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Measuring Competition Among Students through Experimental Beauty Contest Games: An Overview of Results

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Communication in guessing games: does competition matter?

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Abstract

This paper studies the effect of communication in Experimental Beauty Contest Games (BCG). It is analyzed if the depth reasoning level (main output of BCG) is affected by the communication and the competition among students (from different schools/degrees). In our BCG, cooperation between members of each classroom was allowed (but not explicitly encouraged). We found that cooperation improves dramatically the rationality levels of the experimental subjects; also, there are significative differences in the competition level depending on the degree hardness.

J.E.L. Classification: C91, D83, I21
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1 Introduction

Beauty Contest Game (BCG) is a simple guessing game that facilitates the evaluation of the individuals' (experimental subjects) level of reasoning. The

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basic BCG is as follows: a certain number of subjects are invited to play a game, simultaneously all of them have to choose a number from an interval (generally $[0, 100]$). The winner is the player whose number is closest to p-times the mean of all the chosen numbers, being $0 < p < 1$, and she receives a fixed prize, the losers get nothing.

The distribution of chosen numbers lets us analyze the depth of reasoning of agents, say, level 1 includes people who expect that the other players behave randomly so they choose $p * mean$ (being $mean = 50$ if the choice distribution is uniform), level 2 if she expects that the other's depth of reasoning is level 1, then she chooses $p^2 * mean$, ..., generalizing, at level K are people who choose $p^K * mean$ because they believe that the other people are at level $K - 1$. If K is big, $p^K * mean \simeq 0$, so if we repeat the process *ad infinitum* ($K = \infty$) we reach the theoretical solution[1], 0, the highest level of reasoning (see Figure 1). Random answers are called level 0 of reasoning. A level of reasoning higher than 3 is rare in BCG experiments [see Bosch-Domènech et al., 2000], although this Iterated Best Replay Behavior (IBRB) is quite common [Ho et al., 1998].

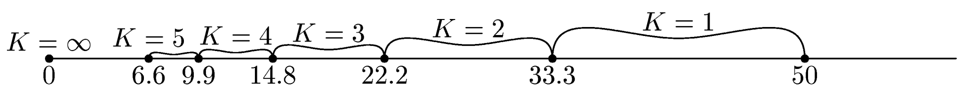

Figure 1: An example of different reasoning levels

Figure 2, taken from [Ho et al., 1998, pg. 951], also shows the convergence to the zero solution but from a dominance iterative point of view. Any number chosen between 66.6 and 100 is dominated by 66.6 ($100 * 2/3$, if $p = 2/3$), so we say that the interval $[66.6, 100]$ corresponds to an irrational behavior ($R(0)$ for us). Rational individuals will always choose a number in the $[0, 66.6]$ interval. Applying the same reasoning, $R(1)$ players will choose a number below 66.6 (but above 44.4), but 2/3 of 66.6 will dominate again any number between 44.4 and 66.6, so we say that any number below 44.4 (and above $44.4 \cdot 2/3 = 29.6$) correspond to a $R(2)$ individual. Following this iterative reasoning level process *ad infinitum*, we get the theoretical Nash equilibrium (0, with $R(\infty)$). This process is called, in game theory, weakly dominated strategies elimination; this game is dominance solvable.

[1] Although all answers (numbers) are possible game solutions if *all* subjects choose the same number, only "0" is a Nash equilibrium.

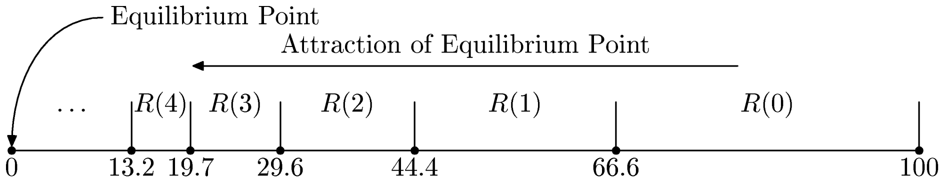

Figure 2: Iterated reasoning of individuals by eliminating dominated strategies

Besides, BCG experiments are different. Sometimes subjects are students, other times professors or newspaper readers (different knowledge). Payoffs may be a fixed or variable amount of money, or just a "present" (a beautiful *pteridium aquilinum* in one of our cases!). In some cases there is a short time to answer, in others, a too long time. Some games are one-shot, others are repeated. Another main variation from the basic game is the order statistic used: usually it is the mean, but Duffy and Nagel [1997] use the median and the maximum. Instead, we will experiment using the mode.

