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Are individuals with higher cognitive ability expected to play more strategically?

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Abstract

This paper experimentally analyzes the relationship between cognitive abilities and strategic behavior. In our experiment, individuals play in a sequential game where computing the equilibrium is challenging. After playing the game, we measure the individual's cognitive ability using the Raven's test. The results we obtain reveal that the number of strategic decisions (played in the sequential game) increases significantly among the individuals with higher cognitive ability (measured by the Raven's test), as compared to those with lower cognitive ability. These results confirm that individuals with higher cognitive abilities play more strategically.

Keywords: Strategic Behavior, Cognitive abilities, Raven test, Experiments.

JEL classification: A12; C72; C91

1 Introduction

This paper leads to the research about the relationship between cognitive ability and economic behavior. Cognitive abilities are brain-based skills people need to perform any task from the simplest to the most complex. They have more to do with the mechanisms of how individuals learn, remember, solve a problem, and pay attention rather than with any actual knowledge. Even though this concept is quite broad, it seems sensible to think it is related to strategic behavior as a way to understand learning, information acquisition, and many other abilities that an economic agent should manage to act in strategic environments. There is a significant literature on cognitive ability and economic behavior that corroborates this link, although not always reaching the same conclusion. On the one hand, studies of simple bargaining games report an inconsistent relationship between agents' behavior and cognitive ability (Brandstätter and Güth, 2002; Millet and Dewitte, 2007). On the other hand, in repeated prisoner's dilemmas, a meta-study reports higher levels of cooperation in universities that admit students with high-standardized test scores (Jones, 2008). Cognitive ability scores have a high predictive power for individuals' behavior, which is central to economics. These for example include correlations between cognitive ability and wages, education, employment, and occupation (Cawley et al., 2001), as well as smoking, illegal drug use, and teen pregnancies (Heckman et al., 2006). Furthermore, Warner and Pleeter (2001), in a study on retirement decisions found that lower cognitive ability was correlated with a preference for lump-sum payments over annuities at discount rates of up to 30%. However, this controversial relationship might be explained by the fact that the tests used were designed to predict real world outcomes (Geary, 2004).

This paper contributes to the literature on cognitive abilities and strategic behavior. Within this literature, see for example Cokelly and Kelly (2009), Bayer and Renou (2011), Dufwenberg et al. (2010), Gneezy et al. (2010), Levitt et al. (2011), Carpenter et al. (2013), to name just a few.[1] A common factor in many of these studies is that they use games solvable by iterated deletion of strictly or weakly dominated strategies. Likewise, the ability of individuals to perform complex chains of reasoning is associated with their ability to iteratively delete dominated strategies. Carpenter et al. (2013), Gneezy

[1]Further studies on the relationship between strategic behavior and cognitive abilities are Al-Ubaydli et al. (2014), Allred et al. (2014), Baghestanian and Frey (2015), Bayer and Renou (2012), Brañas-Garza et al. (2011), Brañas-Garza et al. (2012), Burks et al. (2009), Kiss et al. (2015), and Jones (2008, 2014), among others.

et al. (2010), Dufwenberg et al. (2010), and Levitt et al. (2011) use versions of the Race Game[2] to examine inductive reasoning and document the diverse ability of participants to play optimally. These papers find a strong correlation between cognitive ability and sophistication in a game of iterative dominance. They also point that similar results arise in a game requiring induction. Furthermore, Bayer and Renou (2011) find that subjects with better cognitive abilities display a more sophisticated behavior. Cokelly and Kelly (2009) in a framework in which individuals have to take decisions under risk, find that individuals with better cognitive abilities make more choices consistent with expected values.

