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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 information on levels of reasoning on individuals' choices in *p*-beauty contest games. In the baseline design, subjects received information only on the average and target values from the previous period. In the alternative design, the winner(s) explained in a short message (30 words maximum) what reasoning he/she applied in selecting the target value and then stopped playing. The winner's message, the winning number, the target and average values were then displayed on all computer screens. The results show that non-winning players imitate the level of rationality of winners, and a significant proportion of the population adopt strategies which are best responses to other imitators' behaviour rather than to the average level of rationality. Both the imitative strategies and the best responses to the imitative strategies stimulate a strong acceleration of the learning process.

Keywords Guessing games · Experiments · Imitation

JEL Classification C72, C91, C92

Introduction

"Beauty-contests" are popular examples of why people may fail to reach the Nash equilibrium in dominance solvable games.[1] The structure of the game is well-known:

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[1] The game originated with J. M. Keynes' famous example of a newspaper competition, regarding the way expectations are formed in financial markets (see: Keynes, 1936, chapter 12, p. 136, Italian edition, 1947). 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.

players are asked to pick a number, m_i, in a closed interval [0, 100]. For a given number of players, k, the winner of the contest (who receives a fixed sum of money) is the subject whose guess is closest to the number $T = pM_t$ (the "target"), where M is the mean 'guess' at time t, and p ($0 < p < 1$) is a (known) parameter. For values of p less 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 only a few levels of reasoning, as suggested in the original J. M. Keynes' example, then the Nash equilibrium will rarely be observed and, therefore, playing the optimal strategy may not be a smart response.

The simplicity and rich implications of the p-beauty contest game make it a popular basis for economic experiments which examine depth of reasoning. The first such experimental use, in the seminal paper by Nagel (1995), proposed a model of choice under bounded rationality. The *Iterated Best Reply* (k-step learning) model (Camerer et al., 1998) states that human learning uses only finite levels of reasoning, and players calculate the best response 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 types of subjects pools. The most important result is that, in classroom experiments, the most common learning behaviour amongst players does not go further than the first or second level of reasoning and while the average guess steadily decreases over time the level of reasoning of players does not increase. Exceptions are found in experiments in which subjects were experienced or skilled in game theory. Higher levels of reasoning have also been found in large scale experiments run through newspaper competitions (Bosch-Domenech et al., 2002).[3]

Different information settings have also been tested. In some scenarios, players are provided with the individual choices of their partners as well as the average choice and the target (Nagel, 1995); in other cases, only the target and the average choice is provided. More closely related to this work are the recent papers which focus on the study of the effects of strategic uncertainty on convergence and learning. In a 2-person beauty contest game (Grosskopf and Nagel, 2001), subjects received feedback on the choice of their co-players. In this full-information framework, learning is faster than in the alternative scenario where subjects receive no information on the rationality of

[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 (Guth et al., 2001; Nagel, 1995; Duffy and Nagel, 1997).

[3] For detailed surveys (see Camerer, 2003; Camerer et al., 2004). Experiments on p-beauty contest games have been undertaken with a wide variety of informational and structural conditions. The relevance of financial incentives (Camerer et al., 1998) and the robustness of behaviour to changes in the structure of the game (Duffy and Nagel, 1997) have been analysed. 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 substantial effects on the decision process.

their opponents. The type of decision making process (individual vs. group decision making) also seems to make a difference on learning in guessing games. Kocher and Sutter (2005), demonstrated that groups perform better than individuals; they more quickly learn how to play as well as outperforming individuals in direct competition. These results suggest that when there is communication about the level of reasoning required to solve the game, people learn to play dominant strategies sooner.

The analysis presented here, looks at a slightly different issue. Results from an experiment on p-beauty contest games with inexperienced subject pools and two different information treatments are reported. In Sessions S1a and S1b (the baseline designs), the only pieces of information provided in each period were the target number and the average value (T, M). In Sessions S2–S8, in each of the six stages of the game, the winner(s) explained the reasoning he/she had 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 as well as the target and average values were then displayed on all computer screens. In these sessions, therefore, the information provided concerned not only the aggregate measure of rationality (M), but also the individual level of rationality of a representative agent, whose strategy was successful in the previous stage (W).