Why the mode? We are looking for collusive behavior among students. Mode drives students to collusion. When mode is the reference, students have a clear incentive to colude: if all (or the majority) of them choose 0, then they will win!

The structure of the paper is as follows. The second section explains the theoretical background; the experiment and its instructions is discussed in the third. Section four shows the results and the statistical analysis. Finally, section five concludes.

2 Theoretical background

The BCG original idea was mentioned by Keynes [1936] when he wanted to express that a clever investor has to "anticipate the basis of conventional valuation a few months hence, rather than ... over a long term of years" (pg. 155), so he could act in the stock market before the rest of investors do.

The formal game model was introduced by Moulin [1986] in the way explained in the introduction. The unique equilibrium of the game is obtained by iterated elimination of the weakly dominated strategies, that is 0.

After this basic framework, some experimental researchers started an investigation area on BCG or "*p-beauty*" (see Ho et al. [1998]). The first experimental study is Nagel [1994, 1995], other works are Bosch and Nagel [1997a,b], Bosch-Domènech et al. [2000], Duffy and Nagel [1997] or Ho et al. [1998]. See also Nagel [1998] for a deeper survey of the literature.

The main aim of Nagel [1994, 1995] was to contrast an iterated best-reply dominance model (IBRD) from the data set (see figure 1).

The several game versions of BCG noted above allow to analyze the concept of iterated dominance, which is an useful tool to study how many rationality levels individuals reach, such as Nagel [1998] says:

> "...BCG is an ideal tool to study how many iterated levels subjects actually apply." (pg. 106).

Generally BCG has been runned with isolated subjects, that is, individuals without communication between them. So, the idea of "cooperation" has not been studied in BCG.

As an example of non-cooperative BCG with isolated subjects, we present figure 3. In this "standard" experiment, participants are colleagues from some departments of economics from Jaén, Vigo, Autónoma of Barcelona and Carlos III of Madrid[2].

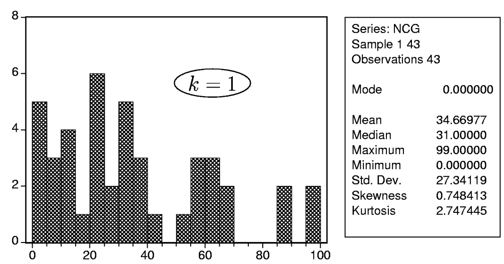

Figure 3: Non-Communication BCG

As we used the mode as the reference signal, a game like this becomes a lottery if some of the subjects are not perfect rational. This result (p=2/3, $n = 43$, mean= 34.6 or $k = 1$ is not better than Nagel [1998] ($p = 0.7$, $n = 3$, mean= 47.88 & for $n = 7$, mean= 46.07) or Bosch-Domènech et al. [2000] ($p = 2/3$; Financial Times: $n = 1468$, mean=18.91, Spektrum: $n = 2729$, mean= 22.08, Expansión: $n = 3696$, mean=16.99).

[2]By e-mail (to implicitly discourage communication), 43 unexperienced experimental subjects were given the instructions and asked to return their responses. At the end of the experiment the (five) winners were paid by a beautiful plant.

So, the mode gives similar results as the average or median when communication is not allowed. We are interested in collusive behavior. Since communication let the agents to estimate a distribution function of their group, if we allow the subjects to talk between them, we can expect an increase in the number of "0"-answers (and a decrease in the average).