Bearing all these results in mind, we focus on dynamic mechanisms of perfect information, i.e. frameworks where individuals know all previous moves when their turn to make a decision comes. In this setting, a subgame perfect Nash equilibrium can be computed by backward induction. Even though backward induction may simplify the computation of subgame perfect Nash equilibria, backward induction might be troublesome when the game involves multiple stages, see Binmore et al. (2002) and Levitt et al. (2011). Therefore, to simplify the analysis of individual's strategic behavior we use a one-shot sequential game (see Benito et al., 2015, for details), in which each participant only makes a decision in each game. This sequential game is based on Schelling (1969) segregation model, and has two remarkable properties. On the one hand, in this game it is straightforward to explain the rules that govern the dynamic situation that players face. On the other hand, to compute the equilibrium path is complex. This game considers a society composed by 8 individuals of two types: four individuals are assigned the black type (B) and four are assigned the white type (W). These individuals are distributed along a ring (representing the society) with the following initial configuration: {B, W, B, W, B, W, B, W}. The first ring in Figure 1 illustrates the initial configuration. Let us denote the individuals as their initial location starting from the left to the right and assume that each individual in the society would accept up to 50%

[2]See Conway (2001) for a description of the Race Game.

of unlike neighbors, over a neighborhood composed by one individual at each side, when achieving her first best outcome. Through these parameters we determine whether an individual is happy (if the number of neighbors like her is larger than or equal to one) or unhappy (if the number of neighbors like her is zero). From the initial configuration of the society, unhappy agents may move in turns, starting from the left, to the nearest place at their right that fulfills their neighborhood configuration demands.[3] However, if an individual moves, she has to pay a moving cost of $C \in \{0, 5, 20\}$ Euros.[4] Not moving implies that the individual pays no moving cost. Then each player has two possible actions: either staying at her initial location or moving to the nearest space with a neighbor of her same type. In this game, each agent has an initial endowment equal to the moving cost C. If the agent ends up with at least one neighbor like her, she gets an extra payoff of 50 € (without taking into account the moving costs). Unhappy agents do not receive any payoff, but they have to pay the moving cost if they decided to move when their turn came. Within this framework, Benito et al. (2015) show that with moving costs, there exists (a unique) Subgame perfect equilibrium in pure strategies in which all individuals are happy, in which only players initially in positions 4 and 8 move ($C > 0$). When the moving cost is zero (when $C = 0$), there are two equilibrium paths: one that coincides with the game with positive moving costs; and, another that emerges when players at positions 1, 4 and 7 move. Figure 1 illustrates this equilibrium path. Following Benito-Ostolaza and Sanchis-Llopis (2014), we use Benito et al. (2015) experimental game to analyze individuals strategic behavior.[5]

The moving cost C defines three different frameworks: one without moving costs ($C = 0$), one with low moving costs ($C = 5$) and one with high moving costs $C = 20$). Within these three scenarios we define as strategic decisions those in which an unhappy player decides to stay when her best response is to stay, (for example positions 1, 2, 3

[3]By "nearest" we mean a place reached by passing the smallest number of neighbors in the way.

[4]We have three schemes, one without moving costs ($C = 0$) and two with moving costs ($C = 5$ or 20).

[5]Benito et al. (2015) show that not many agents play the equilibrium path.

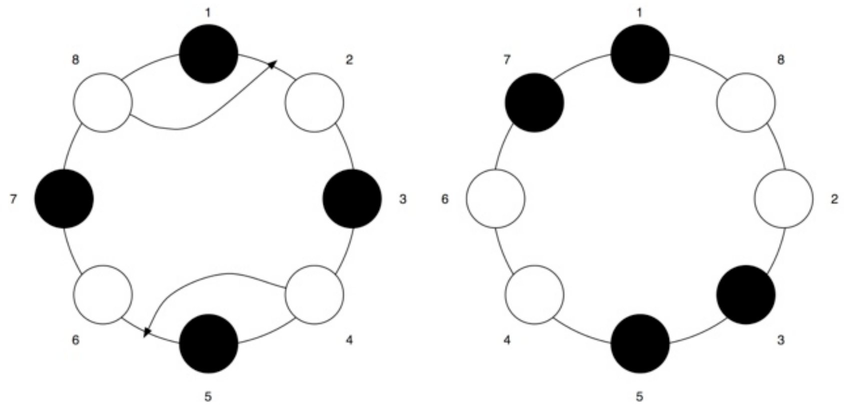

Figure 1: Nash equilibrium in a game with 8 players.

