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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 the functioning of such markets with the help of experiments 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. We discuss several concepts that might explain the observed excess entry.

JEL classification: C92; D81.

Keywords: Winner-take-all market; Excess entry; Experiment, Market entry.

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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 he is judged on 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 which 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 people who will enter such a market. This is due 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 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 five 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 (1995), for instance, conjecture that the problem of inefficient entries in winner-take-all markets increases with the number of potential entrants. This induced us to vary the group size in our experiment. In one treatment, there was a group of 7 potential entrants; in the other, the group size was 11. With our parameters, in both treatments, the social optimum was one entry and in the Nash equilibria the expected number of entries was between 3 and 3.8. Hence, 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 was 4.11; with a group size of 11, on average 5.32 subjects entered. Hence, it turned out that even more people entered than predicted by the Nash equilibrium. This result contradicts the findings of a number of experiments on market entry games where quick convergence to the Nash equilibria was observed (e.g., Sundali, Rapoport and Seale, 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 the sources of the excess entries. 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 (McKelvey and Palfrey, 1995). This concept has successfully been applied to explain the selection of Nash equilibria as well as of 'anomalies' (see for instance Anderson, Goeree and Holt, 1997; Goeree and Holt, 1999). We find that random errors in the sense of the quantal response equilibrium concept can explain the increase of entries in the size of the group. To understand the level of the entry probability, however, one has to assume that at least some fraction of the subjects gets some utility from entering that goes beyond the monetary payoff (e.g. they are risk loving or like competition).

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 formulated a winner-take-all game. Thereby we tried to keep the game as simple as possible to not confuse the subjects with unimportant features. In our experiment, the players have to decide simultaneously whether to enter a winner-take-all market or to stay out. If they enter the market, they can win a high prize. However, only one person – the winner – actually wins this prize. The other entrants get nothing. The players who stay out get a comparatively low payoff, which is independent of the behavior of the other players. We denote by n the number of players in a group and by e the number of players who decide to enter the winner-take-all market (the entrants). By $\pi(e)$ we denote the prize the winner gets when the number of entrants equals e.

The feature that the subjects have to decide simultaneously reflects the fact that in real career decisions people rarely have accurate information about the entry decisions of their potential competitors. The reason for giving a prize only to the winner of the winner-take-all market was chosen to make the game as simple as possible so that the subjects can easily calculate the expected payoff of the different alternatives. Those subjects who do not enter the winner-take-all market get a comparably sure payoff, independent of the others' decisions. This represents the choice of a job in a normal labor market. The payoff is then randomly distributed with an expected value of σ. The reason for not paying a sure amount of σ to the players who stay out was as follows. We did not want people to enter the winner-take-all market just because entering is more entertaining than staying out. Entering may lead to a "thrill" from winning or losing. To make the two alternatives as similar as possible, there was also some "thrill" involved if a player stayed out.

We assume that the prize function $\pi(e)$ increases in e. This reflects the argument, substantiated by Frank and Cook (1995), 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 the higher the more people enter.

Since 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 oneself in a specific sport, the bigger gets 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 decreases 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.

Another important design feature is the determination of the winner among all entrants. In our game, the winner is determined randomly. Each entrant gets a random number and the subject with the highest number wins. Therefore, each entrant has a probability of *1/e* to get the prize. By randomly determining the winner we can be sure that all subjects are in the exact same position and have no prior information about their winning chances.[1]

2.2. The parameters and the payoff function

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.

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 players who choose to stay out get a payoff of either 40 or 50, each with probability .5. Therefore, the expected value σ equals 45. In our experiment, we varied the group size, i.e., the maximum number of subjects that could enter the market. There was a treatment with a

[1] At first sight this random device might be seen as a crude simplification which 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. 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 too. Whether he really makes it to the top ten 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. Furthermore, the results of market entry games conducted by Camerer and Lovallo (1999) suggest that our result of the excess entry would have been even more articulate if we had determined the winners by ability, measured e.g. by the number of correct answers in a quiz.

group size of 7, called WTA7 treatment (for Winner-Take-All 7), and a treatment with a group size of 11, called WTA11 treatment. For both treatments, the value of $\pi(e)$ is shown in Table 1.

2.3. Theoretical prediction

Nash equilibria

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 less) other players are already in the market, entry is worth 51.7 (or more) while staying out is worth only 45. On the other hand, if three players (or more) are already in the market, then entering has an expected value of only 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

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

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 equation (1) is satisfied, the player is indifferent between entering and staying out. So entering with probability p^* is a best reply and, 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 (in which case 3 players always enter and the others never enter) and 3.80 (4 players enter with a probability of .95 and the others never enter). A complete description of all equilibria is given in the appendix.

Social optimum

In the social optimum, exactly one subject enters: 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.

Table 2: Equilibrium predictions and social optimum

N	7	11
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

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 increase in the group size.

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, Seale, Erev and Sundali (1998) or Sundali, Rapoport and Seale (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 lower number of entries. From experiments we know that people have a preference for group-efficient outcomes, e.g 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. However, from Cournot oligopoly games, which are more akin to our game than public goods games, there is evidence that the Nash equilibrium is a good predictor if the group size exceeds 3 subjects (see Huck, Normann, Oechssler, 2001). 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 (1995) 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, Slovic and Tversky, 1982). On the other hand subjects could perceive the process of choosing the winner as not completely random and outside of their influence, i.e. 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, Pope, Selten, Vogt, 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 some 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 group. This is because the other subjects that do not exhibit these motives cannot outweigh the excess entry by staying out. This being the case, excess entry will increase in the group size, which is our second hypothesis:

HA_2: The number of entries increases in the group size.

Note that this hypothesis contradicts hypothesis $H0_2$, 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 the group size.