The aim of this study is to evaluate the importance of information about levels of reasoning (W) on individuals' choices. Thus the analysis presented is a contribution to research in the expanding field of social learning in games (Çelen et al., 2002, 2005; Nyarko et al., 2005; Altavilla et al., 2006). As noted in 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, social learning refers to the process by which individuals learn by observing the actions of other players. Specifically, in the research of Çelen et al. (2002, 2005), as well as in the present paper, the focus is on the way individual behaviour may be affected not only by observing other players' actions (here, the winning number), but also by information on the strategic behaviour adopted by other players (here, information on the winner's level of reasoning). In the real world, social learning is a very important aspect of every day decision making; people try to obtain as much 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 proven to be successful in the past. In this paper, as well as in Çelen et al. (2002, 2005), it seems that we take social learning very seriously and behaviour is more influenced by other players' advice on the best strategic choice than the choice itself. The experiment reported here shows that social learning speeds up individual learning to a considerable extent. Consequently, convergence to equilibrium is much faster in Sessions S2–S8, than in the baseline designs (S1a, S1b).

Experimental design 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 S2). Each game lasted 6 periods (4 periods in Session S2) and there were 17–20 students in each group (10 in Session S2).

Table 1 The experiment

Sessions	No. 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

Note: T = target; M = average value; *WN* = winning number.
Session 1b: baseline Session with theoretically trained subjects.

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 S1b (the second baseline design) students were all trained in mathematics (four were graduate students in economics, while the other participants were maths and physics students) and the economics students (almost half of the group) had previous game theory' training, although none had participated in economic experiments before. The aim in choosing the subjects' pools for the baseline designs (sessions S1a and S1b) 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. None of the participants, however, had any previous knowledge of p-beauty contest games.

Overall, 163 subjects participated in the experiment, 125 subjects in the 'augmented information' sessions and 38 in the two remaining baseline games.

Table 1 summarises the main elements of the experiment.

The prize for each round of the game 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 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 each session participants knew the average and target values in every period, but, in Sessions S2–S8, participants were also informed of the winning number and had access to the "winner's message." From periods 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 a 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; and (3) the other participants

report that your message was useful when they answer the questionnaire on completion of the session."[4]

The winner would stop playing at that point, but would collect the extra price only at the end of the session.[5] 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 asked for an explanation of the reasoning applied for each choice. In Sessions S2–S8, however, the further task of judging and ranking winners' messages was added.[6]

The expected effect of the extra information of the winning number (denoted as *W*, hereafter) and the winners' message is not unequivocal. The information might be misunderstood, useless or wrong and in these cases one would expect that the messages do not influence the learning process (or that they even slow it down). Alternatively, messages may increase the rationality of the remaining subjects, who are also aware that this model is common knowledge among all players. In this case, the impact on the learning process is likely to be quite different: people may imitate and consequently the learning process may be accelerated. Conjectures on the effects of information are then represented by the following alternative, albeit not necessarily mutually exclusive, claims.

Claim 1. information on *W* has a negative impact on learning

Winners' messages and numbers always have a negative impact on learning: experimental evidence shows 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

[4] This message appeared only on the winners' computer screens. In the instructions, all players were informed of the existence of an extra prize for winners who reported their reasoning at the end of the period, but only winners were informed of the criteria on the basis of which the prize was awarded. A copy of the Instructions can be downloaded from the journal's website.

[5] There was no incentive to win later in the game, since staying on did not increase the individual's 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 earned by non-winners, and €9 (€6 + €3. e.g., the value of the prize plus the prize for the message) earned by a unique winner 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.

[6] As noted by a referee, an alternative experimental design might be employed 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 of this alternative setting is, however, 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 at finding the "optimal strategy", but tells us very little about the subject's learning process and his conjecture on the level of rationality of the population. My main interest was to study the learning process and for this reason I adopted this specific experimental design.

Table 2 Average and median values in no-information setting

	1		2		3		4		5		6	
Ses/Per	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

Note: Average values excluding spoiler choices in brackets.

Table 3 Average and median values in the information setting

	1		2		3		4		5		6	
Ses/Per	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

Note: Average values excluding spoiler choices in brackets.

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 uninformed setups.

Results section: Convergence and learning

Tables 2 and 3 report the mean and median values respectively, while Table 4 reports the frequency of the strategies (numbers) chosen by subjects, in each period for Sessions S1a, S1b and S2–S8 respectively.

