Journal of Public Economics 139 (2016) 40–52

Contents lists available at ScienceDirect

Journal of Public Economics

journal homepage: www.elsevier.com/locate/jpube

Cognitive performance in competitive environments: Evidence from a natural experiment☆

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ARTICLE INFO

Article history:
Received 2 October 2014
Received in revised form 4 May 2016
Accepted 5 May 2016
Available online 12 May 2016

Keywords:
Cognitive performance
Competition
Natural experiments

ABSTRACT

Competitive situations that involve cognitive performance are widespread in labor markets, schools, and organizations, including test taking, competition for promotion in firms, and others. This paper studies cognitive performance in a high-stakes competitive environment. The analysis takes advantage of a natural experiment that randomly allocates different emotional states across professional subjects competing in a cognitive task. The setting is a chess match where two players play an even number of chess games against each other alternating the color of the pieces. White pieces confer an advantage for winning a chess game and who starts the match with these pieces is randomly decided. The theoretical analysis shows that in this setting there is no rational reason why winning frequencies should be better than 50-50 in favor of the player drawing the white pieces in the first game. Yet, we find that observed frequencies are about 60-40. Differences in performance are also stronger when the competing subjects are more similar in cognitive skills. We conclude that the evidence is consistent with the hypothesis that psychological elements affect cognitive performance in the face of experience, competition, and high stakes.

1. Introduction

In recent years, economists have paid considerable attention to the relationship between perceptions and reasoning, and to emotions such as loss aversion, reference points, disappointment and others. There is evidence that these and other behavioral effects are in fact important for explaining a wide range of economic and social behavior.[1] Despite their potential importance, however, little is known about the relevance of these effects on cognitive performance. Do they exist? If so, do they persist in the face of experience, competition, and high stakes? These are the questions we study in this paper.

Understanding cognition is important. Numerous studies establish that measured cognitive ability is a strong predictor of occupational attainment, wages, and a range of social behaviors in adults, and several studies document its importance in predicting the schooling performance of children and adolescents.[2] An emerging body of literature also finds that "psychic" costs explain a range of economic and social behavior (see, e.g., Carneiro et al. (2003), Carneiro and Heckman (2003), Cunha et al. (2010), Heckman et al. (2006a)). Besides social and economic outcomes, recent research shows that cognitive ability is also important for financial market outcomes.[3] Thus, numerous settings represent competitive situations that involve cognitive performance (e.g., test taking, student competition in schools, competitions for promotion in certain firms and organizations, and others), and understanding the relationship between cognitive performance

☆ We thank Luis Cabral, David De Meza, Leontxo García, Diego González-Díaz, Robert Östling, Pedro Rey-Biel, Yona Rubinstein, David Str ömberg, Richard Thaler, Oscar Volij, two anonymous referees, and participants in seminars at LSE, Bristol, Munich, Pisa, Stockholm IIES, Erasmus, Ben Gurion, Collegio Carlo Alberto, IMEBE and the Chess Grand Slam Final Bilbao-Shanghai for useful comments. Financial supports from the Spanish Ministerio de Economía y Competitividad and FEDER (projects MTM2011-27731-C03, MTM2014-60191-JIN, ECO2012-31626, ECO2015-66027-P), from Xunta de Galicia (project INCITE09-207-064-PR), and from the Departamento de Educación, Política Lingüística y Cultura del Gobierno Vasco (IT-869-13) are gratefully acknowledged.

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[1] Camerer (2003), Rabin (1998) and DellaVigna (2009) provide excellent surveys.

[2] See, for instance, Neal and Johnson (1996), McArdle et al. (2009), and other references therein. Heckman et al. (2006b) review this literature and present an analysis of the effects of both cognitive and noncognitive skills on wages. They show that a model with one latent cognitive skill and one latent noncognitive skill explains a large array of diverse behaviors including schooling, work experience, occupational choice, and participation in various adolescent risky behaviors.

[3] See, for instance, Agarwal and Mazumder (2013), Bertrand and Morse (2011), Gerardi et al. (2010), and Cole and Shastry (2009).

http://dx.doi.org/10.1016/j.jpubeco.2016.05.001
0047-2727/

and psychological effects is an important question in the literature on human capital, schooling, behavioral economics and others.

This paper contributes to these strands of economics literature by studying the impact of psychological differences on cognitive performance in a competitive environment. The analysis benefits from the opportunity provided by a randomized natural experiment that, in effect, exogenously assigns different emotional states across subjects. Similar natural experiments to the one we study have been used to examine the role of psychological effects when subjects perform non-cognitive tasks, and this paper extends the analysis to study their impact on the performance in cognitive tasks. As such, and to the best of our knowledge, it represents the first study that evaluates the causal link from behavioral effects to cognitive performance in a competitive setting taking advantage of a natural experiment.

