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# Excess entry in an experimental winner-take-all market

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**Abstract**

"Winner-take-all" markets (i.e., markets in which the relative and not the absolute performance is decisive) have gained in importance. Such markets have a tendency to provoke inefficiently many entries. We investigate such markets in an experiment and show that there are even more inefficient entries than predicted by the Nash equilibrium. Moreover, this effect increases with group size. Quantal response equilibrium predicts the increase in group size but fails to predict the excess entry in the smaller group. We show that the excess entry is not caused by coordination failures. Furthermore, individual entry behavior is not significantly linked to risk preferences.


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## 1. Introduction

For the income of a tennis player it is not important how good he is in absolute terms, but whether he beats others or not. If he is better than others he will earn a lot of money; if not, even if he is very good in absolute terms, he will not be able to earn his living by playing tennis. This criterion serves to qualify professional tennis as a "winner-take-all" market, a market that is characterized by two properties: (i) relative performance is more important for payoffs than absolute performance and (ii) the payoff of the best performers is much higher than the payoff of the second best performers. In the fields of sports and performing arts, the existence of winner-take-all markets is most obvious. However, also in the markets for lawyers, for CEOs, or for academics, relative performance is much more important than absolute performance. An excellent overview of the structure and the economic importance of winner-take-all markets can be found in the book "The Winner-Take-All Society" by Frank and Cook (1995). They convincingly argue that an increasing share of labor and other markets show the characteristics of winner-take-all markets. This is problematic because winner-take-all markets tend to produce an inefficiently high number of entrants to the fact that each person who enters a winner-take-all market imposes an externality onto the other people in the market by reducing

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their probability to win. There is a lot of evidence that “winner-take-all” markets are inefficient; many young people try to become football stars or actors and very few succeed. Economically more important, many new companies fail, in the US about 60 percent in the first 5 years. However, since we do not know the preferences of the market participants, this evidence is not completely unambiguous.

In this study, we present the first experimental investigation of entry behavior in winner-take-all markets. The experimental method is very well suited to this question because we can control many factors that cannot be controlled in the field. For instance, in an existing winner-take-all market it is hard to know the number of (potential) entrants and their abilities, the payoff people expect to get, the winning probabilities, and the beliefs people hold about others’ entry decisions. As a consequence, we cannot determine the efficient number of entries. Likewise, it is impossible to calculate the Nash equilibria for that particular winner-take-all market. In our experiment, we control for the number of potential entrants, their abilities, the winning probabilities and the payoffs. Hence, we can determine Nash equilibria and the social optimum of our experimental winner-take-all market. Moreover, to be able to determine the rationality of an individual’s entry decision, we elicit beliefs about the other subjects’ entry decisions.

Frank and Cook conjecture that the problem of inefficient entries in winner-take-all markets increases with the number of potential entrants. We explore this argument by varying the group size. In one treatment there is a group of 7 potential entrants; in the other, the group size is 11. In our experimental winner-take-all game the social optimum is one entry. The Nash equilibria predict an expected number of entries between 3 and 3.8. Interestingly, group size matters neither for the social optimum nor for the bounds of the Nash equilibria.

In the experiment, we find that there are indeed inefficiently many entries in our winner-take-all market. With a group size of 7, the average number of entries is 4.11; with a group size of 11, on average 5.32 subjects enter. Hence, it turned out that even more people entered than predicted by the Nash equilibrium. This result contradicts the findings of a number of experimental studies on market entry games that report quick convergence to the Nash equilibria (e.g., Sundali et al., 1995). Moreover, and also in contrast to the Nash prediction, this excess entry increases with group size. This trend has an important economic implication: if there are winner-take-all markets, an increase in the number of potential entrants will reduce welfare.

Our experimental design allows us to investigate potential sources of excess entry. Since we elicited subjects’ beliefs about the other players’ entry decisions, we can determine the rationality of each entry decision. We find that on average beliefs are unbiased. We can thus conclude that the observed excess entry is not caused by a coordination failure induced by false beliefs. Even if we control for beliefs, we find that subjects heavily deviate from a rational entry pattern. A theory that explicitly deals with ‘random’ errors is the concept of quantal response equilibrium (QRE). We find that QRE can explain the increase of entries in group size but fails to explain excess entry in our treatment with the smaller group size. A regression analysis shows that there is a substantial heterogeneity among the subjects with respect to the entry decision. Surprisingly, a measure of risk preferences cannot account for this heterogeneity. Thus, to understand excess entry one has to assume that at least a fraction of the subjects gets some utility from entering that goes beyond the monetary payoff.

In Section 2, we describe the experiment, in Section 3, we show the main result and in Section 4, we discuss the result and investigate different reasons for the excess entry. In Section 5, we relate our results to the literature and conclude.

## 2. An experimental winner-take-all market

### 2.1. The winner-take-all game

In order to test the functioning of winner-take-all markets in the laboratory, we formulate a winner-take-all game. In this game, all players have to decide simultaneously whether to enter a winner-take-all market or to stay out. We denote by $n$ the number of players and by $e$ the number of players who decide to enter the winner-take-all market (the entrants, $0 \leq e \leq n$). The players who enter can win a high prize. However, only one player, the winner, actually wins this prize. The size of the prize depends positively on the number of entrants. By $\pi(e)$ we denote the prize the winner gets when the number of entrants equals $e$. The other entrants get a payoff of zero. The players who stay out earn a comparatively low payoff $\sigma$. This “outside option” is independent of the behavior of the other players.

Table 1
Winner's payoff dependent on the number of entrants

| $e$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Prize $\pi(e)$ | 100 | 130 | 155 | 175 | 190 | 200 | 205 | 209 | 212 | 214 | 215 |
| $\pi(e)/e$ | 100 | 65 | 51.7 | 43.8 | 38 | 33.3 | 29.3 | 26.1 | 23.6 | 21.4 | 19.5 |

The winner among all entrants is determined at random with each entrant having the same winning probability. Consequently the expected value of entering the winner-take-all market equals $\pi(e)/e$. The expected value of entering is assumed to be decreasing in the number of entrants.

In our experiments we use the following parameterization of the winner-take-all game. There are two treatments, either with $n = 7$ or 11 potential entrants. Thereafter we will call the treatments WTA7 treatment (for winner-take-all 7) and WTA11, respectively. The function $\pi(e)$ and the expected payoff $\pi(e)/e$ is depicted in Table 1.