2.5. Experimental procedure

We conducted six sessions, three WTA7 sessions and three WTA11 sessions. The 129 subjects were undergraduate students from the Federal Institute of Technology and the University of Zurich. First, the subjects had to read the instructions (see appendix) and to solve the review exercises. When all subjects had finished all the exercises correctly, an oral summary was given and the experiment was started. At the end of the experiment, the subjects had to fill out a questionnaire. The experiment was programmed and conducted with the software z-Tree (Fischbacher, 1999).

Each group played the winner-take-all game for ten periods. In each period, they had to decide whether to enter the market or to stay out. Furthermore, they had to make a guess at how many other subjects in their group would enter the market. After their decision, all the 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. We explained this procedure in great detail. The subjects who stayed out received 50 points if their random number was at least 50 and otherwise received 40 points. Each subject – whether an entrant or not – was informed about how many other subjects entered the market and received 5 points if he had correctly guessed the number of other entrants.

In each session of the WTA7 treatment there were 21 subjects who played in three groups. In the WTA11 treatment there were 22 subjects who played in two groups. After each period, the group composition was randomly changed. At the end, the points that the subjects earned were added up and subjects were paid by a binary lottery. In this lottery, ten points corresponded to a one percent probability of receiving an amount of CHF 50.- (about $33).[2] 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 between 1½ and 2 hours.

3. Main Results

Remember that according to Hypothesis 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 and in Figure 1. Table 3 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. Figure 1 shows the bold columns in Table 3, i.e., the average number of entries in the two treatments in every period. 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

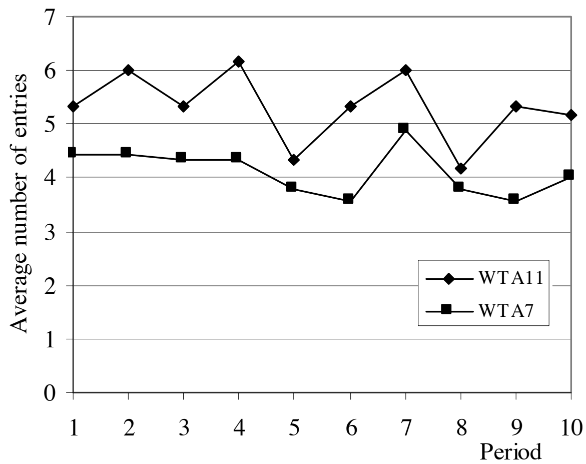
[2] Before a subject received the payment, he had to roll three 10-sides dice, each representing a digit of a 3-digit number. He received CHF 50.- exactly if the number of points he earned in the experiment exceeded this 3-digit number.

session was also always greater than the maximal expected number of entries in equilibrium (3.80). Hence Hypothesis HA_1 can be supported with p=.016.[3]

Table 3: Average number of entries in all sessions (S1 to S6) and periods. Averages over treatments in bold face.

Period	S1 WTA7	S2 WTA7	S3 WTA7	**Average WTA7**	S4 WTA11	S5 WTA11	S6 WTA11	**Average WTA11**
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**

Figure 1: Average number of entries in the two treatment conditions



The average number of entries in the WTA11 treatment is consistently higher than predicted by the Nash equilibrium. 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%-level. This difference also remains significant if we consider only the last periods, i.e., period *i* to 10 for any *i*. It is

[3] 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.

remarkable that the number of entries is higher for the WTA11 treatment. The Nash equilibrium does not predict such an increase[4].

To summarize the main results in short: (i) There is inefficient excess entry in the two 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 was excess entry and that this excess increased with group size. We will now deal with different possible sources of this excess. First, we will show that the observed excess entry is not caused by an underestimation of the other players' entry probability. Of course, people make errors in their estimates of how many other players will enter. However, these estimations are not biased in any direction. Secondly, we show that quantal response equilibrium correctly predicts that the number of entries increases with market size. Furthermore, we show that individual entry behavior cannot be explained by risk preferences. Finally, we discuss other reasons for the observed excess entry.

4.1. Excess entry is not caused by wrong beliefs

In our experiment, the subjects do not know for sure how many of the other subjects will enter the 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 good in order to achieve the equilibrium outcome quickly. To assess whether wrong beliefs are responsible for excess entry, we asked the subjects to make an estimate on how many other subjects will enter the market. They had to enter their guesses together with their entry decisions on the same screen. Recall that each correct guess was rewarded with 5 additional points.

If these estimates are systematically too low, the difference between the actual number of entries and the guessed number of entries is positive. We call this difference "estimation error". It can be calculated in every period and for every subject. For example in the WTA7 treatment the effective average of other entrants equals 3.524 while the average of all

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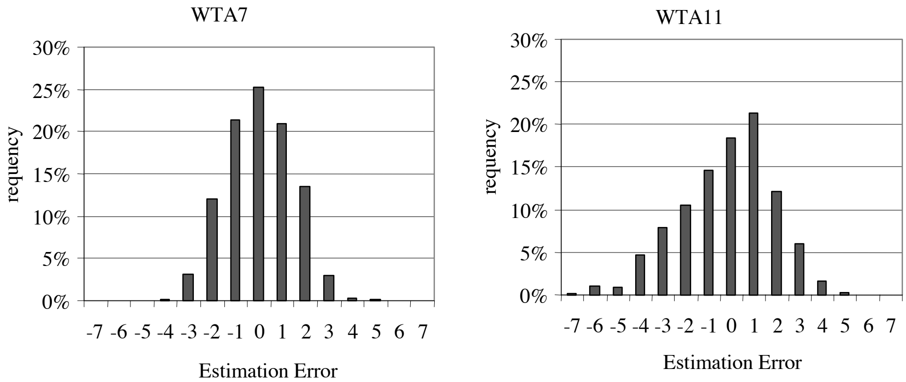
[4] Recall that according to the symmetric mixed equilibrium, one would even expect a slight decrease in the number of entries.

