Revealing the depth of reasoning in *p*-beauty contest games[§]

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ABSTRACT

The aim of this study is to evaluate the impact of the information about levels of reasoning on the individual's choices. I report the results from an experiment on *p*-beauty contest games. The experiment consisted in 9 Sessions, with different information treatments between Sessions 1a, 1b and Sessions 2-8. In Sessions 1a and 1b (the baseline designs), the only pieces of information provided in each period were the target number and the average value (T, M_{t-1}).

In Sessions 2-8, in each of the six stages of the game, the winner(s) explained what reasoning he/she applied in choosing the target number. He/she wrote a short message (30 words maximum) and then stopped playing. The winner's message, the winning number, the target and the average value were then displayed on all computer screens. The evidence from the experiment shows that non-winning players *imitate* the level of rationality of the winners, and there is a relevant proportion of the population who adopt strategies which are *best responses* to the imitators' behaviour rather than to the average level of rationality. Both the imitative strategies and the best responses to the imitative strategies produce a strong acceleration of the learning process.

Keywords: Guessing games, experiments, imitation.

J.E.L. classification: C72, C91, C92.

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Revealing the depth of reasoning in *p*-beauty contest games

Introduction

"Beauty-contests"[1] are popular examples of why people may fail to reach the Nash equilibrium in dominance solvable games. The structure of the game is well-known: players are asked to pick up a number, m_i, in a closed interval $[0,100]$. For a given number of players, *k*, the winner of the contest (who gains a fixed amount of money) is the subject whose guess is closer to the number $T = pM_t$ (the "target"), whereas *M* is the value of the average at time *t*, $0 < p < 1$ is the (known) value of the parameter. For values of p smaller than unity, the game has a unique sub-game perfect equilibrium, with all players choosing 0[2].

However, such a solution requires that all players are perfectly rational, rationality is common knowledge, and everybody expects everybody else to behave accordingly. If people master just few levels of reasoning , as stated in the original J. M. Keynes' example, then the Nash equilibrium will rarely be observed, therefore, playing the optimal strategy may not be a smart response.

For its simplicity and its rich implications, the *p*-beauty contest game is also a popular tool of analysis for economic experiments aiming to test the depth of reasoning. In the seminal paper by R. Nagel, 1995, the game was first experimented and a model of choice under bounded rationality was proposed. The *Iterated Best Reply* (*k*-step learning) model (T. Ho, C. Camerer, K. Weigtel, 1998) states that human learning uses only finite levels of reasoning, and players elaborates best responses to observed choices, as in a Cournot adaptive process, rather than working all the way back to the equilibrium state. A substantial amount of experimental evidence has provided strong support for this behavioural model.

Guessing games have in fact been tested with different subjects pools' characteristics. The most important result is that, while the Nash rational choice is rarely observed in the first period, in classroom experiments the learning behaviour which seems to be common among players does not go further than the first or second level of reasoning. Specifically, it is generally observed that, while the average guess steadily decreases over time, learning does not increase. Relevant exceptions are represented by experiments in which subjects were experienced or skilled in game theory. More relevant, however, higher levels of reasoning have been found in large scale experiments run through newspaper competitions (A. Bosch-Domenech *et al.* 2003)[3].

Different information settings have been designed. In some scenarios, players are provided with the individual choices of their partners as well as the average choice and the target (R. Nagel, 1995); whereas in some other cases, only the target and the average choice is provided. More related to the purpose of this work are some recent papers that focus on the study of the effects of strategic uncertainty on convergence and learning. In a 2-person beauty contest game (B. Grosskopf, R. Nagel, 2001), subjects received feedback on the choice of their co-players. In this full-information framework, learning is faster than in the alternative scenarios where subjects receive no information on the rationality of their opponents. The type of decision making process (individual vs. group decision making) also seems to make a difference on learning in guessing games. M. G. Kocher, M. Sutter, 2005, demonstrated that groups perform better than individuals, In fact, they learn faster how to play as well as they outperform individuals in direct competition. These results suggest that when there is communication on the level of reasoning required to solve the game, people learn faster to play dominant strategies.

In this paper, I take a different perspective. I report the results from an experiment on *p*-beauty contest games with inexperienced subject pools and two different information treatments. In Sessions 1a and 1b (the baseline designs), the only pieces of information provided in each period were the target number and the average value (T, M_{t-1}). In Sessions 2-8, in each of the six stages of the game, the winner(s) explained what reasoning he/she applied in choosing the target number. He/she wrote a short message (30 words maximum) and then stopped playing. The winner's message, the winning number, the target and the average value were then displayed on all computer screens. In these Sessions, therefore, the information provided regarded not only the aggregate measure of rationality (M_{t-1}), but also the individual level of rationality of a representative agent, whose strategy was successful in the previous stage (W_{t-1}).

The aim of this study is to evaluate the importance of the information about levels of reasoning (W_{t-1}) on the individual's choice. In this respect, this experiment offers a contribution to the previous research on social learning in games (B. Çelen, S. Kariv, A. Schotter, 2002, 2005; Y. Nyarko, A. Schotter, B. Sopher, 2005; C. Altavilla, L. Luini, P. Sbriglia, 2006). As correctly noticed in B. Çelen *et al.*, 2002, 2005, a contradictory element of the literature on social learning is that it does not explore very social phenomena. In fact, what it is intended by the definition of social learning is the process by which individuals learn by observing the actions of other players. Specifically, in the field of research of B. Çelen *et al.*, 2002, 2005, as well as in the present paper, the focus is on the way the individual behaviour may be affected not only by the observation of other players' actions (here, the winning number), but also by the information on the strategic behaviour adopted by other players (here, the information on the winner's level of reasoning). In real world, social learning is a very important aspect of every day decision making, and people try to obtain as many advice, suggestions and hints as they can every time there are decisions to be made. In fact, in making investment plans, or in buying financial assets, our choice is likely to be influenced by other individuals, especially if their choices have proved to be successful in the past. In this paper, as well as in B. Çelen *et al.*, 2002, 2005, it seems that we take social learning very seriously , and – more than the specific action – our behaviour is bound to be influenced by the other players' advice on the best strategic choice. In the context of the experiment that is reported here, social learning is proved to speed up individual learning by a considerable extent, so that the convergence to the equilibrium is much faster in Sessions 2-8, than in the alternative contexts (Sessions 1a, 1b).