If, for instance, one player enters the market, this player receives 100. If two players enter one receives 130 and the other receives nothing. The expected payoff for the two entrants equals 65. The players who choose to stay out get a payoff of either 40 or 50, each with probability .5. Therefore, the expected value $\sigma$ equals 45. In the experiment we play 10 periods of the winner-take-all game using a stranger matching protocol. Finally, all the payoffs mentioned so far are not directly converted to real money in our experiment. Instead, the numbers correspond to probability points for a binary lottery conducted at the end of the experimental session. By earning higher profits in the experiment subjects can increase the probability of earning a certain amount of money.[2]

### 2.2. *Features of our design*

In this section we comment on the crucial features of our design. First, the subjects decide simultaneously about whether to enter the winner-take-all market or not (i.e., the players have to form beliefs about the number of entrants). This feature reflects the fact that in real career decisions people rarely have accurate information about the entry decisions of their potential competitors.

Second, all entrants but the winner earn zero profits. The reason for paying only the winner a positive payoff is simplicity. This feature makes it very straightforward for the subjects to calculate the expected payoff of the different alternatives.

Third, $\sigma$ is low and randomized with a small variance (compared to the winner-take-all market). This "outside option" represents the choice of a job in a normal labor market. Instead of paying a fixed amount of $\sigma$ we introduce some randomness in order to make the two alternatives as similar as possible. Since entering the winner-take-all market may lead to a "thrill" from winning or losing, we need to have a comparable feature for the subjects who do not enter the winner-take-all market.

Fourth, we assume that the prize function $\pi(e)$ increases in $e$. This reflects the argument, substantiated by Frank and Cook, that in a large market the winner will perform better than in a small market. This can, for instance, happen as a purely statistical effect: the expected maximum of randomly distributed abilities is higher the more people enter. When absolute performance also plays a role, the winners' earnings increase in $e$. Another argument for a positive connection between the number of entrants and the winners' prize is that, for example in sports, the more people engage in a specific sport, the bigger grows the public interest and the media attention. This typically results in higher earnings for the top performers. However, the marginal increase of the prize due to an additional entrant is likely to decrease with the number of entrants. Hence, $\pi(e)$ must be concave, and therefore, the *expected* prize $\pi(e)/e$ decreases in $e$. This implies that entrants impose an externality on other entrants (i.e., if a player enters, he reduces the other players' expected value of entering).

Fifth, the winner is determined randomly among all entrants. All entrants have the same probability of winning, namely $1/e$. This random procedure might be seen as a crude simplification that disregards the fact that, in reality, people have different abilities and therefore different winning chances. Furthermore, they have some knowledge about their relative position in the distribution of abilities, and they can influence their winning chances by own effort.

[2] This remuneration scheme (binary lottery) was introduced by Roth and Malouf (1979).

Nevertheless, for the following reasons we think that our way of modeling the winner-take-all market is appropriate. For example, at the time a tennis player decides to invest in a professional tennis career, he might well have exceptional abilities, but so do most of the other potential competitors. Whether he really makes it to the top 10 or not is at the time of the decision very uncertain and might therefore be seen as random for him. Similarly, a career in academia is to a large extent dependent on one's ability, but since many competitors have comparable abilities, it is still partly a question of luck whether one finds attention for his papers and books or not.[3]

Sixth, in our experiments we repeat the game 10 times. Although this feature does not correspond with our motivating illustrations of winner-take-all markets (career decisions are usually not taken 10 times in a row), we apply 10 consecutive entry decisions in order to control for learning effects. However, since we do not want the subjects to perceive the game as a repeated game, we use a stranger matching protocol.

Finally, we use the binary lottery mechanism to pay our subjects. This mechanism has the property that it induces risk neutral behavior in the experiment if the subjects are expected utility maximizers. This feature facilitates the calculation of Nash equilibria since we do not have to care for the subjects' risk preferences.[4]

### *2.3. Theoretical predictions*

In the following, we describe the Nash equilibria for risk neutral players. The pure strategy Nash equilibria in this game can be described as follows. Any three of the players enter the WTA market and the other players stay out. If two (or fewer) other players are already in the market, entry is worth 51.7 (or more) while staying out is worth 45. On the other hand, if three players (or more) are already in the market, then entering has an expected value of 43.8 (or less). This prediction holds irrespective of group size $n$ as long as $n \geq 3$.

There is also a unique *symmetric* equilibrium in mixed strategies. The entry probability $p^*$ is determined by solving the equation:

$$\sum_{e=1}^{n} \binom{n-1}{e-1} p^{*^{e-1}} (1-p^*)^{n-e} \frac{\pi(e)}{e} = \sigma. \tag{1}$$

The left-hand side of this equation is the expected value of entering for a player if all other players choose the mixed strategy to enter with probability $p^*$. It is a sum over all possible numbers of entrants, given the player in question enters. The first part of the expression shows the probability of the binomial distribution of other entrants $(e-1)$, while the second is the expected prize given $e$. The right-hand side is the expected value of staying out. If Eq. (1) is satisfied, the player is indifferent between entering and staying out. Therefore, entering with probability $p^*$ is a best reply. Since the game is symmetric, this is true for all players and therefore constitutes a Nash equilibrium. In the symmetric equilibrium the average number of entries decreases with the group size for $n > 3$. The expected number of entries equals 3.80 for $n = 4$, 3.63 for $n = 7$ and 3.55 for $n = 11$. For $n > 3$, there are also many asymmetric equilibria in mixed strategies. However, it can be shown that in any equilibrium, the expected number of entries is between 3 (equilibrium in pure strategies) and 3.80 (four players enter with a probability of .95 and the others do not enter). A complete description of the equilibria is given in Appendix A, which is available on the JEBO website.

Recall that thus far we assumed risk neutrality. What is the effect of risk preferences on the entry decision? Entering the winner-take-all market is clearly more risky than staying out. If all players are symmetric and risk averse, the expected number of entrants is lower than calculated above. On the other hand, if all players are risk loving, then entering the winner-take-all market becomes more attractive and there will be a higher expected number of entrants. If, however, we assume a mix of risk preferences among the players then the two effects are likely to offset each other.

[3] The results of market entry games conducted by Camerer and Lovallo (1999) suggest that our result of excess entry in the winner-take-all market would have been even more articulate if we had determined the winners by their abilities, measured for example by the number of correct answers in a quiz.

[4] There is, however, evidence that the binary lottery mechanism does not always work in the desired direction. Selten et al. (1999), for instance, showed that binary lotteries do not reduce anomalies. Anderhub et al. (2000) did not find a difference between applying and not applying the binary lottery technique in a "saving game". Furthermore, Rabin (2000) suggested another reason for the absence of a connection between risk preferences and entry behavior. He shows that expected utility theory implies approximately risk neutral behavior when monetary stakes are small. The main reason for adapting the binary lottery is to have an unambiguous Nash prediction and not because we think it 'rationalizes' subjects' behavior with respect to risk attitudes.