estimates is 3.490. The difference between these two numbers is the average estimation error and equals +.034. In the WTA11 treatment, the average estimation error is -.18. If the subjects underestimate the number of other entries, the estimation error as defined here is positive. In the WTA7 treatment we observe that the subjects did on average underestimate the number of other entries, but the coefficient is very close to zero. In the WTA11 treatment it is larger but negative, which means that the subjects did overestimate the number of other entrants. Figure 2 shows the histograms of the estimation errors. In the case of the WTA7 treatment, the distribution looks completely unbiased. In the WTA11 treatment, the distribution shows a larger variance compared to the WTA7 data. This reflects the fact that it is harder to predict the number of other entrants in larger groups. In contrast to the WTA7, the distribution here looks biased, i.e. it has a mode at 1. This means that the case, where the subjects estimate one entrant too little is the most frequent.

Figure 2: Histograms of the estimation error for all subjects in all periods. The estimation error is the difference between actual number of other subjects who enter and the belief of the subject.



To find out whether these estimation errors can produce the observed excess entry, we classify the decisions. Table 4 shows all 1290 single decisions[5] split up by whether the subject entered or not and whether the stated belief was below, equal to or above 3. In the upper left cell of the table are those who enter and at the same time believe that more than three others will enter. These are the ones who probably deliberately created excess entry.[6] The counterpart, those who tried to offset excess entry, are found in the lower right cell. The second row shows the decisions at a belief of 3. Here we have no way of judging the

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[5] Since the game-theoretic solution and also our hypothesis HA_1 are independent of the group size, we combine the data of the two treatments, WTA7 and WTA11. Nevertheless, the results are similar for WTA7 or WTA11 data alone.

[6] 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 3 consistent with a rational entry decision.

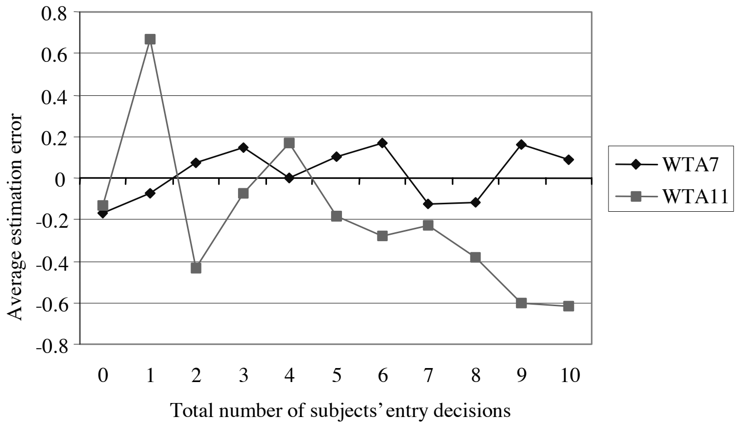
rationality of a single decision, because according to the Nash equilibrium in pure strategies, the player should stay out. On the other hand, if the symmetric Nash equilibrium in mixed strategies is played, 3 other entrants is the mode of the distribution of other entrants and therefore the optimal belief. At the same time, the player at hand should enter with probability 0.519 in the WTA7 treatment and 0.323 in the WTA11 treatment. After all we can say that the fraction of entry decisions is much larger than the Nash equilibrium predicts, irrespective of which equilibrium concept is used. According to this evidence a large part of entrants did not enter due to coordination failures. The lower left and the upper right cells support this conclusion. These decisions are "belief-rational", i.e. given that a subject believes that less than 3 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. According to this definition, 63 out of 83 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: 140 non-entrants overestimated the entry behavior of the other subjects and therefore stayed out erroneously.

Table 4: All 1290 observations classified according to the entry decisions and the belief. The numbers in parentheses show the number of observations where the belief was in the wrong range.

	Enter	Not Enter
Belief >3	402	480 (140)
Belief =3	204	96
Belief <3	83 (63)	25

Furthermore, if underestimation causes excess entry, then subjects who enter more frequently during the ten periods should have higher underestimations. Figure 3 shows how the average estimation error of subjects is correlated with the number of entry decisions. For instance, in the WTA11 treatment, the subjects who entered in all 10 periods had an estimation error of -.6. Recall that this means they even overestimated the entry behavior of the others.

Figure 3: Average estimation error dependent on the total number of subjects' entry decisions.



As shown in Figure 3, there is hardly any relation between the estimation error and the number of entries in the WTA7 treatment. The relation is stronger in the WTA11 treatment, but it works in the opposite direction: the more subjects enter, the more they *overestimate* the others' entry behavior.[7] To conclude: Subjects have rather realistic beliefs. They are not completely unbiased but the errors in the beliefs cannot explain the observed pattern of excess entry.