Experimental designs and financial incentives.

The experiment was conducted in Siena (June 2004, January 2006) and consisted of 8 Sessions and one pilot study (reported here as Session 2). Each game lasted 6 periods (4 periods in Session 2) and there were 17-20 students in each group (10 in Session 2).

I tried to select students who had no experience of experiments on games, as it could be hypothesized that the impact of information would be greater for players who had no previous knowledge of game theory and experiments. However, in Session 1b (the second baseline design) students were all theoretically trained, meaning that some of them (almost half of the sample) had previous game theory' training (there were four graduate students in Economics, while the other subjects were math and physics students), though none had participated in economic experiments before. The aim in choosing the subjects' pools for the baseline designs (Sessions 1a and 1b) was to compare the effect of information with respect to two groups of uninformed and inexperienced players, who in one case were nevertheless skilled in problem solving. No participants, however, had any previous knowledge of *p*-beauty contest games.

Overall, 163 subjects participated in the experiment, 125 subjects in the information designed Sessions and 38 in the two remaining baseline designs.

Table 1 summarises all main aspects of the experiment.

INSERT TABLE 1 ABOUT HERE

The prize for each contest was €6 (€8 in the pilot study), which would be equally shared in the case of more than one winner and all students collected a participation fee of €3. Detailed instructions (see Appendix) were handed to all at the beginning of the Session, and time was provided for thinking and asking questions. In all 9 Sessions *p* was equal to 2/3, the value of the parameter being common knowledge, and participants were allowed to enter decimal numbers.

In every Session participants knew the average and the target in every period, but, in Sessions 2-8, participants were also informed on the winning number and had access to the "winner's message". From period 2-6 (2-4 in the pilot study), a message would appear on the winners' screen:

> "You won! We ask you now to describe, in few words (30 words maximum), the reasoning you followed in choosing your number. We ask you to be sincere and accurate, because with this message you may be able to gain an extra prize of €3. We will follow three criteria in deciding whether to award you the extra prize: 1) your answer is reasonably coherent with your choice; 2) your message is useful, e.g., in the next competition the distance between the participants' choices and the target is lower than in the previous competition; 3) the other participants will consider your message useful when answering the final questionnaire."

The winner would stop playing and collect the extra prize only at the end of the Session[4]. The aim of the extra prize was to encourage subjects to reveal their reasoning as accurately and truthfully as they could. The incentive to be truthful was increased by the fact that they would stop playing in any case.

Two different types of final questionnaires were given to subjects at the end of the Session; both asking to explain the reasoning applied for each choice , but with a further task (for Sessions 2-8): judging and ranking the winners' messages[5].

The expected effect of the extra information of the winning number and the winners' message (denoted as W, hereafter) is not unequivocal. The information may be either misunderstood, useless or wrong and in these cases one would expect that the messages do not influence the learning process (or they may even slow it down). Contrastingly, messages may forward a rationality model for the remaining subjects, who are also aware that this model is common knowledge among all players. The impact on the learning process in this case can be opposite to the alternative scenario: people may imitate and consequently the learning process may be affected in turn. The conjectures on the effects of information are then represented by the following (not necessarily) alternative claims.

CLAIM 1: ***information on W has a negative impact on learning***

Winners' messages and numbers always have a negative impact on learning: the experimental evidence show that individual choices are negatively affected by all types of messages (good or bad).

CLAIM 2: ***information on W has a positive impact on learning***

Winners' messages and numbers have a positive impact on learning even when the information is confusing. "Good" and "bad" information always increase the speed of learning compared to the uninformed setups.

Result Section: Convergence and Learning.

Tables 2 and 3 report the average and median values, while Table 4 – where S2-S8 are aggregated in one Session - reports the frequency of the strategies (numbers) chosen by all subjects, in each period and for each Session.

INSERT TABLE 2 AND 3 ABOUT HERE

Comparing individual choices in the first and subsequent periods, it is easy to see that there are significant differences across Sessions. First period choices are, with few exceptions, in the range 20-50 in all cases, and this result is in line with the other studies (C. F. Camerer, 2003). From the second period on, however, there are fewer similarities among the different treatments. In seven of the eight Sessions where information on W was disclosed, choices approach the equilibrium value of zero at a faster rate. In Table 4, evaluating individual choices, one can see that more than half of the population of the information treatments chose numbers in the interval 0-3 from the third period on.

INSERT TABLE 4 ABOUT HERE

In the final stage, players chose numbers smaller than 1.5 (precisely, 45% in S3 and 39% in S5) and 2.5 (46% in S4 and 60% in S8), in four out the seven Sessions. In Session 6, 29% of the population played numbers lower than (or equal to) 1, while, in S7 – the Session in which convergence to the equilibrium value of zero is faster – 60% of the population played numbers lower than (or equal to) 0.5 in the sixth stage. Conversely, in both baseline designs (1a and 1b), in the final period, the proportion of subjects choosing numbers smaller than 2.5 was 5% in Session 1a, and 6% in Session 1b.