This process permits the individuals to learn dynamically from other people expected reasoning behavior. This experiment is quite similar to Ho et al. [1998]. In their design the information is based on the previous period choices. Instead, in our case non formal communication among students generates expectations of behaviors. Therefore, Ho et al. [1998] learning process is based on an evolutive game; ours is an iterative learning game without common knowledge.

But communication *per se* does not guarantee anything, it is necessary the cooperation among participants.

3 The experiment: subjects, design and instructions

3.1 Motivation

In reality, an individual, even if she reaches 0, the theoretical BCG solution, can not be sure she has won because other individuals might not be so intelligent (they would choose a number different from 0) and the order statistic could be bigger than 0. The only way to ensure the victory is to have correct information about other people reasoning levels. But since is not public information, people have to collude if they want to win. Obviously, as this special BCG uses the mode —not the mean— as the statistic, the necessary coalition size to win is only 51% of the total size[3]. Therefore, this design encourages the formation of coalitions, which approximates the "spillover" of IBRD subjects over their classmates.

In this uncertain context, any IBRD student has two options: cooperating or not cooperating.

(1) By "cooperation" we mean that she explains to everybody that 0 is the right answer.

[3]Instead, with the average, specially if the group is small, must be closer to 100%.

(2) She does not cooperate if she does not say anything to anybody (although payoffs are not rival) just because she prefers to be the only winner.

Then, for these IBRD students, the payoffs are: Cooperation, gift for sure. No Cooperation, $p \cdot W + (1-p)L = p \cdot W$ if L=0, being p the probability of winning.

So, any rational agent chooses cooperation[4].

3.2 Subjects

We ran the experiment at the university classrooms, so the subject pool were the typical classroom-attendance pupils. The experiment day was randomly selected.

They are first year undergraduate students in different schools. Table 1 resumes all possible classifications.

code	*school*	*time*	n	*years*
B1–A	Business Studies	1 week	60	5
B1–B	Business Studies	2 weeks	44	5
B1–C	Business Studies	3 weeks	32	5
L1	Law	1 week	11	5
A1–A	Labor Affairs	1 week	44	3
A1–B	Labor Affairs	2 weeks	27	3
M1–A	Management	1 week	18	3
M1–B	Management	2 weeks	50	3
M1–C	Management	1 week	21	3
P1–A	Public Administration	1 week	32	3
P1–B	Public Administration	2 weeks	41	3

Where *code* is the classroom label, *school* is the specific career (Spanish) name, *time* is the period given to answer, n is the group size, and *years* the degree duration.

Table 1: Experimental subjects features

[4]Cooperation could be an egoist behavior, because in this case she ensures a positive payoff, but it also could be originated by an altruistic behavior.

3.3 Instructions

We explained to all individuals in every group the experiment rules: 1) Participants are asked to choose a real number in the interval $[0, 100]$. 2) They had to submit their choices at a certain date. 3) The winner was the person (or persons) whose number is closest to 2/3 of the mode of the elected numbers. 4) Individuals are asked to explain their reasoning process. 5) Communication was not explicitly encouraged. 6) They were given an extra-clue: they are advised that they will notice it when they have reached the solution.

The total sample in our experiment is divided in three treatments, attending to the answering time: one, two or three weeks.

The experiment was explained orally. Payoffs for all the winners were 0,5 extra-points in the final grade of a course selected to run the experiment[5]. The answers were collected in written form at the end of the experiment with a short questionnaire (see appendix A.1) .

3.4 Methodology

Meta-analysis is a quantitative method used to explore the heterogeneity of empirical results and estimate overall outcome measures. In this investigation, the measure to study is the proportion p_i between two variables (defined below), that is, if there are k experimental sessions, each with a sample size n_i, $i = 1, ..., k$, we will obtain k proportions. The analysis of the heterogeneity of the results of the BCG experiments can be done by using a fixed effect model or a random effect model.

The fixed effect model assumes that all the studies have the same proportion,

$$H_0 : p_1 = p_2 = ...p_k, \tag{1}$$

so, it assumes no heterogeneity between the subsamples.