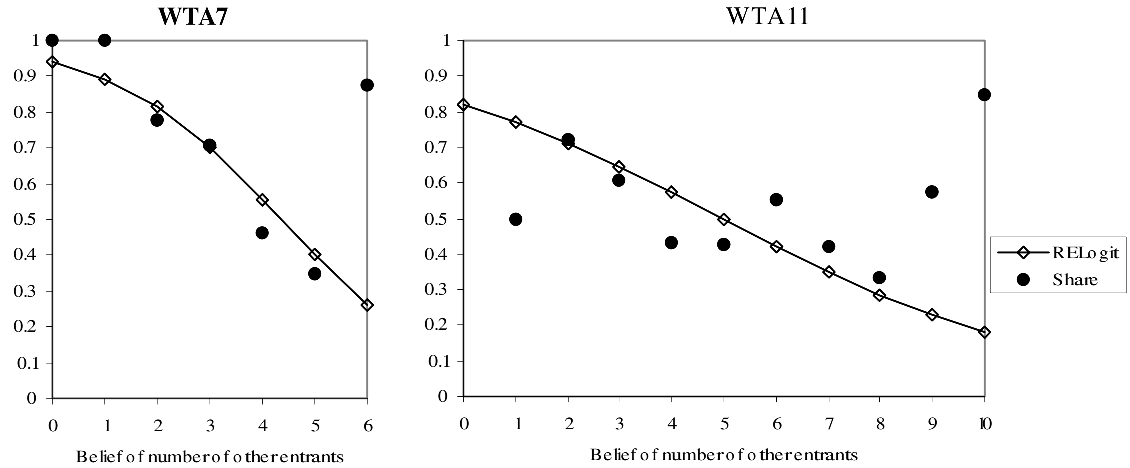
4.2. Why does excess entry increase with group size?

Given the beliefs about the other players' entry decisions, we can apply a logit 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 and therefore we apply a random effects logit estimation. The results of this estimation for both treatments are shown in the line plots in Figure 4. The data points labeled as "Share" show the empirical entry probability, which is the share of the subjects who entered the winner-take-all market among all subjects that stated 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 although the subjects do not behave exactly according to this pattern, the empirical entry

[7] 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.

probability decreases with higher beliefs – at least for the beliefs between 2 and 5 where more than 80 percent of the observations are found.

Figure 4: The graph "RELogit" shows the entry probabilities by a random effects logit estimation dependent on the belief of the number of other entrants. "Share" shows the actual share of subjects that entered among all subjects that stated the corresponding belief.



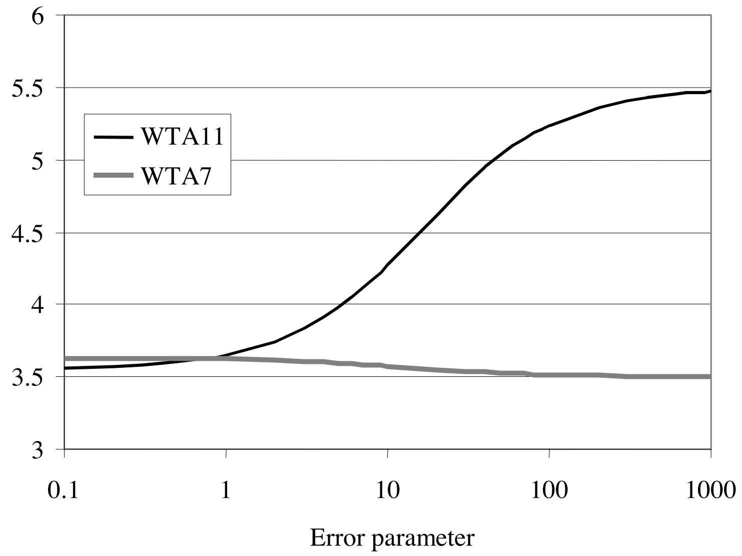
Yet more remarkable than this decline are the big deviations from the PNE pattern. Do we have to consider these decisions as errors, i.e., do we have to conclude that subjects did not maximize their payoff or that they did not state their true belief? We cannot conclude that all decisions that deviate 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 2 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 enters 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 3 are not rational, either.

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 to choose 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 experimental data (see e.g. Goeree, Holt and Palfrey, 2000; or Capra et al., 1999). We very briefly present this model. Let π_i^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

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

The parameter μ is the error parameter. It specifies 'how strongly' errors are made. If the error parameter is very small, the values of the exponentials $\exp(\pi_i^e / \mu)$ are very different 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 therefore we get an (almost) uniform probability distribution. In the following we denote by QRE the logit equilibrium as specified above. Figure 5 shows the predicted number of entries of the symmetric quantal response equilibrium in our two games. For low error parameters the prediction converges to the symmetric Nash equilibrium. However, if the error parameter is not too low, i.e. if it is above 1, the QRE predicts more entries in larger groups.

Figure 5: Expected number of entries in the symmetric QRE.



The differences between the WTA7 and the WTA11 treatment are in line with the QRE prediction. However, QRE fails to predict the excess entry in the WTA7 treatment. As the figure shows, errors shift the expected number of entries into the direction of 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. [8]

The quantal response equilibrium does not only make equilibrium predictions. Given a belief about the other players, it also predicts the best reply. 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. We can now verify whether or not at least 50% of the subjects entered if and only if the expected payoff from entry was higher than the expected payoff from staying out. As we have seen in Figure 4, the entry frequency is always at least 50% for beliefs below 3 and it is below 50% for beliefs above 3 except for beliefs of 6, 9, and 10 (where there are very few observations). This result is in line with quantal response equilibrium.

4.3. Risk preference and market entry

We saw that errors alone cannot explain the excess entry in the WTA7 treatment. Could risk attitudes have caused the excess entry as observed in the experiment? First note that excess entry can only be explained if a significant part of the players are risk seeking. To get about 4 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 subjects will react and prevent the excess entry by staying out. In order to test whether risk preferences can explain our result we administered a post-experimental questionnaire. The subjects had to specify a certainty equivalent for two lotteries, i.e. they had to answer the following hypothetical question: "You can buy a lottery ticket. In this lottery every seventh [third] ticket is a win. The prize will then be Fr 50.-. What would you pay at most for such a ticket?" Table 5 shows the expected value of the two lotteries as well as our results.[9]

[8] The maximum likelihood estimation of the error parameter μ equals 99. Separate estimations for the two groups get a μ of zero in the WTA7 treatment and 146 for the WTA11 treatment. This also shows that QRE alone cannot explain all features of the data.