One common feature between both Sessions 1a-1b and Sessions 2-8 is the presence of spoiler choices (e.g., players choosing $m_i = 100$) (C. F. Camerer *et al.*, 1998) in several rounds[6].

Excluding spoiler choices, the values reported in Tables 2-3, show a different picture (see values in brackets and medians). In Sessions 2-8, the effect of spoiler choices is greater than in 1a-1b, affecting the behaviour in the subsequent stages of the game. In Session 3, for example, 35% of the subjects were playing m_i<0.5, in the fourth period[7]. The proportion drops to zero in the following period, and increases to 10% in the final round. In the second baseline design (1b), the same proportion is fixed over time (0.05%), and is not dependent on spoiler choices.

The differences between Sessions 1a -1b and Sessions 2 - 8 are confirmed by the Mann-Whitney U-tests run on the initial and final periods of the game. The tests compared the initial and final distributions in 1a with the initial and final distributions in S2-S8[8]. A similar procedure was adopted for 1b in relation to S2-S8. The results are fairly consistent across comparisons. In fact, comparing the initial distributions in the two alternative settings, the null hypothesis is accepted in both cases (p=0.20 and p=0.32 in the comparisons between 1a/S2-S8 and 1b/S2-S8, respectively). On the contrary comparing the final distributions, the null hypothesis is rejected in both cases (with p<0.00001).

Finally, a further characteristic of the convergence process is underlined by the values of the standard deviation. Whilst in all Sessions the standard deviation decreases over time, in the informed setups it approaches zero from the fourth period on. In the final period, in fact, the values of the standard deviation in 1a and 1b were around 2 (2.0 in Session 1a and 2.6 in Session 1b, respectively) while they converge to values smaller than 1.0 in Sessions S3-S8[9]. A result on convergence can therefore be stated:

RESULT 1: Information on W positively affects the process of convergence to the equilibrium in the p-beauty contests games. In Session 2-8 the average choice decreases at a faster rate than Session 1a and 1b, as well as the variance of the choices.

An important question relates to the effects of W on aggregate and individual learning. In the following part of the paper, the decision process is analyzed, examining aggregate the individual choices.

First, as shown in Table 5 and 6, I classify the learning process in subsequent levels of reasoning (R. Nagel, 1995; R. Duffy and R. Nagel, 1997; C. Camerer *et al.*, 1998, M. G. Kocher, M. Sutter, 2005). In this way, the choice of individual *i*, at time *t*, is classified in level *n*, if it corresponds to: $m_i = p^n M^*$;

where: $M^* = M_{t-1}$. Individual choices can therefore be grouped in intervals of learning: $L_n = \left[p^{n+\frac{1}{2}} M^*, p^{n-\frac{1}{2}} M^* \right]$ [10].

INSERT TABLE 5 AND 6 ABOUT HERE

As before, from period 2 to period 6, some basic differences across Sessions can be underlined. In Sessions 1a and 1b, the aggregate choices show that the decision process settles down to the first and second level of reasoning. In 1a, the majority of players adopted strategies within the L_1 interval, throughout the Session, though a consistent proportion of the population adopted strategies within L_2 in periods 5 and 6. In 1b, there is a high proportion of choices within the L_2 interval in periods 3 and 4, then the learning settles at the first level of reasoning. Between the two Sessions there are however some differences. In Session 1a the process of convergence appears to be faster, and to involve the large majority of the players. In the case of the theoretically trained subjects (1b), there is a significant - and constant through time - deviation from the first and second level of reasoning and such deviation is almost equally distributed between higher and lower levels. In both cases, however, it is not possible to reject the well-known result emerging from previous experiments (C. F. Camerer, 2003) which suggest that, in the case of inexperienced players, while the average guess decreases over time, learning does not increase and usually varies between the first and the second levels of reasoning.

Different results may be observed in Sessions 2-8. Here, an increase in aggregate learning is registered in the final stages of the game. In fact, when the dynamics of the lower classes of learning (L_0 and L_1) are compared with the highest class of learning (L>3) , one can see that in all the informed Sessions, the size of the lower learning classes tend to shrink whilst on the contrary – with the exception of S3 and S8 - the size of L>3 tends to increase. Two interesting aspects can be noted; first, considering periods 5-6 in Sessions S2-S8, whilst aggregate learning, on average, settles to the second and third level (that is, at a level only slightly higher than the non- information treatment, but still in line with previous research works), the proportion of players adopting more sophisticated strategies of the highest level of rationality (L>3) increased in four of the seven Sessions (S2, S4, S7, S5). Second, in these four Sessions the same proportion exceed the 20% of the total.

When the speed of learning exceed the third or fourth level the unravelling to infinite steps of reasoning is possible (A. Bosch-Domenech, *et al.* , 2002). Therefore, it is legitimate to argue that the high learning speed can be credited as the main reason of the fast convergence process in S2, S4, S7, S8.

As for the remaining Sessions S3, S8 (and partially S6), one cannot say that the learning dynamic is similar to the one observed in Sessions 1a and 1b. In fact, if one compares the L_3 class (and L>3) in the two contexts, one can conclude that the speed of the learning process is higher in S3, S6 and S8 than it is in 1a and 1b.

What connection can be inferred between the level of rationality expressed in the winners' messages and the evolution of rationality in S2-S8?

As a first step, a similar method of classification is adopted of the levels of rationality expressed in the messages as for Tables 5 and 6. Here, however, such levels are classified using the further specifications contained in the instructions, e.g., in Table 7, a *c* will indicate that the rationality level was expressed by the chosen strategy, but the message was confused. Moreover, for classifications' purposes, indications given by the winning players have been used.