Comparing individual choices in the first and subsequent periods, it is easy to see that there are significant differences across sessions. In line with other studies, first period choices are, with few exceptions, in the range 20–50 (Camerer, 2003). Furthermore, the Mann-Whitney U-tests on the initial period of the game does not reject the null hypothesis of no difference in choices in the comparisons S1a/S2–S8 ($p = 0.20$) and S1b/S2–S8 ($p = 0.32$).[7]

From the second period on, however, there is less similarity between baseline and alternative designs. In six of the seven sessions where information on W was disclosed, choices approach the equilibrium value of zero at a faster rate.

Table 4 shows that more than half of the population in the information treatments chose numbers in the interval 0–3 from the third period on.

In the final stage, a substantial proportion of players chose numbers smaller than 1.5 (precisely, 45% in S3 and 39% in S5) or 2.5 (46% in S4 and 60% in S8) in four out

[7] As in Table 4, S2–S8 are aggregated.

Table 4 Relative frequency of the choices

Choice	Session 1A						Session 1B						Sessions 2–8					
Per.	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**

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 the final period of both baseline designs (S1a and S1b), the proportion of subjects choosing numbers smaller than 2.5 was 5% in S1a, and 6% in S1b.

One common feature of baseline and alternative designs is the presence of spoiler choices (e.g. players choosing $m_i = 100$) (Camerer et al., 1998) in several of the rounds.[8]

Inspection of the median values (as well as the mean values excluding the spoiler choices reported in brackets) in Tables 2 and 3 shows that in Sessions S2–S8, the presence of spoilers is more influential than in S1a-S1b and that their effects on behaviour carry over into subsequent stages of the game. In Session 3, for example, 35% of the subjects were playing $m_i < 0.5$, in the fourth period. The proportion drops to zero in the following period, and increases to 10% in the final round.[9] In the second baseline design (1b), the same proportion is fixed over time (0.05%), and is not dependent on spoiler choices.

Finally, a further characteristic of the convergence process may be observed by looking at the variability of choices across subjects. Whilst in all sessions the standard deviation of choices decreases over time, in the informed setups it approaches zero from the fourth period on. Indeed, in the final period, the values of the standard deviation in 1a and 1b were around 2 (2.0 in Session S1a and 2.6 in Session S1b, respectively) while they converge to values smaller than 1 in Sessions S3-S8.[10] A result on convergence can therefore be stated:

Result 1. Information on W positively affects the process of convergence to equilibrium in p-beauty contests games. In Sessions S2–S8, the average choice and is variance decrease at a faster rate than Sessions S1a and S1b.

A further important issue concerns the effects of W on aggregate and individual learning.

In Tables 5 and 6, the learning process is classified by level of reasoning (Nagel, 1995; Duffy and Nagel, 1997; Camerer et al., 1998; Kocher and Sutter, 2005). Specifically, the choice of individual i, at time t, is classified as level n, if it corresponds to: $m_i = p^n M_{t-1}$.

Individual choices can therefore be grouped in intervals of learning: $L_n = [p^{n+\frac{1}{2}} M_{t-1}, p^{n-\frac{1}{2}} M^*_{t-1}]$.[11]

[8] "Spoiler choices" are often justified by frustration or lack of motivation. See Camerer et al. (1998).

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

[10] Specifically, the standard deviation in the final period was equal to 0.45 in S3, 0.27 in S6, 0.19 in S7 and 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.

[11] I conventionally adopted $M_{t-1} = 50$, for the first interval.

Table 5 Levels of reasoning over time in the no-information sessions (Sessions 1a, 1b)

Ses.	S1a					S1b				
Per.	**L_0**	**L_1**	**L_2**	**L_3**	**>3**	**L_0**	**L_1**	**L_2**	**L_3**	**>3**
1	0.20	0.25	0.15	0.10	**0.30**	0.35	**0.41**	0.06	0.06	0.12
2	0.20	**0.47**	0.27	0.06	–	**0.25**	**0.25**	0.13	**0.25**	0.12
3	0.29	**0.78**	0.11	–	–	0.29	0.12	**0.41**	–	0.18
4	0.05	**0.79**	0.16	–	–	0.13	0.13	**0.47**	0.20	0.07
5	–	**0.68**	32.0	–	–	0.17	**0.45**	0.33	–	0.05
6	–	**0.60**	0.35	–	0.05	0.17	**0.50**	0.17	0.11	0.05

As before, from period 2 to period 6, some basic differences between the two types of session can be identified. In Sessions S1a and S1b, the decision process settles down to the first and second level of reasoning.