[9] The table does not show all 129 observations. The missing data stem from subjects that 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% chance of winning Fr. 50.- more than Fr. 50.-. Obviously these statements are caused either by a misunderstanding of the task or by the fact that the answer on this question had no financial consequences.

Table 5: Results from the certainty equivalent questionnaire.

	1/7 lottery	1/3 lottery
Expected value	7.14	16.67
Average certainty equivalent	6.85	13.37
Standard deviation	5.34	6.48
Proportion risk seeking	30%	25%
Number of observations	127	126

On average our subjects are risk averse, but the standard deviation is rather high and we find about 25 to 30% of the subject stating they were willing to pay more for the lottery than its expected value.[10] As explained before, this share of risk seeking subjects is too small to cause the excess entry.

Furthermore, if risk seeking behavior was to cause excess entry, we should observe a close connection between risk preferences and individual entry decisions. A logit estimation is used to check whether the risk preference as measured with the certainty equivalents can explain different entry behavior of the subjects. Table 6 shows the estimated influence of the certainty equivalents and other parameters on individual entry probability. 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 the estimation without the risk attitude measures and the models 2 to 4 show the estimation with either one or both of the certainty equivalents.[11] The dummy for WTA11 (variable b) has by far the largest and most significant influence on the entry probability. This reflects the fact that the subjects did adjust their entry probabilities to the group size. Yet remember that we observe a larger number of entries in the WTA11 treatment, which means that the adjustment of the individual entry probability to the group size was smaller than it should have been according to the Nash equilibrium prediction. The belief variables c) and d) are significant only for the WTA7 treatment. This reflects the fact that the negative connection between the belief and the empirical entry probability is more distinct in the WTA7 treatment than in the WTA11 treatment (see figure 4). In neither of the models does the certainty equivalent exert a significant influence on peoples' entry probability. For the second lottery, the certainty equivalent has even the wrong sign.

[10] Compared to the literature, this is a rather high share of risk seekers. For example Goeree, Holt and Palfrey (2000) find *at most* 25% risk seeking players.

[11] The two measures of risk preferences are naturally highly correlated. The models 2 and 3 show that the lack of significance in the model 4 is not caused by multicollinearity.

Table 6: Logit regressions for the entry decision as dependent variable (1 if enter, 0 otherwise). We use a robust calculation of the standard errors with the sessions as clusters. Note: Significance levels using two tailed tests: *= significant at 5-percent level, **= significant at 1-percent level.

Variable	Model 1	Model 2	Model 3	Model 4
(constant)	2.815**(8.152)	2.793**(7.030)	2.947**(6.896)	2.943**(7.022)
a) Period	-0.042(-1.815)	-0.045(-1.877)	-0.043(-1.869)	-0.046(-1.868)
b) Dummy for WTA11	-2.519**(-6.296)	-2.666**(-5.820)	-2.593**(-5.333)	-2.650**(-5.700)
c) Belief * dummy for WTA7	-0.632**(-5.550)	-0.662**(-5.077)	-0.648**(-4.936)	-0.645**(-5.046)
d) Belief * dummy for WTA11	-0.027(-0.466)	-0.015(-0.245)	-0.023(-0.332)	-0.010(-0.138)
e) Certainty equ 7		0.021(1.795)		0.069(1.529)
f) Certainty equ 3			-0.007(-0.354)	-0.038(-1.689)
N	1290	1270	1260	1250
Prob>F	0.0000	0.0000	0.0000	0.0000
Log likelihood	-859.549	-843.954	-838.214	-826.916

[*] Period = Period in the experiment; Dummy for WTA11 = 1 for WTA11, 0 for WTA7; Belief = belief of how many other subjects enter in this period; Market size = 7 for WTA7 treatment, 11 for WTA11 treatment; Certainty equ 7 [3] = "You can buy a lottery ticket. In this lottery every seventh [third] ticket is a win. The prize will then be Fr 50.-. What would you pay at most for such a ticket?"

Table 6 shows that risk preferences as measured with certainty equivalents have little to no predictive power on individual entry decisions. A reason for the absence of this connection might lie in the way we paid our subjects. Following the idea of Roth and Malouf (1979), we paid subjects using a binary lottery. If subjects are expected utility maximizers, then – independent of their risk attitude – they should behave as if they were risk neutral. Consequently, different risk preferences – in the sense of expected utility theory – should not be responsible for any phenomenon in this experiment. However, there is evidence that the binary lottery mechanism does not always work in the desired direction. Selten, Sadrieh and Abbink (1998), for instance, showed that binary lotteries do not reduce anomalies.[12] 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.

There are many motives that result in a behavior that is similar to risk seeking. Subjects could also enter too frequently because they get – independent 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. However, as explained in the design of the experiment, we tried to make the two alternatives (entering in the winner-take-all market and staying out) as similar as possible. In both alternatives, the payoff is a random variable. The

[12] See also Anderhub et al. (2000) who did not find a difference between applying and not applying the binary lottery technique in a “saving game”.

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. So 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. A tentative explanation for the excess entry would be that subjects enjoy the thrill of competition or have a strong "illusion of control", i.e. they erroneously believe that they can influence random processes (Langer, 1975).

5. Related Results and 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. Irrational 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 cannot explain excess entry.

Our results are in contrast to other market entry games where subjects succeeded to coordinate on the Nash equilibrium (Rapoport, Seale, Erev and Sundali, 1998; Sundali, Rapoport and Seale, 1995). 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 extend 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 (1975) 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.