Some examples of the messages that are classified in L_2 are reported below:

"Between 0 and 100 the average is 50; 2/3 of the average is 33.33. If everybody declared 33.33, the new target would 22.22. I tried to play 22.22, but I did not succeed, so I played 22". [11]

"I thought that the number of participants was irrelevant. I thought the average number would be 50, therefore: 50(2/3)=33.33. I thought everybody would have made the same calculation, so I played 22" (S2, Period 1; Winners 1 and 2)

Moreover, the following message is also classified as L_2 , but a *c* is added[12]:

"Since everybody knows the mechanism by now, I calculated that all participants would play a number lower than the previous target" (S3, Period 3).

From the inspection of Table 7, it can be inferred that the level of rationality of the winner strongly affects the population's level of rationality in the subsequent period. In fact, in all 7 Sessions, the proportion of subjects adopting strategies of equal or higher levels of rationality of the winner's strategy in period *t-1* varies between 33.4% (S2, period 4) and 100%. Moreover, this proportion tends to increase over time, even in the presence of confused messages.

To summarize, the information on the winners' strategies does affect the individuals' decisions and its effects do not disappear even in the presence of confused messages; on the contrary, there seems to be a cumulative impact of the winners' information on the individual choices.

INSERT TABLE 7

A further point regards the correct evaluation of the specific effect of the information on the winning number and of the information on the winner's message. Disclosing the winning number in Sessions 2-8 by itself should have little influence on learning (compared to 1a-1b), since the experimental settings are alike[13]. It may happen, however, that (clear) messages and/or winning numbers are in different classes compared to the target. In fact, in this case, they represent different pieces of information, and it is legitimate to ask which of the two has a larger effect on behaviour. Out of 38 (clear and confused) messages indicating the depth of reasoning applied by the winner, and the corresponding winning numbers, there were no cases of conflicting informational signals. One can therefore conclude that – compared to Sessions 1a and 1b – both the winner's message and the winning number speed up learning. However, since learning increases even in the case of confused (and very confused) messages[14], and the messages themselves are – on average - within the second and third learning classes, how can one assess the correct relevance of this specific signal on subjects' behaviour? In my opinion, it could be stated that messages have three different but complementary effects on behaviour.

First of all, messages such as: "the number of participants is irrelevant" (S2, periods 1 and 3)[15], "this is a game of chance" (S4, period 3), "I calculated that all participants would play a number lower than the previous target" (S3, period 3) decrease the level of structural uncertainty by explaining some of the game structural characteristics.

Secondly, messages such as: "someone must be playing 100" (S4, period 3) - e.g., there are spoilers; "I thought the majority of the participants would have based their choices on the previous reasoning, considering the same average and then calculating the two third of it. Of this number I calculated the two third" (S6, period 2) – e.g., there are imitators - decrease the level of strategic uncertainty, by explaining some characteristics of the players' behaviour.

Finally, messages like: "In the first period, I did not consider that others would have solved the problem so fast, so I played 33.33. The following messages induced participants to choose numbers close to the winning number. Therefore I started to play 6, that is 2/3(9), that is 2/3(14), that is 2/3(22). But I only won in the fourth period" (S2, period 4); "Following the 3 previous messages I calculated the 2/3 of the previous value….the numbers tend to be closer…." (S6, period 4) – e.g., following the indication of the winners is useful because it provides a good proxy of the way people are behaving - provide a general model of rationality by expressing a conjecture on the players' rational behaviour.

In short, the influence of W on behaviour does not depend only on the winner's conjecture on the average level of rationality but also on his/her understanding of the structure of the game, and this related effect on learning persists also in the case of confused messages. The effects of the winner's messages on aggregate learning can be therefore summarised in the following result.

RESULT 2: The information on W always affect the players' learning process. The level of rationality in S2-S8 is higher than in Sessions 1a-1b, and the level of rationality of the winner in period *t* influence the population's rationality in the remaining periods.

A further questions is how the information on W affect the individuals' decision process. In 1a and 1b, the only piece of information given to players was the average value, M (and the target, T), that is, players received only statistical information on the aggregate level of rationality in the experiment. In Sessions 2-8, players were informed both on the aggregate level of rationality (M) and on the individual level of rationality of a representative agent (W), whose strategy was successful in the previous stage. In my opinion, the answer to which of the two rationality signals had a greater influence on the decision process of non-winners in Sessions 2-8 is reported here:

RESULT 3: W sets the pace of the learning process in the experiments. Players *imitate* the level of rationality of the winners, and there is a relevant proportion of the population who adopt strategies which are best responses to the imitators' behaviour rather than to the average level of rationality. Both the imitative strategies and the best responses to the imitative strategies produce a strong acceleration of the learning process.

In order to disentangle the relative importance of M and W on the behaviour of non-winners, I analysed – for Sessions 3-8 – a model of the form[16]:

$$\ln\left(\frac{x_{it}}{x_{it-1}}\right) = \alpha_i + \beta \ln\left(\frac{x_{it-1}}{x_{it-2}}\right) + \gamma \ln\left(\frac{M_{t-1}}{x_{it-1}}\right) + \delta \ln\left(\frac{W_{t-1}}{x_{it-1}}\right) + \varepsilon \; ; \quad \mathbf{(1)}$$

Where: x_{it} represents the strategy played by individual *i* at time *t*. Table 8 presents the values of the estimated coefficients – γ and δ – with standard errors in brackets.