Table 2
Equilibrium predictions and social optimum

| Treatment | WTA7 | WTA11 |
|---|---|---|
| Number of entries in a Nash equilibrium in pure strategies | 3 | 3 |
| Expected number of entries in the symmetric Nash equilibrium | 3.63 | 3.55 |
| Maximum expected number of entries in a Nash equilibrium | 3.80 | 3.80 |
| Number of entries in social optimum | 1 | 1 |

In Appendix A, we show a series of asymmetric Nash equilibria where some players enter for certain, some players randomize, and some players stay out for certain. Heterogeneous risk preferences are likely to produce equilibria of this sort. Anyway, recall that we have paid our subjects using the binary lottery mechanism which, in theory, induces risk neutral behavior.

Note that our winner-take-all game clearly contains the externality problem discussed in Frank and Cook. While individual rationality induces at least three players to compete for the price, already the second entrant has a negative impact on total welfare. If no other player enters, it is socially beneficial to enter because the payoff equals 100, which is higher than the expected payoff of staying out (45). However, if there is any other player in the market, the prize increase for the winner caused by the additional entry is always less than 45. For instance, if there is a second entrant, the additional prize is $30 = 130 - 100$. Note that all Nash equilibria are inefficient. Table 2 shows the expected number of entries in the Nash equilibria and the social optimum for the two group sizes.

The numbers in Table 2 show that standard theory predicts virtually no relation between group size ($n$) and the number of entrants ($e$). If at all, the relation should be negative (which is the case if the symmetric Nash equilibrium in mixed strategies is played).

But what if the players do not play the Nash equilibrium perfectly? A theory that explicitly deals with errors is the concept of the quantal response equilibrium (QRE, McKelvey and Palfrey, 1995). In this concept, players do not always play the best strategy. However, the probability of choosing a strategy depends positively on the payoff of that strategy choice (given the other players' choices). A special case of the quantal response equilibrium, the logit equilibrium, has been successfully applied to explain the selection of Nash equilibria as well as 'anomalies' (see e.g., Goeree et al., 2002; or Capra et al., 1999; Anderson et al., in press; Goeree and Holt, 1999).

We very briefly present this model. Let $\pi_i^{\mathrm{e}}$ be the expected payoff of a player if he chooses action $i$ for fixed actions of the other players. Then, in a logit equilibrium, this player chooses the strategy $i$ with probability $p_i$ which is given by

$$p_i = \frac{\exp(\pi_i^{\mathrm{e}}/\mu)}{\sum_j \exp(\pi_j^{\mathrm{e}}/\mu)}. \tag{2}$$

The parameter $\mu$ is the error parameter. It specifies 'how strongly' errors are made. If the error parameter is very small, the values of the exponentials $\exp(\pi_i^{\mathrm{e}}/\mu)$ differ a lot, and therefore the probability distribution will be concentrated in the best reply. If, on the other hand, the error parameter is very large, then the exponentials will all be close to 1, and we get an (almost) uniform probability distribution. In the following we denote by QRE the logit equilibrium as specified above. Fig. 1 shows the predicted number of entries of the symmetric quantal response equilibrium for the two group sizes we administered. For low error parameters the prediction converges to the symmetric Nash equilibrium. However, if the error parameter is above 1, QRE predicts more entries in larger groups than in smaller groups.

To conclude, standard economic theory predicts no difference in the number of entries between our two treatments while QRE predicts a positive relation between group size and the number of entries provided the error parameter is large enough.

### 2.4. Hypotheses

The Nash equilibria give us clear predictions that can be summarized as follows:

**H0$_1$.** The average number of entries is between 3 and 3.80.

**H0$_2$.** The number of entries does not depend on group size.

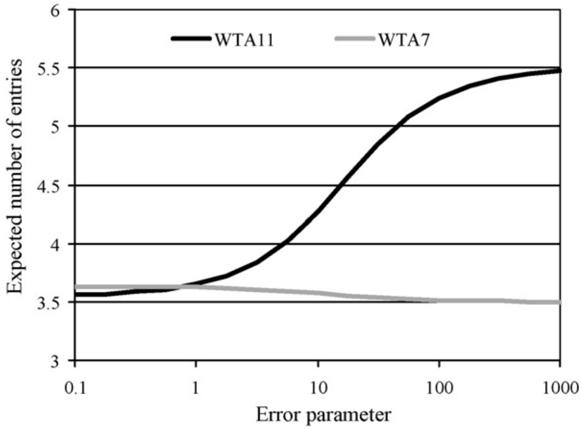


Fig. 1. Expected number of entries in the symmetric QRE for two group sizes $n = 7$ and 11.

There is strong experimental evidence for the Nash equilibrium to be a good predictor for the number of entries in market entry games. For example, Rapoport et al. (1998) or Sundali et al. (1995) study market entry games with different market capacities. The difference between these studies and our experiment lies in the market structure. While in the usual market entry game all players who enter receive the same payoff, our market is a winner-take-all market.

On the other hand, there are good reasons for assuming that the Nash equilibrium prediction is inappropriate. First, the social optimum requires a much smaller number of entries. From experiments we know that people have a preference for group-efficient outcomes; for example subjects often contribute to public goods, even in large groups (see Ledyard, 1995; Isaac and Walker, 1988). If these forces are relevant in the winner-take-all market, fewer people should enter than the Nash equilibrium predicts. On the other hand there is evidence from Cournot oligopoly games that the Nash equilibrium is a good predictor if the group size exceeds three subjects (see Huck et al., 2004). Cournot games are more akin to our game than public goods games. Thus, in our experiment, efficient entry is not a very likely outcome. A second reason why the Nash equilibrium prediction might fail is due to excess entry. One reason for this excess entry lies in what Frank and Cook call the "overconfidence problem". Although in our experiment the selection of the winner is at random, people might still be overconfident about their winning chances. Many psychological studies show that overconfidence is an important phenomenon (see Kahneman et al., 1982). On the other hand, subjects could perceive the process of choosing the winner as not completely random and outside of their influence; that is, they have an "illusion of control" (Langer, 1975). Another possible explanation for excess entry is that people like the "thrill of competition" or experience an "attraction to chance" (see Albers et al., 2000). They might attach a higher value to a win in the game than just its monetary payoff. For these reasons we state the following hypothesis:

**HA$_1$.** The number of entries is higher than predicted by the Nash equilibrium.

If a sufficient number of the subjects are overconfident or show one of the other discussed traits that produce excess entry, it is likely that we observe more entries in larger groups. This is because the other subjects who do not exhibit these motives cannot outweigh the excess entry by staying out (because they stay out already). This being the case, excess entry will increase in the group size. Our second hypothesis is, therefore:

**HA$_2$.** The number of entries increases in the group size.

Note that this hypothesis contradicts H0$_2$, which is suggested by the Nash prediction. The minimum and maximum predictions of the average number of entries do not change with group size whereas the average number of entries in the symmetric Nash equilibrium even decreases with group size.