and 7 in figure 1). This decision distinguishes the most sophisticated behavior from all other best responses that an agent may take in the course of the game. More precisely, in general, each agent may face two possible situations: a situation in which she is already happy and a situation in which she is not. In the first case, the best response is just to stay in the same location. We characterize this behavior as a non-sophisticated one, even being the best response in that situation. For instance, if the agent at position 1 moves between agents 2 and 3, automatically all become happy as agent 2 (who is of the white type) would be next to agent 8 (who is also a white type agent) and agent 3 (who is of the black type) has agent 1 next to her (who is also a black type agent). As a result, the best response for both agent 2 and agent 3 would be to stay, as they are already happy. When an unhappy agent faces her best response, she may be either move to the closed position satisfying her "happiness condition" or stay at her location. For the first case, for sure, she becomes happy after her decision. Nevertheless, the second case implies a more sophisticated way of thinking with several assumptions of rationality. Namely, she should compute by backward induction the best reply for the rest of agents after her. Moreover, she would assume that all of them behave rationally. Therefore, when we define this second case as strategic behavior, we are clustering the most sophisticated performances. This cluster would be used to disentangle the relation between strategic behavior and cognitive skills.

To measure the individual's cognitive ability we use Raven's Progressive Matrices, often referred as Raven's Matrices or Raven's Test. The test consists of multiple-choice intelligence tests for abstract reasoning, originally developed by Dr. John C. Raven in 1936, (Raven, 1936). In each part of the test, the subject is asked to identify the missing item that completes a pattern (see Brañas-Garza et al., 2012, for detailed information). Each Raven's test has the same format: it is a 3 x 3 matrix in which the bottom right entry is missing. The individual undertaking the test has to select the missing element in the matrix from 8 possible alternatives provided. Solving Raven's matrices type problems essentially requires figuring out the underlying rules that explain the progression of shapes. In figure 2 we plot an example of these matrices. The final score is a measure of the individual's ability for abstract analytical reasoning and fluid intelligence, that is, a type of ability that does not rely on knowledge or skills acquired from experience as opposed to crystallized intelligence (see Horn and Cattell, 1966). One of the main reasons for using the Raven's Test is that it is a "non-cultural", "non-verbal" and "non-manual" test. The fact that the test is "non-verbal", means that it can be used with individuals with different language, education and verbal ability. "Non-manual" means that it can be applied regardless of the status or motor skills of the person being tested. And, finally, "non-cultural" implies that knowledge acquired through education is not decisive for its application. In addition, the Raven's Test is classified as a factorial test (Spermann, 1904) within the psychometric research. This research aims to achieve the maximum possible saturation of the "G" factor.[6] Therefore, we can consider that the Raven's test measures an individual "G" factor.

Acknowledging that agents have distinct cognitive abilities (as measured by Raven's test), this study focus on verifying whether individuals with higher cognitive abilities play more strategically. For this purpose we use data from a previous experiment

[6]The "G" factor is a construct developed in psychometric investigations of cognitive abilities that measures general intelligence, which can be considered as an individual endowment independent of culture and other environmental issues.

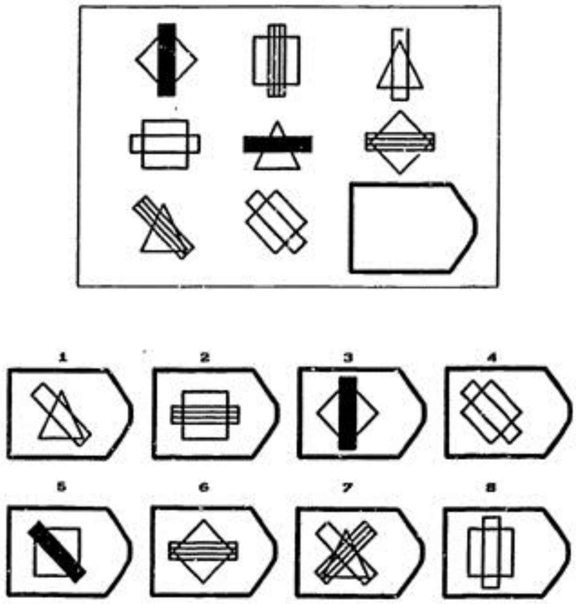

Figure 2: Example of a pattern in the Raven's Test.

(Benito-Ostolaza et al., 2015) to analyze how strategic behavior varies across cognitive abilities at the individual level. In our experiment, individuals play a sequential game where calculating the best reply at each decision stage might be very demanding. To measure individual cognitive ability agents provide information on the Raven's test after playing in the game. With this information at hand we analyze the different (strategic) behavior between individuals with different cognitive abilities.