If we found heterogeneity, the proper formulation would be the random effect model. This assumes that proportions are randomly distributed, and

[5] As we needed an academic reward for the experiment, it was necessary the collaboration of some colleagues ready to give some extra points to the winners. Therefore, our students are only from the Social Science Faculty, which seems to signal a higher degree of competitiveness (even for the teachers!) in the other faculties.

typically, it follows the univariate normal distribution. Hence, this model includes two sources of variation, the inter and intra groups variance.

So, to test whether it is reasonable to assume that all the samples are estimating a single underlying population parameter, and whether variation obtained in the estimations seems to be distributed randomly, we consider the following test statistic:

$$Q = \sum_{i=1}^{k} w_i \left(p_i - \overline{y}_w\right)^2, \tag{2}$$

where,

$$\overline{y}_w = \frac{\sum\limits_{i=1}^{k} w_i p_i}{\sum\limits_{i=1}^{k} w_i} \tag{3}$$

is the weighted estimator of proportion mean and w_i is the inverse of variance of the estimated proportion in the ith sample:

$$w_i = \left(\frac{p_i\left(1-p_i\right)}{n_i}\right)^{-1}. \tag{4}$$

Q is approximately distributed as a χ^2 distribution on $k-1$ degrees of freedom under H_0.

We use the method of DerSimonian and Laird to derive random effects summary estimates for the proportion mean. The random effects estimates are weighted averages of the estimated proportions. The weights w_i^* are based on the corresponding fixed effects weights and the Q statistics,

$$\overline{y}_w^* = \frac{\sum\limits_{i=1}^{k} w_i^* p_i}{\sum\limits_{i=1}^{k} w_i^*}, \quad w_i^* = \frac{1}{\left(D + \frac{1}{w_i}\right)}, \tag{5}$$

being

$$D = Max\left\{0, \frac{\left(Q-(k-1)\right)\sum\limits_{i=1}^{k} w_i}{\left(\sum\limits_{i=1}^{k} w_i\right)^2 - \sum\limits_{i=1}^{k} w_i^2}\right\}. \tag{6}$$

The inter-study variation in the outcome measure, $\hat{\sigma}^2$, is calculated as

$$\hat{\sigma}^2 = \begin{cases} 0 & \text{if} \quad Q \leq k-1, \\ \frac{(Q-(k-1))\sum_{i=1}^{k} w_i}{\left(\sum_{i=1}^{k} w_i\right)^2 - \sum_{i=1}^{k} w_i^2} & \text{otherwise.} \end{cases} \tag{7}$$

The Q is also the basis for testing if the random effect model is proper. If all samples have the same proportion, then their variance is 0 and $\sigma^2 = 0$. So, testing the null hypothesis $H_0' : \sigma^2 = 0$ is equivalent to test H_0 in equation (1).

4 Results

4.1 Descriptive Analysis

Along this section we will compare the data set from our (eleven) tests. Figures 4 to 13 explore the several communication games (see also appendix A.2). This data sets let us obtain some preliminary ideas.

If we compare communication with no communication games (see the example in page 4, figure 3) it is clear that, in the former ones, observations are concentrated around the theoretical game solution; however, responses are widespread along the entire interval in the latter.

So, in the non-communication game the average is 34.6, that is, a reasoning level of $k = 1$; in the other cases, we obtain levels from 0 to infinity:

- $k = 0$ for A1–B (mean 50.5),
- $k = 3$ for groups B1–A, B1–B and A1–A (means 20.7, 21.6 and 21.5 respectively),
- $k = 4$ for P1–A (mean 12.5),
- $k = 5$ for B1–C and P1–B (means 8.2 and 7.7),
- $k = 6$ for M1–A (mean 5.0),
- $k = 7$ for M1–B (mean 4.2),
- $k \rightsquigarrow \infty$ for M1–C (mean 0.23) and,