### *2.5. Experimental procedure*

We conducted six sessions, three WTA7 sessions with 21 subjects and three WTA11 sessions with 22 subjects. The 129 subjects were undergraduate students from the Federal Institute of Technology and the University of Zurich. First,

Table 3
Average number of entries in all sessions (S1–S6) and periods

| Period | WTA7 | | | | WTA11 | | | |
|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | Average | S4 | S5 | S6 | Average |
| 1 | 5.3 | 3.7 | 4.3 | **4.4** | 8.0 | 4.5 | 3.5 | **5.3** |
| 2 | 4.7 | 4.3 | 4.3 | **4.4** | 8.0 | 6.0 | 4.0 | **6.0** |
| 3 | 4.0 | 4.3 | 4.7 | **4.3** | 5.5 | 7.0 | 3.5 | **5.3** |
| 4 | 5.0 | 4.3 | 3.7 | **4.3** | 8.5 | 6.0 | 4.0 | **6.2** |
| 5 | 4.0 | 3.7 | 3.7 | **3.8** | 5.0 | 3.5 | 4.5 | **4.3** |
| 6 | 3.0 | 3.7 | 4.0 | **3.6** | 7.0 | 4.5 | 4.5 | **5.3** |
| 7 | 4.0 | 6.0 | 4.7 | **4.9** | 7.5 | 5.0 | 5.5 | **6.0** |
| 8 | 4.0 | 4.0 | 3.3 | **3.8** | 4.0 | 4.5 | 4.0 | **4.2** |
| 9 | 4.0 | 3.3 | 3.3 | **3.6** | 6.0 | 5.5 | 4.5 | **5.3** |
| 10 | 4.3 | 4.0 | 3.7 | **4.0** | 6.5 | 4.5 | 4.5 | **5.2** |
| Average | 4.23 | 4.13 | 3.97 | **4.11** | 6.60 | 5.10 | 4.25 | **5.32** |

Averages over treatments in bold face.

the subjects had to read the instructions (see Appendix B) and to solve the review exercises. The instructions contain the information about the group size $n$, which remains constant during a session. When all subjects had finished all the exercises correctly, an oral summary was given and the experiment was started.

In each of the 10 periods, subjects had to decide whether to enter the market or to stay out. The two alternatives were labeled as 'Alternative A' and 'Alternative B'. The decision screen contained the payoff information (i.e., the function $\pi(e)$ and $\sigma$). Furthermore, the subjects had to guess the number of other subjects in their group who would choose alternative A (i.e., they had to indicate their *belief* about the number of other subjects entering the winner-take-all market).

After the entry decision, all subjects were assigned a random number (uniformly distributed between 0 and 100). The entrant with the highest random number received the prize; the other entrants received nothing. The subjects who stayed out received 50 points if their random number was at least 50 and 40 points otherwise. At the end of each period all subjects were informed about how many other subjects in their group entered the market and received five additional points if they had guessed the number of other entrants correctly. After that, the group composition was randomly changed and the next period began. The subjects were informed about the group size and the random mechanism in the instructions.

At the end of the experiment, the subjects had to fill out a questionnaire containing, among others, questions about risk attitudes. In particular, subjects had to indicate their certainty equivalents for two hypothetical lotteries. They had to answer the following question: "You can buy a lottery ticket. In this lottery every seventh [third] ticket is a win. The prize will then be CHF 50.-. What would you pay at most for such a ticket?"

All points that the subjects earned during the 10 periods of the experiment were added up and subjects were paid by a binary lottery. In this lottery, 10 points corresponded to a 1 percent probability of receiving an amount of CHF 50.- (about $33).[5] Over and above the lottery, the subjects received a flat show up fee of CHF 10.-. The average total earning was CHF 31.-. The experiment lasted roughly 90 min. The mean earnings in the experiment were about equal to the amount students could have earned in the same time at a typical side-job. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007).

## 3. Main results

Remember that according to $HA_1$, the number of entries is above the Nash equilibrium, which is between 3 and 3.80. An overview of the entry decisions is given in Table 3, which shows the average number of entries. Each row shows one period, the non-bold columns show session averages, and the bold columns show averages over a whole treatment.

[5] Before the subjects received their payment, they had to roll three 10-sided dices, each representing a digit of a three-digit number. They received CHF 50.- if the number of points they earned in the experiment exceeded their three-digit number.

We see that in both treatments and in all periods the average number of entries is much higher than the prediction of the pure strategy Nash equilibrium. The average number of entries was always at least 3 and, with the exception of period 6 in S1, it was strictly greater than 3. The average number of entries per session was also always greater than the maximal expected number of entries in equilibrium (3.80). Hence $HA_1$ can be supported with $p = .016$.[6]

Our second hypothesis addresses treatment effects. Table 3 shows that the average number of entries in the WTA11 treatment is consistently higher than in the WTA7 treatment. Indeed, a comparison of the two treatments gives unambiguous results. The WTA11 session averages of the number of entries are all higher than the WTA7 session averages. A Mann–Whitney test supports $HA_2$ at the 5 percent level (one-sided). This difference also remains significant if we consider only the last periods (i.e., period $t$ to 10 for any $t$). It is remarkable that the number of entries is higher for the WTA11 treatment. This increase is in line with the QRE prediction but not with the Nash equilibrium.[7]

To summarize the main results in short (i) there is inefficient excess entry in both treatments, (ii) the excess entry is considerably and significantly higher in the WTA11 treatment compared to the WTA7 treatment. In the next section, we examine different explanations for these results.

## 4. Sources of excess entry

In the previous section, we have seen that there is excess entry and that this excess entry increases with group size. We will now deal with different possible sources of excess entry. First we show that the observed excess entry is not caused by an underestimation of the other players' entry probabilities. Of course, people make errors in their estimates of how many other players will enter. However, these estimations are not biased in any direction. Second, we compare our results to the prediction of the quantal response equilibrium. Finally, we show that individual entry behavior cannot be explained by risk preferences.