To summarize our contribution to the existing literature, our results are in line with those obtained in previous studies where cognitive ability is a key factor for playing strategically. We add to the literature a new framework for analyzing the link between cognitive ability and strategic behavior that was not studied previously. We find that individuals playing in a one-shot sequential game with multiple players, the number of strategic decisions significantly increases for agents with high cognitive abilities, in terms of the Raven's test, in contrast to agents with low cognitive abilities, confirming our initial hypothesis.

The remainder of the paper is as follows. Section 2 presents the design and implementation of the experiments and the equilibria predictions. Section 3 analyzes the results, and Section 4 lays out the main conclusions.

2 Design of the experiment

2.1 Schelling game

In what follows we explain the design of the experiment of the Schelling game (this experiment is similar to Benito et al., 2011 & 2015). To ensure that subjects playing have a preference for like neighbors in their neighborhood (that make them happy), agents get 50 € if they end up in a neighborhood where at least one of their adjacent neighbors (either to the left or to the right) is of their same type (black or white) by the end of the game. In the case that none of the adjacent neighbors is of their same type by the end of the game, subjects receive 0 €, as we consider that this individual is unhappy in that neighborhood. We organize individuals into groups of eight around a circle (which represents the society). To initially allocate all participating individuals in each circle, we follow a random sorting scheme where the first individual is assigned the black type, the second individual the white type, and so on. Thus, the initial configuration in each circle is $\{B, W, B, W, B, W, B, W\}$ (see the first circle of Figure 1), where each subject's type is easily identifiable by a black/white scarf. Notice that in the initial configuration nobody is happy. Therefore, subjects will have the opportunity to either stay or move, from their original location, when their turn comes. Each individual has an initial endowment of $C \in \{0, 5, 20\}$ €. This endowment has to be given up should the player decide to move to a neighborhood she likes better (with at least one neighbor of her type). The moving costs C define three different frameworks we use in the experiment: one without moving costs ($C = 0$), one with low moving costs ($C = 5$) and one with high moving costs ($C = 20$). As stated above, we capture the individual's utility function through a fixed prize that might be earned if a subject ends up with a like neighbor (50 €). Thus,

- Subject 1 may decide to stay or to move, paying the moving cost of C € if she moves;
- After subject 1 has taken her decision, subject 2 (to the left of subject 1) faces an identical decision problem;
- Then subject 3 faces the same decision, etc.

The way we introduce moving costs in the experiment is very simple: we place the money on the floor in front of each subject (subjects can see a C € bill at their feet). Players are informed that they would loose this money should they decide to move. The analogy with real life is quite obvious: you leave your home or friends behind when you move.

Individuals play five rounds in the game without moving costs ($C = 0$). In the treatments with moving costs, $C \in \{5, 20\}$, in addition to the 5 rounds, we run another additional 5 rounds.[7] In each round a random device replaces subjects in new positions (and therefore the color of their scarves changes accordingly). In the experiments we randomly select two out of eight participants in each circle (society) to be paid. Therefore, in each game:

- An individual might earn 0 € if she ends up unhappy (without any neighbor like her) and has moved, or C € if she ends up unhappy and has not moved.
- If she ends up happy (in a neighborhood with at least one neighbor like her) she earns 50 € if she has moved or $50 + C$ € if she has not moved.

In summary, two out of the eight participants are randomly selected to be paid 0 €, C €, 50 € or $50 + C$ €, depending on her situation at the end of the selected round.

[7]We repeated the game in order to increase the number of observations in our analysis. This repetition is done using a surprise restart. We do not change the rules or any other aspect of the game. Our results indicate that there is not any impact on the results (between the two sessions) and therefore we pool the data across the 2 sessions (10 rounds) in our empirical analysis.

2.2 Raven

In the Raven's test, each agent faces a pool of 60 matrices. In each of these matrices or tests, the subject is asked to identify the missing item that completes a pattern, as in Figure 2.

2.3 Implementation

The experiments were implemented at the School of Economics of the University of Granada (Spain) on April 20th, 2009.