INSERT TABLE 8 ABOUT HERE

In four of the six Sessions under consideration (S3, S4, S6, S8), the value of the estimated coefficient δ is statistically significant whereas the γ coefficient is not, suggesting that non-winners' change in behaviour is more respondent to the information on W than to the information on M. In Session 5 and 7, δ is not statistically significant (in Session 7 it is actually negative). However, considering single-variable regressions – where the effects of M and W are separately tested[17] - a slightly different picture can be gained. Even though there is not a large difference between the two coefficients, W has a greater effect than M on non-winners choices in both Sessions. Specifically, in S5, the value of γ and δ are equal to 1.86 (standard errors: 0.31) and 1.95 (standard errors: 0.32) respectively; in S7, the value of γ and δ are equal to 1.90 (0.29) and 1.92 (0.28).

As a final point, an emphasis should be put on the responses to the imitative strategies. Table 9 presents the dynamics of the choices of non-winning subjects as a response to the level of rationality of the winner of the previous period. For a given $n_W(t-1)$, I classify – in period t – the level of rationality of non-winners as: $n_{NW}(t) = n_W(t-1) + 1$ and $n_{NW}(t) = n_W(t-1) + 2$. The table reports the proportion of each level of non-winners' rationality over the total.

INSERT TABLE 9 ABOUT HERE

The Table shows that the responses to $n_W(t-1)$ never fall below the 6% threshold, and this proportion tends to increase in the final periods of the game. Secondly, there is a difference across Sessions, in as much as in some of them (S4, S7, S6, S3), the proportion of non-winners adopting strategies of higher rationality than the winners of the previous period increases, and in some transition periods represents the large majority of the population.

Conclusions

I analyzed the impact of two different information structures in *p*-beauty contest games. The main conclusion is that, when facing two signals, non-winners often (mostly, in some Sessions) imitate the depth of reasoning of winners, as it was expressed by their choices and declarations. Imitation is the easiest way to solve the game, in the presence of structural and strategic uncertainty. In the context of these experiments, imitation basically means following the winners' understanding of the game's structure and their predictions on M (that is, their predictions on the average depth of reasoning in the previous period). Both aspects seem to provide more insights to non-winning players than the M statistics itself.

The interesting point is that, when imitation is possible, more sophisticated players assume that, when the level of reasoning n has been revealed, it will be imitated in the next period, and therefore they respond by adopting a strategy in the interval $(n, n+1)$, thus producing a further acceleration in the learning process.

Previous experiments in guessing games have proved that subjects learn how to play the game by best-responding to the observed level of rationality in the previous period. In other words, players try to "move ahead" of the average level. When a winning strategy is revealed, subjects imitate that strategy and try to move ahead of the imitators rather than the average level, even when messages are confused.

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Appendix

INSTRUCTIONS

Welcome to our experiment

Please do not try to communicate with the other participants. Read these Instructions carefully. If there are any queries, do not hesitate to ask the organisers. At the end of the Session you will collect your participation fee of €3.

What is the experiment about?

The experiment lasts 6 periods. In each period your task is to choose a number in the interval 0 – 100 (you can also choose 0 or 100 and you can choose integers or real numbers - up to 2 digits). **The winner is the person whose number results to be the closest choice to "the target".**

What is "the target"?

The "target" is a number equal to 2/3 of the average of all numbers chosen by the participants, that is:

$$\textit{Target}= \frac{2}{3}\frac{S}{n}$$

Where: S=the sum of numbers chosen by all participants;
n= the number of participants.

Let us make an example. If there are 5 participants, A, B, C, D and F, and their choices are *a, b, c, d and f* , the target will be:

$$T= \textit{Target} = \frac{2}{3}\left(\frac{a+b+c+d+f}{5}\right)$$

You win if your choice was the closest guess of *T.*

How much does the winner earn?

The prize in each period is €6. If there is more than one winner, the prize will be shared equally.

The winner will privately be informed at the end of the period and will collect the prize at the end of the Session.

SECTIONS ADDED ONLY FOR SESSION 1a AND 1b

INFORMATION: After all participants enter their choice, the computer will calculate the target and will inform you about the value of *T*, the average, and whether you are the winner or not.

QUESTIONNAIRE: At the end of the Session we ask you to answer to our questionnaire (see page 2 of the Instructions), and to explain in a few words what reasoning motivated your choices. Please try to be as accurate as possible!

SECTIONS ADDED ONLY FOR SESSIONS 2-8

INFORMATION: After all participants enter their choice, the computer will calculate the target and will inform you about the value of *T*, the average, and whether you are the winner or not. **The winner's message.** The participant(s) who win the competition cannot play in the periods to follow.

If you are the winner, however, you may be able to gain an extra prize of €3. You will be asked to explain (follow the instructions on your screen very carefully!) what reasoning motivated your choice (30 words maximum). These messages (and winning numbers) will then appear on all computer screens and will automatically be saved, so that the remaining participants can access them at any time. Naturally, if there is more than one winner, there will be more than one message for that period.

On the basis of the criteria that will be clearly explained to you, if you result to be the winner, a message will appear on your screen indicating what you need to do in order to gain the extra prize and what conditions apply for the €3 bonus prize that can be awarded and added to your total earnings.

PLEASE NOTICE THAT WHILE THE FINAL PRIZE OF €6 IS EQUALLY SHARED IN THE CASE OF A TIE, THE EXTRA PRIZE IS AWARDED TO EACH SINGLE WINNER WHOSE MESSAGE FULFILLS THE CRITERIA THAT WILL BE EXPLAINED AT THE END OF THE PERIOD.

