**
	(0.286)	(0.210)	(0.306)	(0.103)	(4.171)	(6.409)	(7.262)	(5.188)
Observations	324	396	324	396	180	265	167	278
Pseudo R^2	.65	.59	.66	.59	.05	.03	.04	.04

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Random effects estimation with robust standard errors clustered at the session level in parentheses using 16 sessions/clusters. The participation decision analysis (columns 2-5) uses a Probit regression specification while the bid analysis (conditional on contest entry, columns 6-9) uses a linear regression specification.

Table E2: Random Effects Regression Analysis of Contest Participation and Bids, $n = 2$ treatment
Comparison of Specifications Involving Different Cut-off Values for CRT Scores and Risk Tolerance

	Participation in Contest $n = 2$				Bid Conditional on Participation $n = 2$			
	CRT>2	$CRT \leq 2$	Risk<6	Risk≥ 6	CRT>2	$CRT \leq 2$	Risk<6	Risk≥ 6
Constant	1.737***	1.631**	1.995*	1.440***	34.567***	41.452***	41.207***	36.812***
	(0.576)	(0.734)	(1.033)	(0.480)	(4.791)	(11.220)	(11.678)	(7.098)
Fee=11	-0.306	0.170	-0.462	0.187	4.775	-0.840	-5.506	3.880
	(0.811)	(0.955)	(1.102)	(0.726)	(4.574)	(5.767)	(8.267)	(3.950)
Fee=25	-0.437	-1.238	-1.596	-0.202	-0.232	-6.056	-6.652	-3.230
	(0.742)	(0.909)	(1.097)	(0.632)	(3.901)	(6.970)	(8.791)	(5.773)
Fee=40	-1.169	-1.588*	-2.189*	-0.730	-11.815**	2.374	-15.850***	0.474
	(0.781)	(0.867)	(1.174)	(0.610)	(5.260)	(14.207)	(5.997)	(13.046)
Fee=70	-1.486***	-2.016**	-2.401**	-1.211**	-25.163***	-2.263	-9.652	-12.120
	(0.516)	(0.844)	(1.214)	(0.536)	(6.866)	(11.313)	(9.360)	(12.445)
Fee=110	-2.634***	-3.369***	-4.751***	-2.159***	3.392	-13.312	24.006***	-11.297
	(0.550)	(0.842)	(1.529)	(0.588)	(33.360)	(10.742)	(4.173)	(14.922)
Order Desc.	-0.847***	1.012*	-0.141	0.109	4.341	14.728	-7.144	22.400***
	(0.322)	(0.558)	(0.429)	(0.166)	(7.754)	(11.746)	(16.054)	(5.908)
Observations	120	168	126	162	71	111	66	116
Pseudo R^2	.68	.62	.71	.60	.15	.03	.08	.13

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Random effects estimation with robust standard errors clustered at the session level in parentheses using 16 sessions/clusters. The participation decision analysis (columns 2-5) uses a Probit regression specification while the bid analysis (conditional on contest entry, columns 6-9) uses a linear regression specification.

Table E3: Random Effects Regression Analysis of Contest Participation and Bids, $n = 3$ treatment
Comparison of Specifications Involving Different Cut-off Values for CRT Scores and Risk Tolerance

	Participation in Contest $n = 3$				Bid Conditional on Participation $n = 3$			
	CRT>2	$CRT \leq 2$	Risk<6	Risk≥ 6	CRT>2	$CRT \leq 2$	Risk<6	Risk≥ 6
Constant	0.772**	1.224***	0.812**	1.154***	41.142***	39.575***	38.106***	41.833***
	(0.390)	(0.281)	(0.364)	(0.280)	(6.542)	(6.199)	(4.523)	(7.975)
Fee=11	0.102	-0.249	0.021	-0.116	-1.411	3.538	1.238	1.224
	(0.454)	(0.321)	(0.418)	(0.275)	(6.421)	(4.628)	(4.587)	(6.200)
Fee=25	0.004	-0.787***	-0.616	-0.313	-5.209	2.687	-4.844	1.427
	(0.539)	(0.305)	(0.513)	(0.257)	(4.533)	(4.505)	(2.960)	(6.454)
Fee=40	-0.686	-0.356	-0.954***	-0.118	-6.686	-2.958	-11.005**	-0.658
	(0.437)	(0.334)	(0.346)	(0.408)	(5.583)	(4.687)	(4.971)	(4.395)
Fee=70	-1.564***	-1.075***	-1.668***	-0.976***	-25.360***	-1.753	-22.475***	-2.744
	(0.402)	(0.393)	(0.355)	(0.352)	(5.093)	(7.106)	(7.707)	(7.185)
Fee=110	-2.405***	-2.011***	-2.532***	-1.873***	-3.688	3.949	-13.128	8.081
	(0.610)	(0.379)	(0.599)	(0.400)	(15.693)	(8.246)	(13.068)	(8.056)
Order Desc.	0.152	0.100	0.320	-0.031	-0.415	7.709	5.466	3.652
	(0.413)	(0.145)	(0.434)	(0.146)	(5.426)	(7.990)	(6.142)	(6.812)
Observations	204	228	198	234	109	154	101	162
Pseudo R^2	.64	.59	.64	.60	.02	.03	.07	.01

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Random effects estimation with robust standard errors clustered at the session level in parentheses using 16 sessions/clusters. The participation decision analysis (columns 2-5) uses a Probit regression specification while the bid analysis (conditional on contest entry, columns 6-9) uses a linear regression specification.