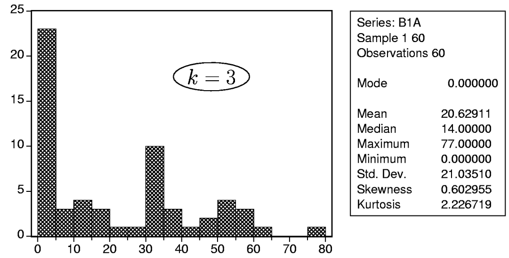

Figure 4: Results from B1–A

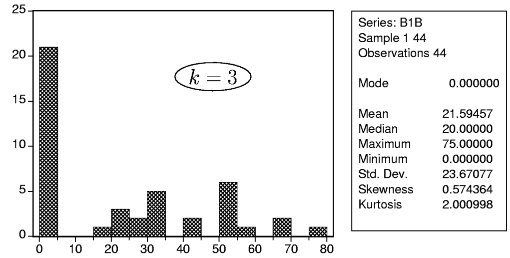

Figure 5: Results from B1–B

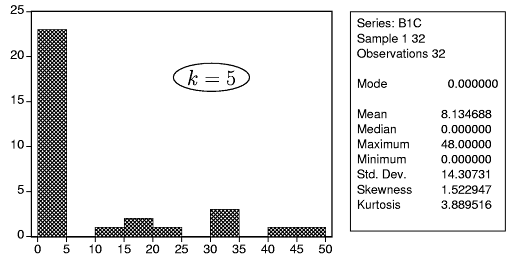

Figure 6: Results from B1–C

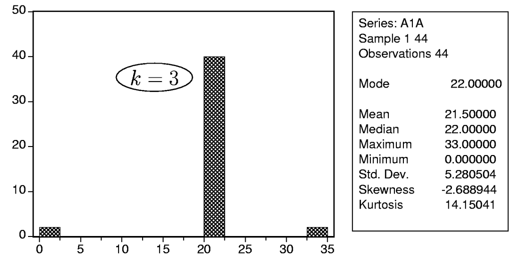

Figure 7: Results from A1–A

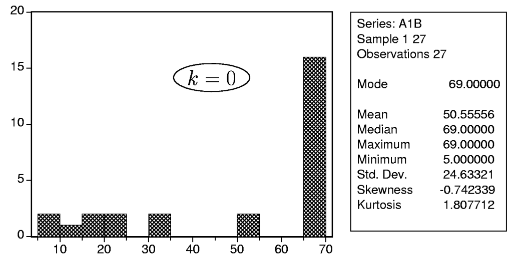

Figure 8: Results from A1–B

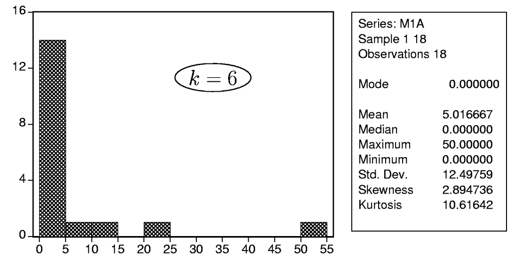

Figure 9: Results from M1–A

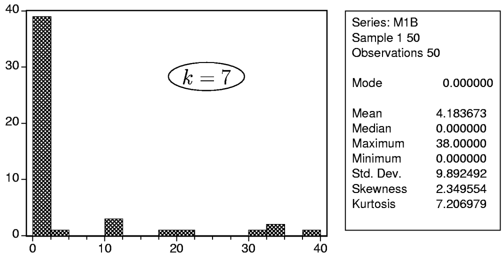

Figure 10: Results from M1–B

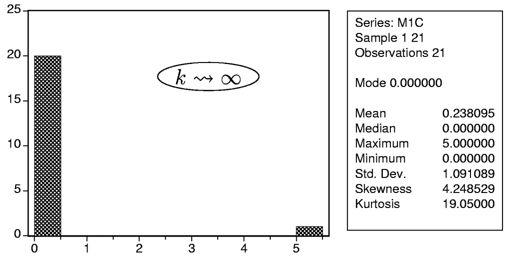

Figure 11: Results from M1–C

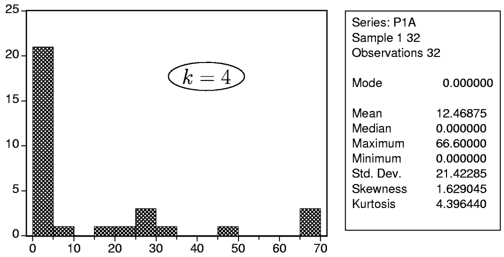

Figure 12: Results from P1–A

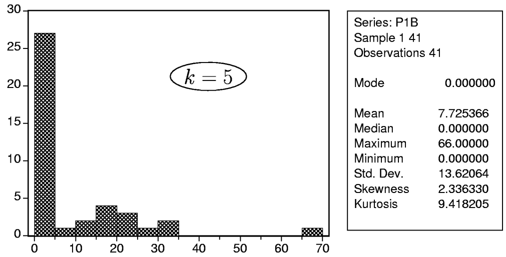

Figure 13: Results from P1–B

- $k = \infty$ for L1.

Only one classroom shows an inferior reasoning level than NCG.

Outcome 1 *Communication induces deeper reasoning levels. Clever students generate an informational spillover onto their classmates.*

If we classify reasoning level by time to answer, we do not find in one week experiments (B1–A, A1–A, M1–A, M1–C, P1–A and L1), two weeks (B1–B, A1–B, M1–B and P1–B) and three weeks (B1–C) any clear difference in k, even it is possible to see an inverse pattern.

Outcome 2 *In contrast to Bosch-Domènech et al. [2000], in our ample time span we do not observe differences in rationality of people.*

Now we will take a close look at the $[0, 10]$ interval [see Bosch-Domènech et al., 2000, pags. 16–17, for an empirical support in a similar approach], so we take the $k = 4$ reasoning level as our “smart” limit. We can observe that only 18% of the individuals in the non-communication game (figure 3) are included in this interval; this is a sensible result because, since there is not communication between agents, we only test the individual reasoning level of each experimental subject. The empirical data from previous literature [Nagel, 1998] shows that there are very few observations of reasoning levels higher than two, independent of the number of the required iterations steps.