In particular, we had 6 societies for each treatment (no moving costs, low and high moving costs) with 8 subjects in each society or ring. We ran 5 sessions for framework without moving costs and 10 sessions for the low and high moving costs frameworks. Overall, we had a total of 144 participants (8 subjects $\times$ 6 societies in 3 frameworks). These participants were randomly recruited from a sample of 191 subjects who signed up to participate in the experiment.

All the experimental sessions were conducted the same day simultaneously. Experimental subjects were randomly assigned to each society/ring and they stayed in the same ring during the whole experiment. Seventeen associate professors, teaching assistants and Ph.D. students (working in experimental economics) monitored the sessions. The monitors received identical training and had the same instructions booklet[8] (including random assignments for each round, payoffs scheme, etc.).

As explained before, the baseline treatment, $C = 0$, was repeated 5 times, therefore it provided information on 5×6 societies ($5 \times 6 \times 8 = 240$ individual data or observations). For treatments with costs, $C = 5$ and $C = 20$, we repeated the experiment after a surprise re-start, and therefore we have information on $(5{\times}6){\times}2$ societies ($(5{\times}6{\times}8){\times}2 = 480$ observations) in both treatments. Table 1 shows the number of experimental data per treatment.

[8] A copy of the instructions booklet is available upon request.

Table 1: Summary of treatments & observations

	sessions	rounds	repetitions	societies	Observations
$C = 0$	6	5	0	25	240
$C = 5$	6	5	1	60	480
$C = 20$	6	5	1	60	480

Finally, we would like to note that before starting the real game, subjects played two trial rounds to make sure that they understood the structure of the game.

After playing in the Schelling game each individual answered the Raven's test in the computer room. The number of observations we have from the Raven's test coincide with those reported in Table 1. The whole experiment lasted 2 hours and the average earning was 30 €.

3 Results

This section presents the results on individual behavior for the two environments (without and with moving costs) described earlier. The objective of this research is to study whether cognitive abilities and strategic behavior are related. We will combine the information on the strategic moves made by individuals (in the games they have played) and their cognitive abilities (measured through the Raven's test).

Our strategy to test our working hypothesis is undertaken in two steps. In the first one we present the results for the games without moving costs (our baseline). In a second analysis, we focus on the results of the games with moving costs. In both cases individuals are classified in 5 categories according to their cognitive ability in the distribution of Raven values: individuals with the lowest cognitive ability (those in the lowest 10% of the Raven's test distribution), individuals between 10-25%, individuals between 25-50%, individuals between 50-75% and, finally, individuals with the highest value, those above 90%.[9]

3.1 Results for the game without moving costs

We start our analysis with the game without moving costs. In this case we obtain that the proportion of individuals behaving strategically is only statistically different for those individuals with a Raven's test between 50-75% at a 10% level of significance (see Table 2). However, none of the differences across the Raven's test categories is significant using the Bonferroni correction for the p-value. Therefore, we find no significant difference in the strategic behavior across the Raven's test distribution. We would like to note that playing strategic is rare in a context of no moving costs. Theorem 1 in Benito et al. (2015) presents the subgame perfect equilibrium for $C = 0$. Actually, at any node of the sequential tree game where the agent is unhappy, "to move" is always a best response. Moreover, the same equilibrium path for $C > 0$ is as well an equilibrium path for $C = 0$. Therefore "best response" is everything except "to stay" when the agent is unhappy. The multiplicity of equilibria when $C = 0$ makes it an inappropriate case to study strategic behavior.

[9] We have used other classifications for the Raven's test results, but changing the categories does not alter the results reported in this paper.

Table 2: Test for the different proportions of strategic players across cognitive ability categories (games without moving costs).

	Difference	p-value
Raven's test below 10%	-0.065	0.383
Raven's test 10-25%	0.062	0.251
Raven's test 25-50%	0.059*	0.052
Raven's test 50-75%	0.010	0.740
Raven's test above 90%	-0.064	0.156

Notes:

1. *, means significant at 10% level of significance. However, using the Bonferroni correction none of the difference would be statistically significant.
2. The number of observations is 240.