### 4.1. *Excess entry is not caused by wrong beliefs*

In our experiment, the subjects do not know how many other subjects will enter the winner-take-all market. If subjects enter because they underestimate the number of other subjects who do so, then the *behavior* of these subjects could be rational. In this case, only the subjects' *belief formation* is not sufficiently accurate in order to achieve the equilibrium outcome quickly. Recall that we elicited our subjects' beliefs about the number of other entrants.

If the subjects' beliefs are systematically too high, the difference between the guessed number of entries and the actual number of entries is positive. We call this difference *overestimation*. It can be calculated in every period and for every subject. If a subject guesses that three other subjects enter the winner-take-all market while only two actually do so, then the variable *overestimation* takes the value of 1. In the WTA7 treatment the average of all estimates is 3.49 while the effective average of other entrants equals 3.52. The difference between these two numbers is the average estimation error and equals −.03. In the WTA11 treatment, the average *overestimation* is +.18. In the WTA7 treatment subjects do on average *underestimate* the number of other entries, but the coefficient is very close to zero. In the WTA11 treatment it is larger but positive, which means that the subjects did *overestimate* the number of other entrants. In both cases the median of the variable *overestimation* is zero, which further substantiates our argument that beliefs are not biased.

However, while beliefs on average are unbiased it might still be the case that those subjects actually causing the excess entry might have especially bad beliefs. To find out whether estimation errors can produce the observed excess entry, we classify the decisions. Table 4 shows all 1290 single decisions split up by whether the subject entered or not and whether the stated belief was below, equal to or above three for the two treatments. In the upper left cell are those who enter and at the same time believe that more than three others will enter. These are the ones who deliberately created excess entry.[8] The counterpart, those who tried to offset excess entry, are found in the upper right cell. The

[6] We have applied a one-sided binomial test that checks whether the session averages are above 3.80. Because the conditions of the hypothesis are independent of the group size, the data of the two treatments can be pooled for this test.

[7] Recall that according to the symmetric mixed equilibrium, one would even expect a slight decrease in the number of entries.

[8] This is not correct under all circumstances. As will be explained later, there are special distributions of the belief of the number of other entrants that can make a belief above three consistent with a rational entry decision.

Table 4
All 1290 observations, classified according treatment, entry decisions and belief

| | WTA7 | | WTA11 | |
|---|---|---|---|---|
| | Enter | Not enter | Enter | Not enter |
| Belief > 3 | 146 (76) | 177 (82) | 256 (53) | 303 (58) |
| Belief = 3 | 156 (112) | 65 (41) | 48 (39) | 31 (27) |
| Belief < 3 | 68 (50) | 18 (14) | 15 (13) | 7 (7) |

The numbers in parentheses show the number of observations where the belief was in the wrong range.

second row shows the decisions at a belief of three. Here we have no way of judging the rationality of a single decision. According to the Nash equilibrium in pure strategies, a player with a belief of three should stay out. On the other hand, if the symmetric Nash equilibrium in mixed strategies is played, three is the mode of the distribution of other entrants and therefore the optimal belief. At the same time, the player at hand should enter with probability .519 in the WTA7 treatment and .323 in the WTA11 treatment. The fraction of entry decisions is considerably higher (.7 for the WTA7 and .6 for the WTA11 treatment). Therefore, the fraction of entry decisions at a belief of three is much larger than the Nash equilibrium predicts, irrespective of which equilibrium concept is used. Taken together, we see that a large number of entrants were aware of the excessive entry behavior of the other group members. Their entry decision is therefore not caused by coordination failures.

In addition to that, if coordination failures were the cause of the excess entry we should observe subjects enter due to false expectations. The lower left cells where the belief is smaller than three shows the decisions that are "belief-rational". Given that a subject believes that less than three others enter, it is rational to enter. In parentheses we show the number of decisions where the stated belief was in the wrong range. A belief is said to be in the wrong range if the belief is smaller (larger) than three while the actual number of other entrants is larger (smaller) than three. In the middle row at a belief of three the number in parentheses is simply the number of cases where the actual number of entrants was different from three. According to this definition, in the WTA7 treatment 50 out of 68 entrants underestimated the entry behavior of the other subjects and, therefore, entered erroneously. Taken alone, this would be evidence for the coordination problem to drive our result, but we observe an even stronger effect in the upper right cell that works to the contrary: 82 non-entrants overestimated the entry behavior of the other subjects and therefore stayed out erroneously. The same holds true for the WTA11 treatment where there are 13 entrants with a wrong belief versus 58 non-entrants with a wrong belief.

Finally, if underestimation causes excess entry, then subjects who enter more frequently during the 10 periods should have higher underestimations. A simple regression[9] shows that this is not the case. On the individual level, the connection between the variable *overestimation* and the total number of entries during the 10 periods is either uncorrelated (WTA7: $\beta = -.54$, $p = .693$) or positively correlated (WTA11: $\beta = .96$, $p = .078$). The latter implies that the subjects who *overestimated* the entry behavior entered more frequently.[10] This point further substantiates our argument that excess entry is not caused by coordination failure.

### 4.2. Why does excess entry increase with group size?

We have shown that often the subjects are well aware of the fact that many others will crowd the winner-take-all market and still enter. In a next step we take a closer look at the relation between the belief and the entry decision.

The dots labeled as "Actual share of entrants" in Fig. 2 show the empirical entry probability for every possible belief separated by treatment. The empirical entry probability is the share of the subjects who enter the winner-take-all market among all subjects that state the corresponding belief. We call "PNE pattern" the behavior that corresponds to a Nash equilibrium: if a subject believes that two or fewer other subjects will enter, then he should enter as well. If he believes that more than three other subjects enter, then he should not enter. First, we observe that the subjects do not

[9] We calculate the standard errors by using sessions as clusters, which takes into account that individual decisions are not independent.

[10] If subjects assume that other subjects behave similarly to themselves ("false consensus effect") then subjects who enter more often expect other subjects to enter more often too. This could explain the observed relation in the WTA11 treatment.