In the communication games these percentages are quite high: 100% in L1, 95.2 % in M1–C, 77.7% in M1–A, 77.5% in M1–B, 75.2% in B1–C, 65.8% in P1–B, 65.6% in P1–A, 48.1% in B1–A, 47.6% in B1–B, 7.4% in A1–B and 4.5% of "genius" in A1–A. If we do not consider the last two groups, it is evident that communication improves general knowledge. In this case, we observe an informational spillover generated by some clever students. In the other two cases, students from Labor Affairs school[6], we observe some (at least) funny results.

Figure 7 shows an interesting and inconsistent behavior. One person became a wrong "leader". When we went to collect the answers, she cried out "write down 22" and everybody followed her. Nobody noticed that $2/3 \cdot 22$ was a better option. Only two people got the right theoretical solution, but 22 was closer to $2/3 \cdot 22$ than 0; so all the people who said 22, won the game! Although, we find an interesting idea: *sometimes reputation is more important than rationality.*

Figure 8 is even more strange, most of the classroom decided to concentrate at a point (69) far from any focal position, but there were two persons who chose randomly 50, so they acted like involuntary "smart" (traitors) leaders, winning the game.

Outcome 3 *In the absence of any brilliant individual (in the collective), communication does not guarantee any improvement in the average level of reasoning.*

But, the remaining question is: why 5 years degree students in business (with higher training) got worst results than 3 years management and public administration ones?

4.2 Does competition matter?

Comparing results from different sessions we observe that, in this order, Law and Management students were the cleverest. But business students (the only

[6]These students have a low morale in Spain, maybe, this could be a good explanation for the Spanish unemployment!

groups with game theory training) did not get good results, why? Could the competition level be a possible cause of such a disaster?