In S1a, the majority of players adopts strategies within the L_1 interval throughout the session although a significant proportion of the population plays strategies within L_2 in periods 5 and 6.

In S1b, there is a high proportion of choices within the L_2 interval in periods 3 and 4, then the learning returns to the first level of reasoning.

There are, however, differences between the two sessions. In Session S1a the process of convergence appears to be faster and involves the vast majority of players. In Session S1b, there is a significant—and constant through time—deviation from the first and second levels of reasoning which 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 (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 second levels of reasoning.

Different results are to be found in Sessions S2–S8. 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. Moreover, two additional observations are warranted here; first, considering periods 5–6 in Sessions S2–S8, whilst aggregate learning, on average, settles to the second or third level (that is, at a level only slightly higher than the non- information treatment, but still in line with the findings of previous research), the proportion of players adopting more sophisticated strategies ($L > 3$) increases in four of the seven sessions (S2, S4, S7, S5). Second, in these four sessions this proportion exceeds 20% of the total.

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

Also for the remaining Sessions S3, S8 (and partially S6), one cannot say that the learning dynamic is similar to the one observed in Sessions S1a and S1b. In fact, if

Table 6 Levels of reasoning over time in the information (a) Sessions

Ses.	S2					S3					S4					S5				
Per.	**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**
(a) Sessions 2–5																				
1	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
2	**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
3	**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**	–	–
4	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
5						–	0.17	**0.58**	0.17	0.08	–	–	0.17	**0.58**	0.25	0.07	0.14	**0.43**	0.08	0.28
6						–	–	0.45	**0.46**	0.09	0.8	0.8	0.15	0.15	**0.54**	0.07	–	**0.31**	**0.31**	**0.31**

Ses.	S6					S7					S8				
Per.	**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**
(b) Sessions 6–8															
1	**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
2	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
3	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	—
4	–	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
5	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
6	–	–	0.28	**0.72**	–	–	–	**0.40**	0.33	0.27	0.17	0.20	**0.47**	0.17	0.07

Table 7 Levels of reasoning of the winners

Sess/Per	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*

Note: c = confused message. Second winner's choice in brackets.

one compares the L_3 class (and $L > 3$) in the two contexts, one can conclude that the speed of the learning process is greater in S3, S6 and S8 than it is in S1a and S1b.

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, in Table 7 a similar method to that used in Tables 5 and 6 is applied to winners' choices to identify their level of rationality. In addition however, a c was used to indicate that the rationality level was expressed by the chosen strategy, but that the message was confused.

To illustrate, three examples of L_2 messages are given below:
"Between 0 and 100 the average is 50; 2/3 of the average is 33.33. If everybody declared 33.33, the target would be 22.22. I tried to play 22.22, but I did not succeed, so I played 22".[12]

"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)

The following message was also classified as L_2 , but a $c$is added.[13]
"Since everybody knows the mechanism by now, I calculated that all participants would play a number lower than the previous target" (S3, Period 3).

Inspection of Table 7 suggests 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 to 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, information on winners' strategies does affect individuals' decisions even in the presence of confused messages; furthermore, there seems to be a cumulative impact of winners' information on individuals' choices.

A further point regards the evaluation of the relative importance of information on the winning number as opposed to the winner's message. Disclosing the winning number in Sessions S2–S8 should, by itself, have little influence on learning (compared to S1a-S1b) since the experimental settings are alike.[14] Sometimes, however, (clear)

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

[13] A copy of all messages can be downloaded from the journal's website.

[14] I thank a referee for pointing out the importance of this issue. 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 exceptions of Duffy and Nagel (1997) (the median game), and Kocher and Sutter (2005) (the heterogeneous setting: individuals versus groups). In both cases, the authors register a faster convergence

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 40 (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 S1a and S1b—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, 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?[15] Messages may have three distinct but complementary effects on behaviour.

First of all, messages such as: "the number of participants is irrelevant" (S2, Periods 1 and 3), "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)—i.e., there are spoilers; "I thought the majority of the participants would have based their choices on previous reasoning, considering the same average and then calculating the two-thirds of it. I then played two-thirds of the resulting number" (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 2/3 of the previous value. . . .the numbers tend to be closer. . . ." (S6, Period 4) provide a general model of rationality by expressing a conjecture on 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.