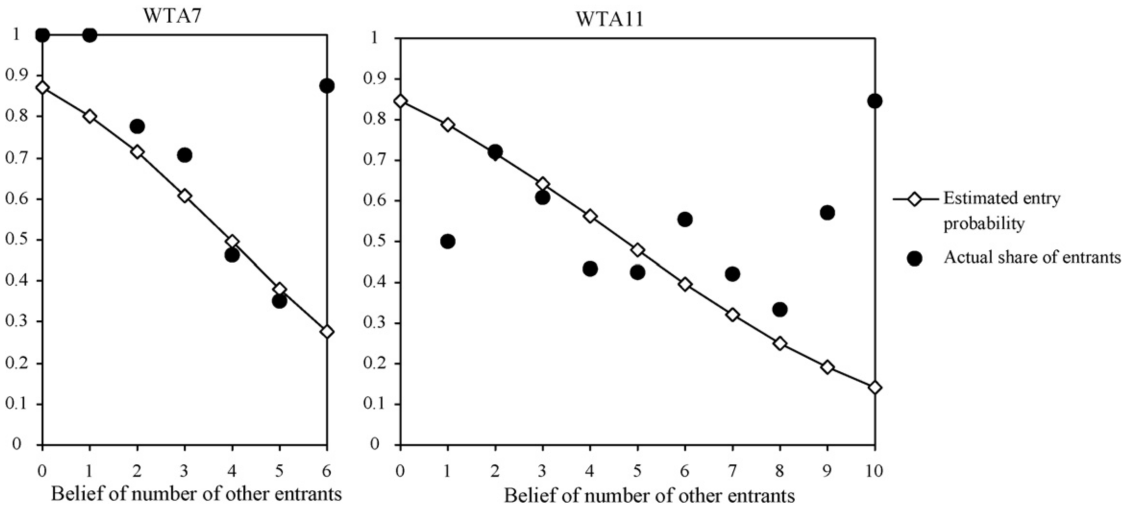


Fig. 2. The graph shows the mean entry probabilities by a probit estimation dependent on the belief of the number of other entrants with individual dummies. The dots show the actual share of subjects that entered among all subjects that stated the corresponding belief.

behave exactly according to this pattern.[11] Yet, the empirical entry probability decreases with higher beliefs, at least for the beliefs between two and five, where more than 80 percent of the observations are found.

Given the beliefs about the other players' entry decisions, we can apply a probit estimation for the entry probabilities for each belief. Since the subjects are heterogeneous with respect to their total number of entries during the 10 periods the error terms are likely to be autocorrelated. Therefore we add an individual dummy for each subject. The estimated mean entry probabilities for both treatments are shown in the line plots in Fig. 2.

In Section 2.3 we discussed the concept of the quantal response equilibrium and its predictions for the winner-take-all game. Recall that in a QRE subjects do not play strict best response but give higher probability weights to strategies with higher payoffs. This allows calculating a probabilistic best reply to a given belief about the other players' entry decisions. Independent of the exact specification of the functional form of the error and independent of the size of the error parameter, it predicts higher probabilities for "better" choices (i.e., the probability to choose a strategy depends positively on the payoff of that strategy choice). Therefore QRE predicts individual patterns similar to those observed in our experiment. As Fig. 2 shows, the entry frequency is always at least 50 percent for beliefs below three, and it is below 50 percent for beliefs above three except for beliefs of 6, 9, and 10 (where there are very few observations). This result is in line with quantal response equilibrium.

Given that the "reaction function" to the own belief is compatible with QRE we now turn to the question whether QRE can explain the differences between the WTA7 and the WTA11 treatment. Recall from Fig. 1 that for a sufficiently high error term QRE predicts a substantial treatment effect. Therefore, the differences between the observed entries in the WTA7 and the WTA11 treatment are in line with the QRE prediction. However, the maximum likelihood estimation of the error parameter $\mu$ equals 99, which is quite substantial, compared to the payoffs in the game. On the other hand, QRE fails to predict the excess entry in the WTA7 treatment. As Fig. 1 shows, errors shift the expected number of entries towards $n/2$. Therefore, in the WTA7 treatment the QRE prediction of the number of entries is between 3.5 and 3.8. The observed average number of entries in the WTA7 treatment, though, equals 4.1. This is above the Nash prediction *and* higher than 3.5. Thus, separate estimations for the two groups get a $\mu$ of zero in the WTA7 treatment. For the WTA11 treatment, we get an estimate of $\mu = 146$. This also shows that QRE alone cannot explain all features of the data.

[11] There is one caveat: we cannot conclude that all decisions that deviate from the PNE pattern are not rational. A subject could, for instance, think that the probability that two subjects will enter equals .4 and the probability that three, four and five subjects enter equals .2 each. In this case, it is rational to declare two as the belief for the number of entries but, nevertheless, not to enter the market. However, if we assume that a subject has a single peaked belief distribution and this subject actually states the peak of his distribution, then entry decisions for beliefs of 9 and 10 can be considered as irrational. Furthermore, it can be calculated that if subjects assume that all other players enter with the same probability, entries for beliefs above three are not rational, either.

Table 5
Probit regressions for the entry decision as dependent variable (1 if enter, 0 otherwise)

| | Dependent variable: Entry decision | | | |
|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 |
| Constant | .335 (.070)** | .392 (.131)** | .428 (.407) | 1.814 (.514)** |
| Period | −.021 (.012) | −.023 (.013) | −.031 (.014)* | −.038 (.015)* |
| Dummy for WTA11 | −.263 (.142) | −.244 (.160) | −.504 (.575) | −1.069 (.649) |
| Average certainty equivalent | | −.006 (.014) | | |
| Belief × WTA7 | | | | −.378 (.083)** |
| Belief × WTA11 | | | | −.271 (.054)** |
| Individual dummies | No | No | Yes | Yes |
| $N$ | 1290 | 1250 | 1050 | 1050 |
| Clustering | Yes | Yes | No | No |
| Pseudo-$R^2$ | .0095 | .0094 | .1778 | .2147 |
| Log pseudo-likelihood | −882.71 | −855.67 | −598.11 | −571.27 |

We use a robust calculation of the standard errors with the sessions as clusters. *Notes*: significance levels using two tailed tests—*significant at 5-percent level and **significance levels using two-tailed tests = significant at 1-percent level. Period = period in the experiment; dummy for WTA11 = 1 for WTA11, 0 for WTA7; belief = belief of how many other subjects enter the winner-take-all market; average certainty equivalent = average between the certainty equivalents stated in the two lotteries of the post-experimental questionnaire.

### 4.3. Risk preference and market entry

We showed that neither errors in beliefs nor errors in the decisions alone can explain the excess entry in the WTA7 treatment. Could risk attitudes have caused the excess entry observed in the experiment? First note that excess entry can only be explained by risk preferences if a significant number of the players are risk seeking. To get about four entries in the WTA7 treatment, *more than half of the players* would have to be risk seeking, because otherwise, even if risk-seeking subjects always enter, the risk averse and risk neutral subjects will react and prevent the excess entry by staying out.