Analyzing the questionnaire introduced in the "answer sheet" (see Appendix, page 17, items 3 to 5) —in which we asked them for explain their reasoning process— we find some interesting ideas that we can combine with the available information from the eight experiments finally selected[7]. With that aim, we perform a meta-analysis on the competitive behavior of subjects using some measures-summary of each experiment. As a measure of collusion among subjects we have defined the next index:

$$\text{Collusion Index } \equiv CI \equiv \frac{Leaders + Followers}{Population}, \tag{8}$$

our intelligence indicator is the "brilliant" people index:

$$\text{Brilliant Index } \equiv BI \equiv \frac{Leaders + Isolated}{Population}, \tag{9}$$

where *Leaders* is the number of persons that guess the right number and share it with other people (in our questionnaire they answered Yes to # 3 and # 5, also they gave a "correct" explanation of IBRD process in # 4); in the opposite, *Isolated* do not share it although they have reached it (that is, in # 4 the answer is right and they said Yes in # 3 but Not in # 5); *Followers* are the persons who have received the right answer from any leader (they recognized in # 3 that they did not); *Population* is the total sample in each session[8].

Table 2 shows the results for the homogeneity analysis of both indexes. The first column represents the indexes as defined above; the second, the Q-statistic used to test the homogeneity between groups; third, the probability limits of acceptance of the null hypothesis and the last one, shows if we accept the homogeneity of the groups at a significance level of $\alpha = 0.05$.

The first important result we get is that BI is homogeneous across the different groups. The Q-statistic value is 10.05 and the p-value is 0.185. Therefore, with $\alpha = .05$, we ought to accept the homogeneous distribution of this index.

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[7] Communication game is used only as a benchmark; Group L–1 is excluded because "Political Economy" is an optional (non-compulsory) subject; groups A1–A and A1–B have been excluded because we are only interested in cooperation that arrives at the theoretical solution.

[8] For a deeper explanation see the working paper, Brañas Garza et al. [2001].

Outcome measure	Q statistic	p-value	Homogeneity
CI	54.2302	$2.1177 \cdot 10^{-9}$	No
BI	10.0572	0.1853	Yes

Table 2: Homogeneity tests for collusion and brilliant indexes

Outcome 4 *Intelligence is equally distributed among schools.*

Fortunately, we find that there are significative differences in the collusion level (CI) between groups. Concretely the value of the Q-statistic is 54.23, and the p-value $2.1177 \cdot 10^{-9}$. So, we can conclude that the CI doesn't show a homogeneous distribution among the eight groups studied. Next, we are going to analyze in deep this heterogeneity taking into account some features of each group (see table 1): answering time, degree, population size[9] and school.

Table 3 shows the results of the homogeneity analysis of CI under these labels. The first column displays the categories of each attribute; the second, the Q-statistic value of the homogeneity test; the third, the probability limit to accept that all groups in each category are homogeneous and finally, we show the suitable model for each case, that is, the fixed effects model if homogeneity is accepted and the random effects model if is rejected at a significance level of $\alpha = 0.05$.

First of all, we have divided the total observations onto two groups according to the time given to return the answers, one week and more than one. The difference between these two subpopulations is not significative. The time to answer has not a clear influence on the collusion level of the participants. There exists heterogeneity in the collusion index within each group but the averages are very similar between the two groups . Therefore, we cant say any concluding remark related to the answering time effect.

Outcome 5 *The answering time is irrelevant for the collusion level achieved in all groups.*

Focusing on degree, three years degree students (P1–A, P1–B, M1–A, M1–B and M1–C) are homogeneous in their low level of competition ($1-0.65$); five years students (B1–A, B1–B, and B1–C) do not display any similarity. So,

[9] We have labeled each group as > 35 or ≤ 35 peoples sample.