A further question is how information on W affects individuals' decision processes. In S1a and S1b, 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 S2–S8, players were informed both

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 from that of other characteristics of their experimental designs. In interpreting the result of my experiment, one might conclude that it is the messages which affect behaviour and not the winning numbers. In fact, it is my opinion that both types of 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.

[15] "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).

Table 8 Values of the estimated coefficients γ and δ

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

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

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. The important point is to assess which of the two rationality signals had a greater influence on the decision process of non-winners in Sessions S2–S8.

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:

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

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.[16]

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 Sessions S5 and S7, δ is not statistically significant (in S7 it is actually negative). However, considering single-variable regressions—where the effects of M and W are included separately—a slightly different picture can be gained.[17] 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 error $= 0.31$) and 1.95 (standard error $= 0.32$) respectively; in S7, the value of γ and δ are equal to 1.90 (0.29) and 1.92 (0.28).

As a result of the previous analysis, it can be asserted that W sets the pace of the learning process in S3–S8. Players imitate the level of rationality of winners, and there is a significant proportion of the population who adopt strategies which are best responses to imitators' behaviour rather than to the average level of rationality. Both imitative strategies and the best responses to imitative strategies produce a strong acceleration of the learning process.

[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 and 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.

Conclusions

I have 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 expressed in 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.

When imitation is possible, more sophisticated players assume that—once 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 $(n, n + 1)$.
This behaviour produces a further acceleration in the learning process.

Previous experiments in guessing games have shown 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 stay one-step-ahead of the average level of rationality. When a winning strategy is revealed, however, subjects imitate that strategy and thereby to try to stay one-step-ahead of imitators rather than simply the average level of rationality, even when messages are confused.

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References

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, *58*, 277–297.

Altavilla, C., Luini, L., & Sbriglia, P. (2006). Social learning in market games. *Journal of Economic Behavior and Organization*, in press.

Bosch-Domenèch, A., Montalvo, J.G., Nagel, R., & Satorra, A. (2002). One, two, three, infinity…: Newspaper and lab beauty-contest experiments. *American Economic Review*, *92*, 1687–1701.

Camerer, C., Ho, T., & Weigtel, K. (1998). Iterated dominance and iterated best-response in experimental p-beauty contests. *American Economic Review*, *88*, 947–969.

Camerer, C. (2003). *Behavioural game theory*. Princeton, New Jersey: Princeton University Press.

Camerer, C., Lowenstein G., & Rabin, M. (Ed.) (2004) *Advances in Behavioural Game Theory*. Princeton, New Jersey: Princeton University Press.

Çelen, B., Kariv, S., & Schotter, A. (2002). The advice puzzle: An experimental study of social learning where words speak louder than actions. *Levine's WPS Series Dept. of Economics UCLA*.

Çelen, B., Kariv, S., & Schotter, A. (2005). An experimental test of advice and social learning. *Levine's WPS Series Dept. of Economics UCLA*.

Duffy, J., & Nagel, R. (1997). On the robustness of behaviour in experimental 'beauty contest' games. *Economic Journal*, *107*, 1684–1700.

Grosskpof, B., & Nagel, R. (2001). Rational reasoning or adaptive behavior? Evidence from a two-person beauty contest game. *Harvard NOM Research Papers*, no. 01-09.

Kocher M., & Sutter, M. (2005). The decision maker matters: Individual versus group behaviour in experimental beauty contest games. *Economic Journal*, *115*, 200–223.

Güth, W., Kocher, M., & Sutter, M. (2002). Experimental 'beauty contest' with homogeneous players and with interior and boundary equilibria. *Economic Letters*, *74*, 219–228.

Keynes, J. M. (1947). *Occupazione. Interesse e Moneta. La Teoria Generale*. UTET, Torino.

Moulin, H. (1986). *Game theory for social sciences*. New York: New York University Press.

Nagel, R. (1995). Unraveling in guessing games: An experimental study. *American Economic Review*, *85*, 1313–1326.

Nyarko Y., Schotter A., & Sopher, B. (2005). On the informational content of advice: A theoretical and experimental study. *Economic Theory*. Special Issue.