QUESTIONNAIRE: At the end of the Session we ask you to answer to our questionnaire (see page 2 and 3 of the Instructions), where we request you to explain in a few words what reasoning motivated your choices (Question 1, page 2), and to rank the winners' messages (Question 2 page 3). Please try to be as accurate as possible!

Example of Page 3:

QUESTION 2:

2) Did you find the winners' messages helpful? (YES/NO);

If NO:

2a) Please indicate why:

If YES:

2b) Please, indicate in the apposite box which message(s) you found:

A) very useful;
B) useful;
C) not so useful, useless.

TABLES

TABLE 1: THE EXPERIMENT

SESSIONS	N. OF SUBJECTS	PERIODS	INFORMATION	QUESTIONNAIRE
1a	20	6	*T*, *M*	YES
1b	18	6	*T*, *M*	YES
2	10	4	*T*, *M, WN, Winners'message*	YES
3	17	6	*T*, *M, WN, Winners'message*	YES
4	18	6	*T*, *M, WN, Winners'message*	YES
5	20	6	*T*, *M, W, Winners'message*	YES
6	20	6	*T*, *M, WN, Winners'message*	YES
7	20	6	*T*, *M, WN, Winners'message*	YES
8	20	6	*T*, *M, WN, Winners'message*	YES

TABLE 2: AVERAGE AND MEDIAN VALUES IN NO-INFORMATION SETTING

SES/PER	1		2		3		4		5		6	
	A	M	A	M	A	M	A	M	A	M	A	M
1a	24.7	22.3	24.7	17.6	22.7	16.5	18.6 (14.3)	14.6	15.5 (11.0)	11.3	8.5	8.7
1b	36.4	26.0	24.3	22.0	13.9	7.2	18.2 (10.7)	6.3	10.7	10.2	6.1	5.3

Legenda: Average values excluding spoiler choices in brackets.

TABLE 3: AVERAGE VALUES IN THE INFORMATION SETTING

SES/PER	1		2		3		4		5		6	
	A	M	A	M	A	M	A	M	A	M	A	M
2	24.3	23.0	24.1	23.0	15.1	14.0	7.8	7.5	---	---	---	---
3	23.7	20.0	15.7	9.2	8.5	6.8	9.4 (1.9)	2.5	4.4	4.1	1.6	1.5
4	30.9	28.3	18.1	18.9	15.6 (9.9)	8.1	7.1	7.0	16.2 (2.2)	2.4	4.9	3.3
5	32.8	33.4	28.2	30.0	17.6	16.2	10.0	8.1	5.6	4.1	2.1	1.9
6	38.7	39.1	21.6	19.1	8.2	7.0	7.9 (1.7)	1.9	3.4	3.4	1.2	1.1
7	23.0	23.7	16.4	15.4	7.6	7.5	2.0	1.9	1.5	0.5	0.5	0.5
8	28.9	26.8	19.4	17.0	10.2	8.9	9.1 (3.4)	3.4	4.9	5.0	2.7	2.2

Legenda: Average values excluding spoiler choices in brackets.

TABLE 4: FREQUENCY OF THE STRATEGIES

	SESSION 1A						**SESSION 1B**						**SESSIONS 2-8**					
STRAT.	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
0-3	20	---	---	---	---	5	5.6	11.1	11.1	5.6	5.6	16.7	8.8	0.9	3.7	**53.6**	**55.7**	**88.9**
4-10	5	25	5	5	45	**90**	5.6	11.1	22.2	**66.7**	**50.0**	**77.8**	5.6	23.5	**63.6**	38.4	39.8	8.6
11-20	15	**35**	**75**	**85**	**50**	5	5.6	**27.8**	**44.4**	11.1	44.4	5.5	16.0	**37.4**	25.2	3.0	1.1	2.5
21-30	15	10	10	---	---	---	22.2	16.7	16.7	5.6	---	---	**26.4**	22.6	2.8	2.0	1.1	---
31-40	**25**	10	---	---	---	---	22.2	22.2	5.6	---	---	---	22.4	8.7	3.8	---	---	---
41-50	10	10	---	---	---	---	**27.8**	---	---	---	---	---	10.4	4.3	---	---	---	---
51-60	10	5	---	---	---	---	---	5.6	---	---	---	---	4.8	0.9	---	---	---	---
61-70	---	5	5	---	---	---	5.5	---	---	---	---	---	3.2	---	---	---	---	---
71-80	---	---	---	---	---	---	--	5.5	---	---	---	---	1.6	0.9	---	---	---	---
81-90	---	---	5	---	---	---	5.5	---	---	---	---	---	---	---	---	---	---	---
91-100	---	---	---	5	5	---	---	---	---	11.1	---	---	0.8	0.8	0.9	3.0	2.3	---
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

TABLE 5: LEVELS OF LEARNING IN THE NO-INFORMATION SESSIONS

Sessions 1a, 1b

PER. SES.	S1a					S1b				
	L_0	**L_1**	**L_2**	**L_3**	**>3**	**L_0**	**L_1**	**L_2**	**L_3**	**>3**
I	0.20	0.25	0.15	0.10	**0.30**	0.35	**0.41**	0.06	0.06	0.12
II°	0.20	**0.47**	0.27	0.06	--	**0.25**	**0.25**	0.13	**0.25**	0.12
III°	0.29	**0.78**	0.11	--	--	0.29	0.12	**0.41**	--	0.18
IV°	0.05	**0.79**	0.16	--	--	0.13	0.13	**0.47**	0.20	0.07
V°	--	**0.68**	32.0	--	--	0.17	**0.45**	0.33	--	0.05
VI°	--	**0.60**	0.35	--	0.05	0.17	**0.50**	0.17	0.11	0.05