There is one study in which massive excess entry is found. Camerer and Lovallo (1999) implemented a market entry game in which subjects who entered the market were ranked. According to this ranking they got a prize. There were two treatments. In one treatment a random device determined the ranking. In the other treatment, the ranking was determined by the performance in a trivia quiz. Whereas in the "random treatment" the number of entries was in line with the Nash prediction, there was massive excess entry with respect to the individual optimum 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 decreased 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.

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Appendix 1: Classification of the Nash equilibria of the winner-take-all game

In this appendix, we characterize all Nash equilibria for our game, still assuming risk neutral players. As we will show, there are many equilibria. However, the players who randomize all use the same probability. This means that the following lemma applies:

Lemma: Let p_i the probability with which subject i enters. If there are two indexes i and j with $0<p_i<1$ and $0<p_j<1$, then $p_i=p_j$.

Proof of the lemma: Since player i and player j randomize, they are indifferent between entering and staying out. Staying out results in an expected payoff of σ for both players. Therefore, entering must have the same value for both of them. Let us consider the probability distribution of the number of other players who enter the market: Let us define $\varepsilon^{(i)}(e)$ as the probability that the number of entrants different from i is e. Then the expected payoff for entering for player i equals $\sum_{e=0}^{n-1} \varepsilon^{(i)}(e) \frac{\pi(e+1)}{e+1}$.

Let us now assume that $p_i \neq p_j$. Without loss of generality, we can assume that $p_i<p_j$.

Therefore, player i expects more other players to enter than player j, i.e., the distribution $\varepsilon^{(i)}(e)$ is more to the right than the distribution $\varepsilon^{(j)}(e)$. Because $\frac{\pi(e+1)}{e+1}$ is monotonously decreasing, this implies that the expected payoff for player i will be lower than the expected payoff for player j. This is in contradiction to the fact that entering must have the same value for both of them. QED

With the help of the lemma, we can easily classify the Nash equilibria by the number n_1 of players who enter with probability 1, by the number n_0 of players who enter with probability 0, and by the number n_p of players who randomize. For given n_1 and n_p, a Nash equilibrium for the WTA7 market is also a Nash equilibrium for the WTA11 market. The following table A1 shows the expected number of entries for all possible Nash equilibria.

Table A1: Expected number of entries for all possible Nash equilibria. The values in the smaller area on the left-hand side hold for the WTA7 treatment; all values hold for the WTA11 treatment;

		Number of players who randomize											
		0	1	2	3	4	5	6	7	8	9	10	11
Number of players who enter with probability 1	0					3.80	3.72	3.67	3.63	3.61	3.58	3.56	3.55
	1				3.77	3.60	3.50	3.43	3.39	3.35	3.33	3.31	
	2			3.68	3.35	3.22	3.16	3.12	3.09	3.06	3.05		
	3	3											

Appendix 2: Translation of the instructions

Instructions

The following economic experiment is financed by the Swiss National Science Foundation. If you read the instructions carefully, you can, depending on your decisions, earn a considerable amount of money.

The instructions we have distributed to you are solely for your private information. During the whole experiment communication between the subjects is strictly forbidden. If you violate this rule we shall have to exclude you from the experiment and from all payments.

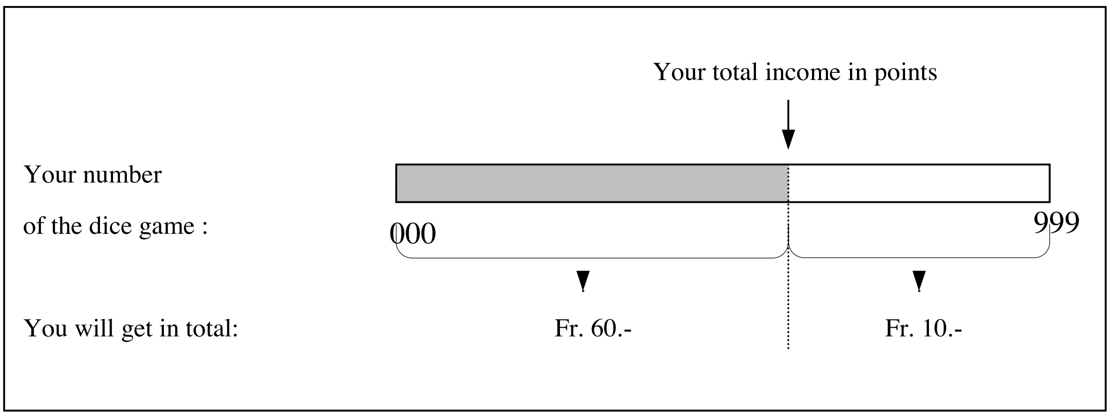
The experiment is divided into 10 rounds and a total of 22 subjects will participate. In each of the 10 rounds these 22 subjects will be divided into 2 groups of 11 subjects. The assignment of the subjects to the 2 groups will be chosen randomly in each round. **The composition of the two groups is therefore different in each round.**

At the beginning of a new round, every subject has to decide between two alternatives A and B. Depending on which alternative you choose, and which ones the other 10 members of your group choose, you can earn a different number of points. In addition, the number of points you earn depends on chance. The 10 rounds are all identical and independent of each other. This means that the points you earn in one round depend only on the decisions in that particular round.

After the 10th round, all the points you earned during the experiment will be added up to your **total income in points**. This total income in points will determine your income in money. The more points you earned during the experiment, the bigger is your chance of winning 50 Francs by a game of dice.