Recall that we elicited risk preferences in the post-experimental questionnaire by asking for certainty equivalents in hypothetical lotteries. On average, our subjects are risk averse, with an average certainty equivalent of 6.85 in the first lottery and 13.4 in the second lottery (expected values are 7.14 and 16.7, respectively). Since the two measures for risk preferences are strongly positively correlated (coefficient = .726, $p = .000$), we will use the average of both measures for the following analysis. About 25–30 percent of the subjects indicate that they were willing to pay more for the lottery than its expected value.[12] As explained before, this share of risk-seeking subjects is too small to cause the excess entry.

Furthermore, if risk-seeking behavior were to cause excess entry, we should observe a close connection between risk preferences and individual entry decisions. In Table 5 we apply probit estimations to check whether risk preferences can explain entry behavior. Dependent variable is the individual entry decision. The data of the WTA7 and the WTA11 treatments are pooled. Since the observations within a session are not statistically independent, we use a robust estimation of the standard error with the sessions as clusters.

Model 1 shows a benchmark regression with nothing but the period number and a treatment dummy as explanatory variables. Interestingly, across all estimations the dummy for the treatment with the higher group size is not significant. This indicates that the subjects do not sufficiently adjust their entry probability to the higher group size, causing the higher excess entry in the WTA11 treatment. In Model 2 we add the coefficient for the average certainty equivalent.[13] The coefficient is far from significance and has even an unexpected sign, it is negative. A negative coefficient would

[12] Compared to the literature, this is a rather high share of risk seekers. For example Goeree et al. find *at most* 25 percent risk seeking players.

[13] Recall that the average certainty equivalent is calculated as the average of the values indicated for the two lotteries. The estimation also fails to produce a significant coefficient if we introduce either one of the certainty equivalents alone. When introducing the certainty equivalent measure we lose a few observations. The missing data stem from subjects who entered values higher than the possible income of the lottery (i.e. they stated they were willing to pay for a lottery with a 33 percent chance of winning CHF 50.- more than CHF 50.-). Obviously these statements are caused by a misunderstanding of the task and were therefore dropped.

mean that subjects with a high certainty equivalent (i.e., risk loving subjects) enter the winner-take-all market less frequent than subjects with a low certainty equivalent. We conclude that risk preferences as measured with certainty equivalents cannot account for individual differences in the entry behavior observed in this experiment.

In contrast, a model allowing for any kind of (unexplained) individual heterogeneity can explain substantially more of the variance in the entry behavior. In Model 3 we replace the risk preference measure by individual fixed effects.[14] Since there are more variables than truly independent observations (the six sessions), we can no longer cluster the data on the session level. The standard errors reported in Model 3 must therefore be interpreted with caution.

In Model 4 we control for the dependency of the entry decisions by introducing the beliefs as explanatory variable. This regression is similar to the one used in Fig. 2. It shows that, corrected for individual fixed effects, subjects are less likely to enter the winner-take-all market if they believe that many others enter. To conclude, the regression results indicate that individual differences are important and at the same time not explainable by our measurement of risk preferences.[15]

## 5. Conclusion

In this paper, we have found excess entry in an experimental winner-take-all market. There is not only excess entry with respect to the social optimum; even more subjects enter than predicted by any Nash equilibrium. Furthermore, we have shown that the number of entries increases with group size even though, in equilibrium, no increase is predicted. The analysis in the previous section has shown that there is (i) large heterogeneity in the frequency of entries into the winner-take-all market, and (ii) sufficiently many subjects enter the market too frequently, causing the excess entry. Biased beliefs can be disregarded as an explanation of the observed pattern of excess entry. Errors in the sense of QRE can explain the increase of excess entry in group size but fail to explain the excess entry in the WTA7 treatment. Furthermore, we showed that risk preferences in the usual sense can explain neither excess entry nor the individual differences.

What might explain our results? In the following we suggest some possibilities. Since our experimental data does not provide information to test these explanations, the discussion necessarily remains speculative. There are many motives that result in behavior that is similar to risk seeking. Some subjects could enter too frequently because they get, independently of the monetary payoff, a utility from entering. The reason for this could be that the winner-take-all market is considered as more entertaining than the outside option. Due to our design choice to randomize the payoff of the “outside option” we can say that this additional entertainment must rather be connected to the competition character of the winner-take-all market than to the random process per se. Presumably the difference lies in the interaction with the other subjects. If a subject stays out, the payoff does not depend on the behavior of the other players; in the winner-take-all market it does. Thus, the attractiveness of the winner-take-all market lies rather in its competition-against-others structure than in the fact that the payoff is uncertain (i.e., subjects could enjoy the thrill of competition).

Excess entry might also occur if subjects overestimate the value of entry or overestimate the winning chance. An explanation based on overestimation of the winning chances offers the concept of “illusion of control” (Langer) and overconfidence. If subjects have illusion of control, they erroneously believe they can influence random processes. Together with overconfidence, this can cause subjects to overestimate their winning chances and may result in excess entry.[16]

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[14] In Models 3 and 4 we lose the observations of 24 subjects who either always (15) or never (9) enter the winner-take-all market during the 10 periods.

[15] One reason for the absence of this connection might lie the fact that we paid our subjects by a binary lottery that induces expected utility maximizers to behave risk neutrally. However, as mentioned in footnote 4, there is evidence that the binary lottery mechanism does not always work in the desired direction. Furthermore, Harrison (1992) challenges the method of eliciting certainty equivalents by a ‘flat maximum critique’ (which certainly applies in our case, since the elicitation was done without incentives).

[16] Prospect theory (Kahneman and Tversky, 1979) is another theory that assumes a distorted probability perception. It assumes that small probabilities are underestimated. However, in our experiment on average 4–5.5 subjects enter and, therefore, the actual winning chance equals around 20 percent. This is higher than what is considered a small probability in prospect theory. Therefore, it does not predict excess entry in our experiment.

Our results are in contrast to other market entry games where subjects succeeded to coordinate on the Nash equilibrium (Rapoport et al., 1998; Sundali et al., 1995).[17] This is very surprising, since the basic structure of the entry decision is very similar in both games. However, we think that the basic difference between a winner-take-all game and a normal market entry game lies in the competition-against-all-others structure. This feature seems to make entering more attractive. We guess that people either have an "illusion of control" or they receive an extra utility from the thrill of competition. In order to test these possible explanations, one could try to measure to what extent the experimental subjects are prone to "illusion of control" or the thrill of competition. The former could be measured by experiments like the ones Langer conducted, the latter by comparing certainty equivalents in similar individual and group lotteries. The obtained measures could be used to explain differences in individual entry behavior in the winner-take-all market.