TABLE 6: LEVELS OF LEARNING IN THE INFORMATION SESSIONS

Sessions 2-5

Per/ Exp			**S2**					**S3**					**S4**					**S5**		
	L_0	**L_1**	**L_2**	**L_3**	**>3**	**L_0**	**L_1**	**L_2**	**L_3**	**>3**	**L_0**	**L_1**	**L_2**	**L_3**	**>3**	**L_0**	**L_1**	**L_2**	**L_3**	**>3**
I°	0.20	0.10	**0.40**	--	0.30	0.12	0.12	**0.35**	**0.35**	0.06	--	**0.44**	0.38	0.12	0.06	0.20	**0.50**	0.05	0.10	0.15
II°	**0.40**	--	**0.40**	--	0.20	--	0.27	0.33	**0.40**	--	0.18	**0.35**	0.29	0.18	--	**0.47**	0.27	0.07	0.13	0.06
III°	**0.33**	0.17	0.17	--	**0.33**	0.08	0.08	**0.69**	0.15	--	--	0.21	**0.57**	0.22	--	.017	0.39	**0.44**	--	--
IV°	0.17	**0.33**	0.17	**0.33**	--	--	--	0.16	**0.42**	**0.42**	--	0.7	**0.80**	0.13	--	--	0.21	**0.43**	0.08	0.28
V°						--	0.17	**0.58**	0.17	0.08	--	--	0.17	**0.58**	0.25	0.07	0.14	**0.43**	0.08	0.28
VI°						--	--	0.45	**0.46**	0.09	0.8	0.8	0.15	0.15	**0.54**	0.07	--	**0.31**	**0.31**	**0.31**

TABLE 6: LEVELS OF LEARNING IN THE INFORMATION SETTING

Sessions 6-8

Per/ Exp			**S6**					**S7**					**S8**		
	L_0	**L_1**	**L_2**	**L_3**	**>3**	**L_0**	**L_1**	**L_2**	**L_3**	**>3**	**L_0**	**L_1**	**L_2**	**L_3**	**>3**
I°	**0.46**	0.16	0.16	0.11	0.11	0.05	**0.32**	0.26	0.16	0.21	0.25	0.25	**0.30**	---	0.20
II°	0.18	0.29	**0.35**	---	0.18	0.**44**	--	0.31	0.19	0.06	0.17	**0.39**	0.22	0.11	0.11
III°	0.12	0.02	0.18	0.29	**0.35**	0.12	--	**0.76**	0.06	0.06	0.22	0.06	**0.50**	0.22	---
IV°	--	0.07	0.13	0.20	**0.60**	--	0.06	0.19	0.31	**0.44**	0.06	0.06	0.25	**0.38**	0.25
V°	0.07	0.20	0.20	**0.33**	0.20	--	0.07	0.22	0.14	**0.57**	0.06	**0.48**	0.38	0.06	0.06
VI°	--	--	0.28	**0.72**	--	--	--	**0.40**	0.33	0.27	0.17	0.20	**0.47**	0.17	0.07

TABLE 7: LEVELS OF RATIONALITY OF THE WINNERS

Per/Sess.	***2***	***3***	***4***	***5***	***6***	***7***	8
1	2 (2)	3*c*	2*c*	2*c*	2 (2)	3*c*(3*c*)	2*c*
2	0	2*c* (2)	2*c*	1*c*	2	2*c*	2
3	3	2*c*	1*c*	2*c*(2*c*)	>3	2	3*c*
4	2	2*c*	3*c*	3	2	>3	1
5		3	2*c*	3	3	2	2*c*

Second winner's choice in brackets

TABLE 8: VALUES OF THE ESTIMATED COEFFICIENTS γ AND δ

SESSIONS	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
γ	0.08 (0.93)	0.20 (0.29)	1.86 (2.96)	-0.17 (0.97)	8.10* (4.88)	-3.20 (2.89)
δ	3.18** (1.34)	1.59*** (0.45)	0.10 (2.84)	2.63** (1.10)	-6.19 (4.89)	5.88** (2.98)

*Note: superscripts *, ** & *** indicate p<.1, p<.05 & p<.01 respectively*

TABLE 9: NON-WINNERS' RATIONALITY AND IMITATIVE BEHAVIOUR

TRANSITION PERIODS	**S3**		**S4**	
	$n_{NW}(t) = n_W(t-1)+1$	$n_{NW}(t) = n_W(t-1)+2$	$n_{NW}(t) = n_W(t-1)+1$	$n_{NW}(t) = n_W(t-1)+2$
1-2	40.0	0	29.4	17.6
2-3	15.3	0	21.4	0
3-4	41.7	41.7	80.0	13.3
4-5	18.2	9.1	53.8	23.1
5-6	9.1	0	16.7	58.3

TRANSITION PERIODS	**S5**		**S6**	
	$n_{NW}(t) = n_W(t-1)+1$	$n_{NW}(t) = n_W(t-1)+2$	$n_{NW}(t) = n_W(t-1)+1$	$n_{NW}(t) = n_W(t-1)+2$
1-2	13.3	7.0	0	17.6
2-3	44.4	0	29.4	35.3
3-4	7.1	28.6	26.7	33.3
4-5	7.1	28.6	33.3	20.0
5-6	30.8	30.8	0	0

TRANSITION PERIODS	**S7**		**S8**	
	$n_{NW}(t) = n_W(t-1)+1$	$n_{NW}(t) = n_W(t-1)+2$	$n_{NW}(t) = n_W(t-1)+1$	$n_{NW}(t) = n_W(t-1)+2$
1-2	18.7	6.2	11.1	11.1
2-3	5.9	5.9	22.2	0
3-4	18.7	25.0	12.5	12.5
4-5	14.3	42.9	37.5	6.2
5-6	33.3	26.7	13.3	6.7

ENDNOTES

[1] The game originated with J. M. Keynes' famous example on newspaper competition , regarding the way expectations are formed on the financial markets (see: J. M. Keynes , 1936, chapter 12, p 136, Italian edition, 1947). H. Moulin , 1986, subsequently modelled Keynes' example as a game with a unique Nash equilibrium, as opposed to the game with infinite equilibria described in Keynes' analysis.