The total amount of money you earn in this experiment will be determined by the following rules:

- You get 10 Francs for sure.
- **In addition to these 10 Francs you may win 50 Francs in a game of dice.** The probability of winning these 50 Francs depends on your **total income in points** at the end of the 10 rounds. In this game of dice, you will throw with 3 ten-sided dice to get a three digit number. There will be a specific die for the first, second and third digit. Possible and equally probable are therefore all numbers between 000 and 999. Your number will be compared to your total income in points. If your number of the dice is lower than or equal to your total income in points, you will get the 50 Francs. If your number is higher than your total income in points, you will get nothing. **The higher your total income in points, the higher is the chance of winning the additional 50 Francs.** The following figure summarizes the process.



What determines your income in one round?

In each round you have to choose one of two alternatives A or B. If you choose alternative A, you will participate in a competition with the other members of your group who choose also alternative A. If you choose the alternative B, you will not participate in the competition.

Possible incomes with alternative A

All members of a group of 11 subjects who choose alternative A participate in a competition. In this competition they have the chance of winning between 100 and 215 points.

Whether you win the competition or not, depends on chance. All participants of the competition get a randomly generated number between 0 and 100. Thereby all numbers between 0 and 100 are equally probable. The winner of the competition is the subject who gets the highest number. If you are the only person in your group, who chooses alternative A, you are the winner.

How many points you can win in the competition, depends first of all on your randomly chosen number. If you are not the winner of the competition, you will get no points in this round. If you are the winner, the number of points you win depends on the number of *other* members of your group, who also have chosen alternative A, i.e., it depends on the number of your competitors. Because your group contains 11 subjects, the number of your competitors lies between 0 and 10. The table below shows the number of points for the winner in relation to the number of competitors. For example, if you win the competition against 4 other competitors, you earn 190 points in this round.

Number of competitors	0	1	2	3	4	5	6	7	8	9	10
Income of the winner in points	100	130	155	175	190	200	205	209	212	214	215

Possible incomes with alternative B

If you choose alternative B, you are not participating in the competition. Instead, you have a 50% chance of earning 40 points and a 50% chance of earning 50 points. Which one of the two numbers of points you get, will also be determined by a randomly chosen number between 0 and 100, where all numbers within this interval are equally probable.

If your number is below 50, you will get 40 points. If your number is 50 or higher, you will get 50 points.

Detailed course of a round

At the beginning of each round, you will see the input screen (Figure 1). In the heading on the left you see the number of the round you are currently in. On the right you see how much time is left for your decision.

In this screen you have to indicate whether you choose alternative "competition" (alternative A) or "no competition" (alternative B).

In addition to that, you are asked about your expectation on the behaviour of the other members of your group. You have to enter the number of *other* subjects in your group, who will choose the alternative "competition". Please note that you enter the number of other subjects – without counting yourself. Because there are 10 other subjects in your group possible values are from 0 to 10. In case your expectation on the behavior of the other members of your group turns out to be correct, you will get a **bonus of 5 points** in this round. This bonus is independent of whether you choose alternative A or B. The answer to this question has no further consequences for the round.

When you finished your inputs, please press the OK button to confirm your decisions.

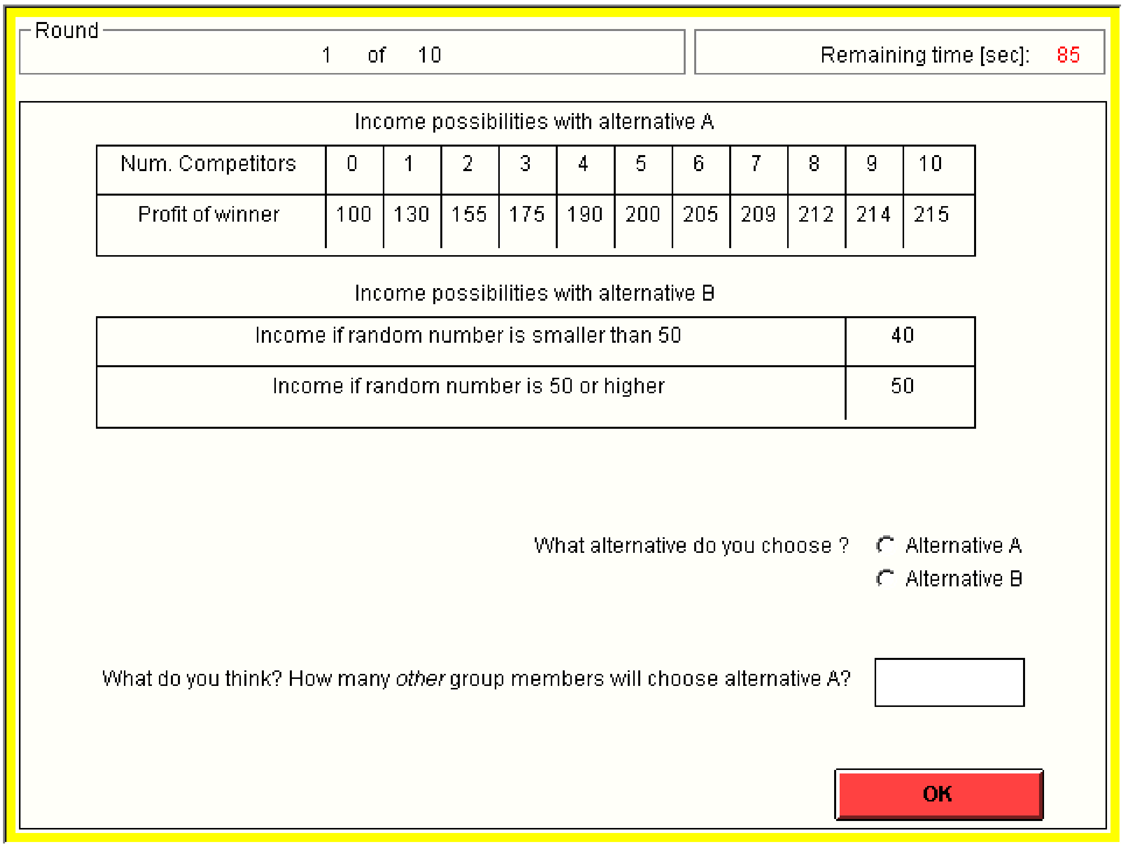


Figure 1: Input screen.