Subpopulations identification		Q-Statistics	p-value	Modelling
Time to answer	1 week	34.9857	$1.2267 \cdot 10^{-7}$	R. E. $\begin{cases} \overline{y}_w^* = 0.5557 \\ \hat{\sigma}^2 = 0.0714 \end{cases}$
	more	18.1018	$4.188 \cdot 10^{-4}$	R. E. $\begin{cases} \overline{y}_w^* = 0.5217 \\ \hat{\sigma}^2 = 0.0276 \end{cases}$
Degree	3 years	8.4825	0.0754	F. E. $\overline{y}_w = 0.6581$
	5 years	7.2738	0.0263	R. E. $\begin{cases} \overline{y}_w^* = 0.3544 \\ \hat{\sigma}^2 = 0.013 \end{cases}$
Population size	> 35	34.8425	$1.31 \cdot 10^{-7}$	R. E. $\begin{cases} \overline{y}_w^* = 0.4491 \\ \hat{\sigma}^2 = 0.0463 \end{cases}$
	≤ 35	5.9825	0.1124	F. E. $\overline{y}_w = 0.6419$
School	BS	7.2738	0.0263	R. E. $\begin{cases} \overline{y}_w^* = 0.3544 \\ \hat{\sigma}^2 = 0.013 \end{cases}$
	M	1.7294	0.4211	F. E. $\overline{y}_w = 0.6715$
	P	6.5794	0.0103	R. E. $\begin{cases} \overline{y}_w^* = 0.6587 \\ \hat{\sigma}^2 = 0.0374 \end{cases}$

Table 3: Testing homogeneity (CI) among groups features.

the former are less competitive than the latter ones, as the average collusion levels indicate: 0.6581 vs. 0.3544.

About group size, the smaller groups (≤ 35) show a higher average collusion index (0.64) and homogeneity within them. However, the bigger groups (> 35) have heterogeneous behavior, being the average index lower (0.44). So, larger size means smaller cooperation.

Outcome 6 *According to general intuition, classroom size seems to be relevant in the competition level.*

Finally, if we discriminate by school, we only find homogeneity in the management school, with a mean 0.67. Public Administration and Business Studies schools are heterogeneous within them. Moreover, note that the average collusion index in BS is notably lower (0.35) than in the others.

Outcome 7 *Five year degree students are a bit more competitive than three year ones. But, the latter are equally cooperative.*

5 Conclusion

In all the previous experimental literature on beauty contest games it is assumed that players think they are more intelligent that the rest, that is the reasoning level of the others is lower than theirs. Our data set confirms this pattern of conduct.

As our main purpose was to find collusive behavior, we use the mode to give them the proper incentives to get this result. So we design a experiment on which subjects are allowed to communicate between them, using several answering times. With that, we attempted to contrast if the existence of communication among subjects is an important element to reach the theoretical solution in an one-shot mode-BCG.

The main conclusions of our experiment are the following:

First, a deeper reasoning level is more likely to be found with communication, that means brilliant agents have a positive spillover effect on other people.

Second, there are different levels of competition among students. The more significative cause of heterogeneity in competitiveness is due to the rivalry inherent in each career.

With the above results, communication could be interpreted as a part of a reasoning process. Following evolutive rationality proposals, like Hayek [1937], we have found that individuals that interact obtain better results because they have better information, but also because interaction with other people let them have a deeper reasoning level than is usual with an individualistic rule.

Result 1 *In non-competitive groups, the spillover effect of intelligent individuals is higher than in competitive ones, but this spillover effect only appears if at least exists one intelligent individual.*

Result 2 *Communication is efficient if there is heterogeneity on agents rationality. In pure competitive groups, there are not differences in outcomes between communication and non-communication games, so the reasoning level of the group is the average of individuals as obtained in Nagel [1998].*

	Isolated	Leaders	Followers
B1–A	4	6	9
B1–B	4	3	11
B1–C	2	6	11
M1–A	0	2	8
M1–B	3	4	32
M1–C	3	4	13
P1–A	1	1	19
P1–B	4	4	17

Table 4: Distribution of right answers on each group

A Appendix

A.1 Questionnaire

Translation of the questionnaire introduced in the answers sheet:

1 Name:

2 Selected number:

3 Did you get the solution alone? Yes/Not

4 If Yes, could you explain the reasoning process that you performed?

5 Did you explain it to anybody? How many?

A.2 Results Table

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