Winner-take-all markets do not only occur "naturally". Often firms create tournament incentives to create incentives for higher effort. Most studies, theoretical (Lazear and Rosen, 1981) as well as experimental (see e.g., Bull et al., 1987; Harbring and Irlenbusch, 2003), focus on this incentive effect. Our study shows that there is heterogeneity with respect to the willingness to enter such a market. Thus, when analysing the impact of tournament incentives on the effort choice, one has to take selection into account. For instance, James and Isaac (2000, p. 1003) investigate the behavior of traders in an experimental asset market and conclude that "tournament contracts can have a clear and destructive effect in asset markets". In their experiment, the players were randomly assigned to the tournament or not. If players could choose the incentive scheme, this effect could be mitigated or even increase. It would be interesting to investigate how the selection that we observe in the experiment interacts with the tournament incentives.[18]

What have we learned about winner-take-all markets? Our experimental results support the argument by Frank and Cook that winner-take-all markets encourage inefficiently many contestants to enter. Not only are our winner-take-all markets as overcrowded as the (inefficient) Nash equilibrium predicts, but the number of entries even exceeds the prediction, further reducing efficiency. Therefore, our experiment also supports what Frank and Cook call the "overconfidence problem", that irrationally many contestants crowd the winner-take-all markets. We have shown that the driving force of the excess entry is not a wrong estimation of the number of other players entering. This implies that informing potential entrants about the winning probability is likely not to mitigate the problem.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jebo.2006.05.018.

## References

Albers, W., Pope, R., Selten, R., Vogt, B., 2000. Experimental evidence for attractions to chance. German Economic Review 1, 113–130.

[17] Gächter et al. (2006) investigate market entry and exit in several Cournot oliopoly markets and find also coordination according to the Nash prediction. An important exception is the study by Camerer and Lovallo, who implement a market entry game in which subjects who enter the market are ranked. According to this rank they receive a prize. The ranking is either done at random or by the performance in a trivia quiz. Whereas in the "random treatment" the number of entries is in line with the Nash prediction, there is excess entry in the "quiz treatment". In contrast to their result, we find excess entry also in a "pure random" treatment. A difference between the random treatment of Camerer and Lovallo and our treatment is that in the experiment of Camerer and Lovallo the payoff of the winner decreases with the number of entrants while in our experiment it increases with the number of entrants. Thus, in our experiment, the externality of an entry is less salient than in the experiment of Camerer and Lovallo. Whether this is actually the reason for the different outcome in the two experiments needs further investigation.

[18] Dohmen and Falk (2006) report results from a real effort experiment where subjects can self-select into either a fixed payment scheme of a tournament. They show that overconfident subjects are more likely to choose the tournament.

Anderhub, V., Güth, W., Müller, W., Strobel, M., 2000. An experimental analysis of intertemporal allocation behavior. Experimental Economics 3, 137–152.

Anderson, S., Goeree, J., Holt, C., in press. Logit equilibrium models of anomalous behavior: what to do when the Nash equilibrium says one thing and the data says something else. In: Plott, C., Smith, V. (Eds.), Handbook of Experimental Economics Results.

Bull, C., Schotter, A., Weigelt, K., 1987. Tournaments and piece rates: an experimental study. The Journal of Political Economy 95, 1–33.

Camerer, C., Lovallo, D., 1999. Overconfidence and excess entry: an experimental approach. American Economic Review 89, 306–318.

Capra, M., Goeree, J.K., Rosario, G., Holt, C., 1999. Anomalous behavior in a traveler's dilemma? American Economic Review 89, 678–690.

Dohmen, P., Falk, A., 2006. Performance pay and multi-dimensional sorting: productivity, preferences and gender. IZA discussion Paper 2001.

Fischbacher, U., 2007. z-Tree, Zurich toolbox for ready-made economic experiments. Experimental Economics 10, 171–178.

Frank, R.H., Cook, P.J., 1995. The Winner-Take-All Society. The Free Press, New York.

Gächter, S., Thöni, C., Tyran, J.R., 2006. Cournot competition and hit-and-run entry and exit in a teaching experiment. Journal of Economic Education 37, 418–430.

Goeree, J.K., Holt, C.A., 1999. Stochastic game theory: for playing games, not just for doing theory. Proceedings of the National Academy of Sciences of the United States of America 96, 10564–10567.

Goeree, J.K., Holt, C.A., Palfrey, T.R., 2002. Quantal response equilibrium and overbidding in private-value auctions. Journal of Economic Theory 104, 247–272.

Harbring, C., Irlenbusch, B., 2003. An experimental study on tournament design. Labour Economics 10, 443–464.

Harrison, G.W., 1992. Theory and misbehavior of first-price auctions: reply. American Economic Review 82, 1426–1443.

Huck, S., Normann, H., Oechssler, J., 2004. Two are few and four are many: number effects in experimental oligopolies. Journal of Economic Behavior and Organization 53, 435–446.

Isaac, R.M., Walker, J.M., 1988. Group size effects in public goods provision: the voluntary contributions mechanism. Quarterly Journal of Economics 103, 179–199.

James, D., Isaac, R.M., 2000. Asset markets: how they are affected by tournament incentives for individuals. American Economic Review 90, 995–1004.

Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. Econometrica 47, 263–291.

Kahneman, D., Slovic, P., Tversky, A., 1982. Judgment Under Uncertainty: Heuristics and Biases. Cambridge University Press, Cambridge.

Langer, E.J., 1975. The illusion of control. Journal of Personality and Social Psychology 32, 311–328.

Lazear, E.P., Rosen, S., 1981. Rank-order tournaments as optimum labor contracts. Journal of Political Economy 89, 841–864.

Ledyard, J.O., 1995. Public goods: a survey of experimental research. In: Kagel, J.H., Roth, A.E. (Eds.), Handbook of Experimental Economics. Princeton University Press, Princeton, pp. 111–194.

McKelvey, R.D., Palfrey, T.R., 1995. Quantal response equilibria for normal form games. Games and Economic Behavior 10, 6–38.

Rabin, M., 2000. Risk aversion and expected-utility theory: a calibration theorem. Econometrica 68, 1281–1292.

Rapoport, A., Seale, D.A., Erev, I., Sundali, J.A., 1998. Equilibrium play in large group market entry games. Management Science 44, 119–141.

Roth, A.E., Malouf, M.W.K., 1979. Game-theoretic models and the role of information in bargaining. Psychological Review 86, 574–594.

Selten, R., Sadrieh, A., Abbink, K., 1999. Money does not induce risk neutral behavior, but binary lotteries do even worse. Theory and Decision 46, 211–249.

Sundali, J.A., Rapoport, A., Seale, D.A., 1995. Coordination in market entry games with symmetric players. Organizational Behavior and Human Decision Processes 64, 203–218.