When all inputs are made, the computer generates a random number between 0 and 100 for each of the subjects.

For the subjects who chose alternative A, this number decides whether they win the competition and earn between 100 and 215 points. For the subjects that chose alternative B, this number decides whether they earn 40 or 50 points.

Your personal random number will be shown in the result screen. In addition, you will get the information about how many members of your group had chosen the alternative A. Below that, you see the details about your earnings in this round. This contains the possible “price” of the competition (if you chose alternative A) respectively the 40 or 50 points (if you chose alternative B) and the 5 points of the bonus, if your guess of the number of other subjects who chose alternative A was correct.

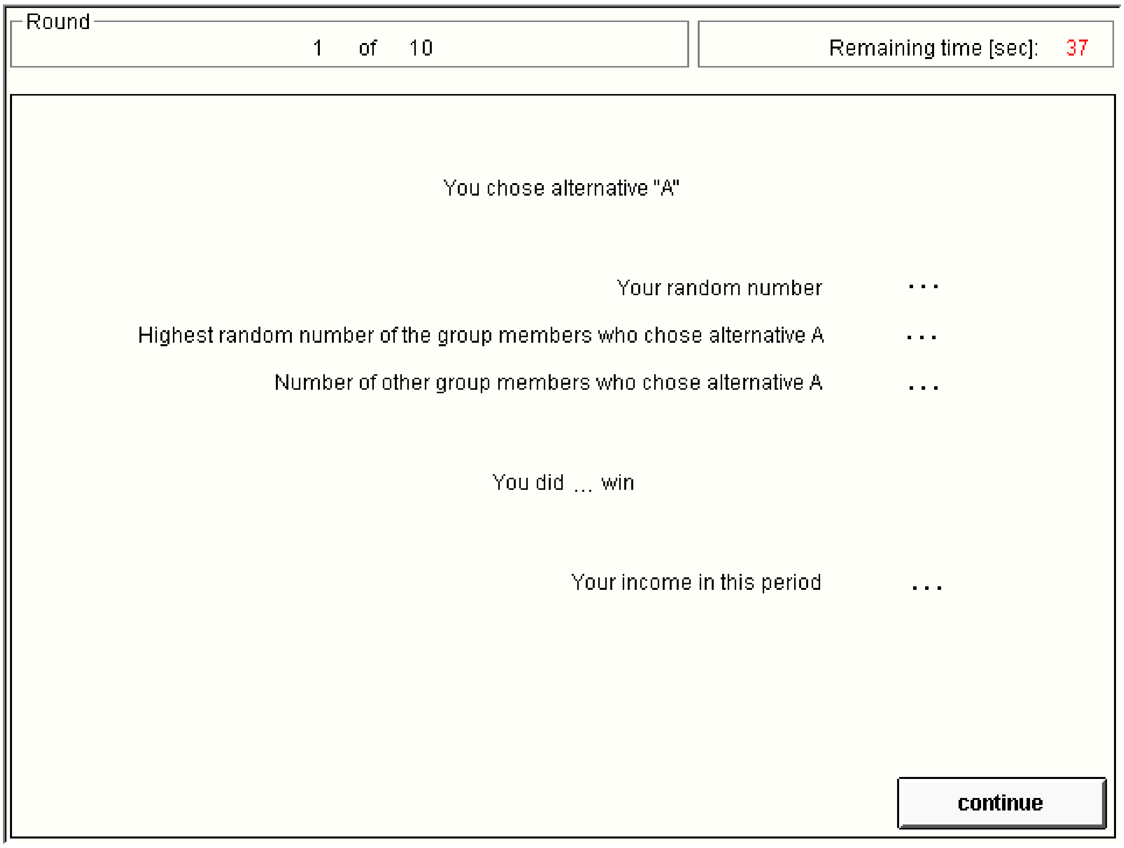


Figure 2: Output screen for alternative A choosers.

Review Exercises

The following review exercises are designed to check your understanding of the possibilities and the pay-off mechanisms of this experiment. The answers on these questions have no influence on the experiment.

1) In the following table you see one possible course of a round. Give for each subject the corresponding income in points in this round (without bonus points).

Subject	Chosen alternative	Random number	Income in points (without bonus)
1	A	76.21	
2	A	62.22	
3	A	83.12	
4	A	33.87	
5	A	80.88	
6	A	54.26	
7	A	35.43	
8	B	50.63	
9	B	71.6	
10	B	0.13	
11	B	22.45	

2) In the following table you see another possible course of a round. Give for each subject the corresponding income in points in this round (without bonus points).

Subject	Chosen alternative	Random number	Income in points (without bonus)
1	A	17.91	
2	B	94.62	
3	A	91.03	
4	B	89.5	
5	A	92.64	
6	B	47.16	
7	A	49.32	
8	B	27.67	
9	A	4.5	
10	B	30.14	
11	A	49.18	

3) The table below shows which alternative each of the subjects had chosen and what number of A-choosers they guessed. You have to indicate for each subject whether he or she earns the 5 points of the bonus or not.

Subject	Chosen alternative	Guess of other A-choosers	Bonus	
			Yes	No
1	A	1	o	o
2	A	2	o	o
3	A	3	o	o
4	A	4	o	o
5	A	5	o	o
6	A	6	o	o
7	B	2	o	o
8	B	3	o	o
9	B	4	o	o
10	B	5	o	o
11	B	6	o	o