The randomized experiment comes from professional sports. Important elements of human behavior are starkly observable in these settings. As Rosen and Sanderson (2001) indicate, "if one of the attractions of sports is to see occasionally universal aspects of the human struggle in stark and dramatic forms, their attraction to economists is to illustrate universal economic principles in interesting and tractable ways." Thus, not surprisingly, a number of prominent findings in economics have been documented for the first time studying sports settings. For instance, without attempting to be exhaustive, Ehrenberg and Bognanno (1990) investigate incentive effects in golf tournaments, Szymanski (2000) studies discrimination using soccer data, Garicano et al. (2005) study social pressure as a determinant of corruption in a soccer setting, and Bhaskar (2009) and Romer (2006) analyze optimal decision-making using cricket and football data respectively.

Much like these sports settings, ours represents a valuable opportunity for studying an open question in the literature for a number of reasons:

First, the situation involves a tractable number of subjects (just two) competing at a game that is considered the ultimate cognitive sport (chess). The game they play has complete information and involves no chance elements. The game is strictly competitive or zero-sum. Pure conflict situations in which one person's gain is always identical to another's loss involve no potential elements of cooperation. As such they represent the cleanest possible context to study competitive behavior. Subjects compete in the same setting and under identical circumstances and, as we will see in the next section, the only difference is the randomly determined order in which they complete a task.

Second, and most importantly, we take advantage of existing results in the literature (to be discussed below) that show that the *order* of competition generates differences in emotional states. Using the same type of randomly assigned treatment and control of these emotional states we extend existing research to the study of performance on *cognitive* tasks in a competitive environment.[4]

Third, the setting involves professional subjects who are characterized by the highest degree of cognitive skills at the specific competitive task they perform as professionals (playing chess). Thus, we can study if biases exist in the face of experience, competition and high stakes. This is also important because existing research has found that individuals with higher cognitive ability demonstrate *fewer* and *less extreme* cognitive biases that may lead to suboptimal behavior.[5]

Fourth, direct measures of cognitive abilities are often lacking in the literature and can be measured only indirectly (through their correlation with other variables). The setting in this paper provides a highly precise measure of the cognitive ability of the players at the task they perform. In particular, subjects have a rating according to what is called the "ELO rating method" (see Section 4), and this rating estimates quite precisely the probability that one player will outperform the other at the cognitive task. This is a valuable advantage of the empirical setting.

Finally, the study concerns high-stakes decisions that subjects are familiar with, that really affect them, to which they are used, and that take place in their own real-life environment. In this sense, it involves a set of useful characteristics in terms of stakes, familiarity and nature of the environment. And from the perspective of observing and measuring behavior, a comprehensive dataset is available where choices, outcomes, and treatments are cleanly measured.

From the theoretical point of view, we also develop rational and behavioral models of optimal play to interpret the empirical evidence. Importantly, these models will contain a contribution to the game theoretical literature on repeated interactions and to the literature on multi-battle contests. In our setting, a match consists in the repeated play of a given stage game but, differently from standard repeated games, the total payoff that players obtain may not be a sum or an average of the payoffs in each period. The existing literature has studied the case of binary outcomes: in each stage game one player wins and the other loses (see Walker et al. (2011)), but we are aware of no study with more than two outcomes. The presence of a third outcome (in our context, win, lose, and tie) brings in the issue of how to chose risk during the match, which we incorporate into the formal frameworks. This represents a novel aspect with respect to the literature on multi-battle contests in which strategic risk taking is not a choice variable (e.g., Konrad and Kovenock (2009)).

The rest of the paper is structured as follows. Section 2 describes the natural experiment and a brief literature review. Section 3 develops formal rational and behavioral models of the task the subjects undertake. The models allow us to identify the conditions under which we may be able to conclude, using the average treatment effects from the natural experiment, whether behavioral elements have an impact on cognitive performance. Section 4 describes the data. Section 5 presents the main empirical evidence, and Section 6 concludes.

2. The natural experiment

In a *chess match*, two players play an even number of *chess games*, typically about 6 to 10 games, against each other. Games are generally played one per day, with one or two rest days during the duration of the match. The basic procedure establishes that the two players *alternate* the colors of the pieces with which they play. In the first game, one player plays with the white pieces and the other with the black pieces. In the second game, the colors are reversed, and so on. Who plays with the white pieces in the first game is *randomly* determined, and this is the only procedural difference between the two players. According to the rules of FIDE (the Fédération Internationale d'Échecs, the world governing body of chess), the order is decided randomly under the supervision of a referee. This random draw of colors, which is typically conducted publicly during the opening ceremony of the match, requires that the player who wins the draw will play the first game with the white pieces. Therefore, the fact that players have no choice of order or color of the pieces makes it an ideal randomized experiment for empirically establishing causality.

The explicit randomization mechanism used to determine which player begins with the white pieces in a sequence of games where both players have exactly the *same* opportunities to play the *same* number of games with the *same* colors, have the *same* stakes, are

[4] As is well known, a randomized experiment is a powerful methodology not often available in the social sciences that ensures that the conditions for causal inference are satisfied (Manski, 1995). There is also a related literature suggesting that providing relative performance information (a consequence of the order of competition in our setting) affects performance (Azmat and Iriberri, 2010).

[5] See, for instance, the recent results in Gill and Prowse (forthcoming). Also, Benjamin et al. (2013) and Frederick (2005) report similar findings for high school and college students, respectively, using different measures of intelligence and cognitive ability.