3.2 Results for the games with moving costs

The results for the games with moving costs[10] indicate that the percentage of agents playing strategically is higher among those individuals with high values in the Raven's test (specially for values equal or higher than 50%). In Figure 3, we show the percentages of strategic players across the different categories of the Raven's test. In each pair of bars (in black and grey), we distinguish between the proportion of strategic players with a Raven's test score below the threshold (grey bar) and those above the threshold (black bar). We see that the proportion of strategic players increases for individuals above the threshold across the 5 categories in which we have classified the scores of the Raven's test. However, the proportion of strategic players below the threshold decreases across the 5 categories of the Raven's test.

[10]In these games agents have to pay 5 € or 20 € if they decide to move from their initial location to a place where they are happy, i.e. with at least a like neighbor.

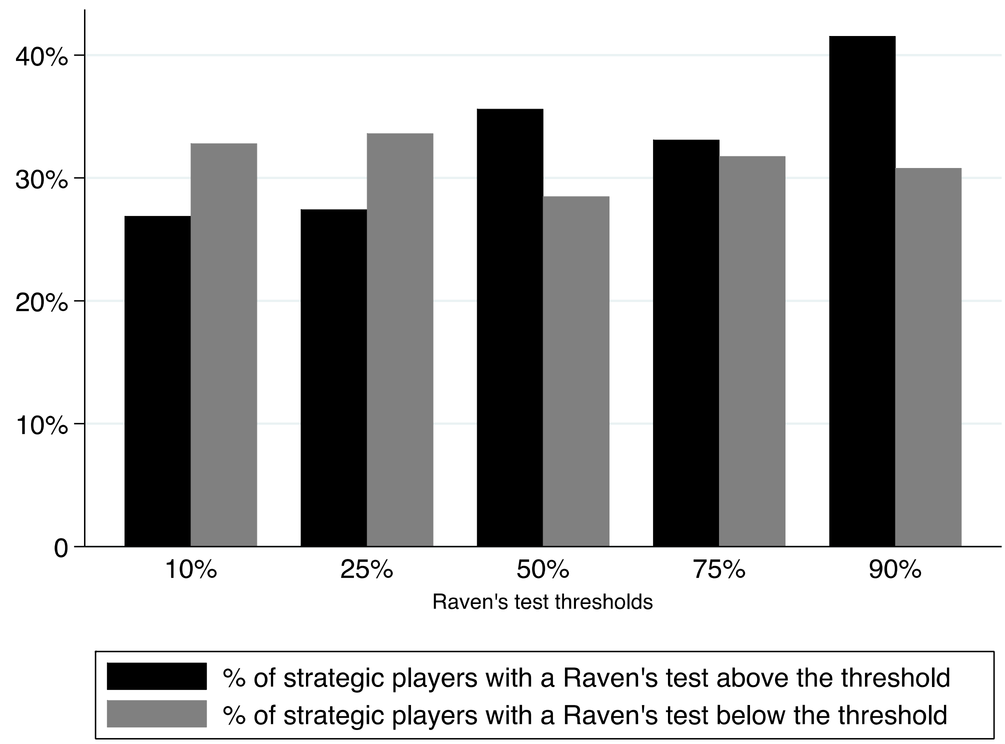

Figure 3: Proportion of strategic decisions across different cognitive ability categories.

In Table 3, we present the differences in proportions of strategic players for each of the 5 categories we have classified the players (according to the Raven's test scores). As it can be checked, the differences for categories 1 and 2 (the lowest levels of the Raven's test) are not statistically significant. However, for the 3 following categories (those with levels of the Raven's test above 25%) we get that in two cases (categories 3 and 5) the differences are statistically significant (these differences remain significant using the Bonferroni correction for the p-value). Further, the difference in strategic behavior in category 5 is higher (and statistically significant) than the one in category 3, indicating that strategic behavior is related to high levels of cognitive abilities and that the proportion of players playing strategically increases with the score of the Raven's test (that measures cognitive abilities of the individuals). These results confirm the working hypothesis of this research.

Table 3: Test for the different proportions of strategic players across cognitive ability categories (games with moving costs).

	Difference	*p*-value
Raven's test below 10%	0.059	0.211
Raven's test 10-25%	0.062	0.080
Raven's test 25-55%	0.071***	0.018
Raven's test 50-75%	0.013	0.690
Raven's test above 90%	0.107***	0.018

Notes:
1. *** means significant at 1 % level.
2. Results for Categories 3 and 5 remain significant at a 9 % level using the Bonferroni correction.
3. The number of observations is 960.