[2] The progressive elimination of dominated strategies may be described by stating that, for player *i*, action: $m_i^{n+1} = p^{n+1}100$ is the best response to *j*'s expected choice, $m_j^n = p^n 100$; in the presence of infinite and symmetric depth of reasoning, as *n* goes to infinity, the symmetric optimal strategy is for players *i* and *j* to announce $m_i^n = m_j^n = p^n 100 = 0$, and share the final prize.

Guessing games have been modelled in many alternative ways, with different final equilibrium points. See, for example, W. Guth *et al.*, 2001, R. Nagel, 1995, J. Duffy and R. Nagel, 1997.

[3] For detailed surveys, see C.Camerer, 2003; 2004. *P*-beauty contests game have been experimented under a wide variety of informational and structural conditions. The relevance of financial incentives (C. Camerer *et al.*, 1998) and the robustness of behaviour to changes of the structure of the game (J. Duffy and R. Nagel, 1997) have been analysed, and the most important results are that changes in behaviour and learning are observed in experienced players, but neither the structure nor the financial incentives seem to have great effects on the decision process.

[4] There was no incentive to win later in the game, since staying on did not increase the individual expected payoff. All players collected €3 at the end of the Session as a show-up fee. The stage payoffs were fixed throughout the entire 6-period game, and varied between 0 gained by non-winners, and €9 (€6+ €3. e.g., the value of the prize plus the prize for the message), gained by the winner (in case of no tie) whose message was awarded the extra price. Winners could not gain more than €9, and the precise details of the reward structure were specified in the Instructions and explained at the beginning of the Session.

[5] As noticed by a referee, an alternative experimental design may be thought in order to assess the depth of reasoning of the players and to study the effect on behaviour of this piece of information. All players (not only winners) could be asked to submit their reasoning *ex ante*, e.g., at the beginning

of each Session, and the individual message could be disclosed in the case of the subject's victory. The advantage of this alternative formulation would be that participants had more time and less pressure to communicate their reasoning. The major drawback, however, of this alternative setting is that the *ex ante* reasoning – at least in the context of *p*-beauty contest games with inexperienced subjects – may be useful to assess the individual decision process aimed to find the "optimal strategy", but tell us very little on the subject's learning process and his conjecture on the population level of rationality. My main interest was to study the learning process and for this reason I adopted this specific experimental design.

[6] "Spoiler choices" are often justified by frustration or lack of motivation. See C. Camerer *et al.* 1998.

[7] A similar situation can be found in S4 (period 5), S6 (period 4) and S8 (period 4). In S4 and in S8, 40% and 29% of the population were playing numbers smaller than 2 , respectively, in the same period in which M increased as effect of spoilers' behaviour; whilst in S6 almost 38% of the people were playing numbers smaller than 1.

[8] As in Table 4, S2-S8 were aggregated in one Session.

[9] Specifically, the standard deviation in the final period was equal to 0.45 in S3, 0.27 in S6, 0.19 in S7, 1.36 in S5 and S8. The value of the standard deviation in Session 4 was 0.47 in the fifth period and increased to 4,0 in the sixth period as effect of spoiler choices in the previous round.

[10] I conventionally adopted M^*=50, for the first interval.

[11] This winner was unable to enter 22.22 because he did not understand how the computer program worked.

[12] A copy of the messages is available on request.

[13] I thank a referee for pointing out the importance of this aspect. There are previous papers which disclose the winning number as in my experiment. This piece of information is proved to have little effect on learning, with the few exception of R. Duffy and R. Nagel, 1997 (the median game), and M. G. Kocher, M. Sutter, 2005 (the heterogeneous setting: individuals versus groups). In both cases, the authors register a faster convergence to equilibrium. However, the specific role played by the information on the winning number is not analysed by the authors and therefore it is not possible to disentangle its influence by other characteristics of their experimental designs. In interpreting the result of my experiment, one might conclude that the messages affect behaviour, and not the

winning numbers. In fact, it is my opinion that *both* information turn out to be useful to subjects, since messages often provide a good explanation for the observed choice of the number. This happens since there is no conflict between what the subject actually says in the message and his/her choice.

[14] "I will be as sincere as possible. In this contest, my choice was only partially determined on the basis of reasoning. I executed the division substituting 20 for *n*; the result is 30, therefore every number should be divided by 30, I thought it would be less than 30…. The choice of 15 was unfortunately random" (S7, period 1, second winner; winning number: 15, value of the average: 23.0).

[15] In fact, in many messages winners claimed that the number of participants did matter.

[16] I owe the estimation of the model to Niall O'Higgins. Variables were estimated in the form of rates of change (i.e. scaled by x_{t-1} and expressed in natural logarithms) to reduce problems with the downward trend common to all variables. Estimation is based on the GMM approach suggested by Arellano & Bond (1991).

[17] I thank a referee for this suggestion. This methodology allows to compare the effect of each variable on non-winners decision process, taking into account the effect of multicollinearity. Considering the single-variable estimates in the Sessions 3,4,6.8, the results are not significantly different from the ones reported in Table 8.