All in all, the results obtained for the games without moving costs and the games with moving costs confirm our working hypothesis: high cognitive ability fosters strategic behavior, specially in games where there are incentives to play strategically (i.e. games with moving costs).

4 Conclusions

We started our discussion inquiring whether there is a relationship between cognitive ability and strategic behavior. In this paper, we experimentally show that this relationship exits and it depends on the level of individuals' cognitive ability. To analyze this relationship we start with a sample of individuals who have to play in a sequential game and also respond to a cognitive test, the Raven's test. We find that agents with a higher score in the Raven's test (that measures cognitive ability) show a more strategic behavior than those that have a lower score. The results we obtain indicate that the proportion of strategic decisions significantly increases in the group of individuals with a high score in the Raven's test in sharp contrast to the other one, confirming our initial hypothesis. These results can be helpful for every day firm decision processes or for any decision choice process. As put forward by Bernhut, (2009), strategic behavior may make a difference in the business course allowing firms' growth and strong performance, especially when operating in a competitive environment. A firm, as a collection of agents following their individual preferences, may be leaded by a manager who should take into account not only the firm's optimization but the workers' behaviors. This task entails a demanding cognitive skill since it combines planning the others' behavior and the best response (Graetz, 2002). The Schelling model captures this instance since at any node, an agent faces the above features: on the one hand, she has to anticipate what would be her followers' behavior; and, in the other hand, she should introduce the above best response in her own utility function. Therefore, our game could be understood as a test of leadership skill.

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Appendix: Instructions of the Schelling Game with costs

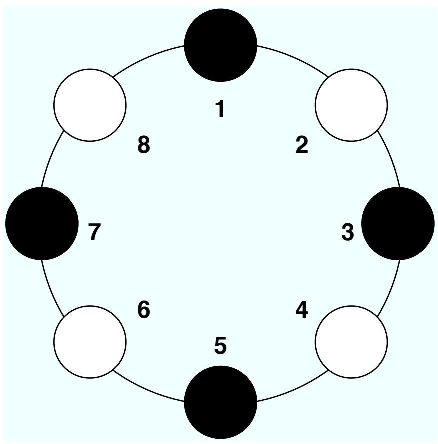
Welcome to this experiment. Thank you for participating. In this sheet we will explain this task's instructions in a very simple way. You should understand them immediately and there should be no questions. Please read them carefully. If you have any doubt, raise your hand. Remember all participants have identical instructions.

0.1. General instructions.

1. Please, put the scarf around your neck.

2. For this task, you are a total of 8 subjects. You have been placed around a circle, arranged randomly. One of the monitors has placed you were you are.

3. There are two types of subjects: those with a black scarf and those with a white scarf. As you will already know, you are black. You can see the others' scarves around the circle.



You may have noticed that you all have 5 (20) euros on the floor. This money can be yours. Continue reading.

0.2. How can I win money?

1. If at the end of the experiment, AT LEAST ONE OF YOUR NEIGHBORS is the same color as you, you will win 50 euros. This is:

   - If both the neighbor at your right and the one at your left are white, you will NOT win anything.
   - If the neighbor you have at your right or the one at your left (or both of them) are black, then you will win 50 euros.

2. We allow you to move. You can move to the closest gap you wish. A gap is the space between two persons. You can jump as you wish (one place, two places, etc...). You can only move to your left, this is, clockwise.

3. When can I move? When it's your turn. The first one to move is chosen with a dice. In consecutive order (to the left) the rest will move.

What happens with my 5(20) euros (from the floor) if I move? You lose them. In the gaps there are no bills. There is only money stuck at the places.

0.3. Well, let's play.

1. Now the dice will be rolled. The first one to move will start and will make his or her decision: {not to move, move jumping one place, move jumping two places, ..., move jumping eight places}.

2. You will have to make that decision.

3. At the end of the task, two out of the eight participants would be randomly selected. If AT LEAST ONE OF YOUR NEIGHBORS is the same color as you, you will win 50 euros and 0 otherwise.

And if you have not moved, you will have 5(20) euros more.