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GO figure: Analytic and strategic skills are separable☆

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ABSTRACT

We measure the game behavior and analytic reasoning skills of expert strategic reasoners: professional GO players. We argue for a distinction between what we call "strategic" and "analytic" reasoning skills and present separate measures to elicit strategic and analytic abilities. The paper investigates the behavior of our subject pool in many different types of one-shot games, including the Traveler's Dilemma, Centipede, Kreps, and Matching Pennies games. We observe that increased strategic skill predicts a greater probability of Nash behavior, while greater analytic skill predicts more cooperative play, even when such behavior is inconsistent with individual rationality.

1. Introduction

In strategic decision-making environments, the reasoning processes that rationalize Nash equilibrium play are cognitively demanding. A growing body of literature in behavioral economics is investigating the link between strategic behavior and cognitive abilities via controlled experiments. This literature provides evidence for a positive correlation between cognitive abilities and Nash equilibrium play in certain economic games (Agranov et al., 2013; Burnham et al., 2009; Gill and Prowse, 2013; Rydval et al., 2009).

Still, cognitive ability is not a monolith. For instance, in *p*-beauty contests subjects with higher scores on various cognitive ability tests are more likely to adopt Nash equilibrium strategies (Brañas-Garza et al., 2012; Burnham et al., 2009; Gill and Prowse, 2013; Rydval et al., 2009). In experimental Prisoner's Dilemmas, on the other hand, subjects with higher cognitive ability scores tend to behave more cooperatively (Burks et al., 2009; Jones, 2008). In experimental dictator games Chen et al. (2013) report that subjects with higher grade point averages are more selfish, whereas subjects with higher scores in the math portion of the SAT are more generous. These results suggest that cooperative and competitive behavior may correlate with different elements of a subject's cognitive skillset. Consistent with these findings, Decety et al. (2004) show that cooperative and competitive behavior engage distinguishable neural processes.

In this study, we further explore the relationship between reasoning skills and competitive as well as cooperative behavior. We posit two types of reasoning—"strategic" and "analytic"—and investigate their potentially heterogeneous influences on choices in games which evoke a conflict between selfish and cooperative behavior. To explore these two types of reasoning, we measure the analytic reasoning skills of professional players of the East Asian board game GO and test their behavior in various one-shot games.

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We focus on GO players for two reasons. First, international GO players are rated under a variation of chess' Elo system, which allows us to quantify their strategic abilities. Elo is a standardized ordinal scheme defined in terms of relative skill, in which higher ranks go to better players. Systems like the Elo ratings have provided experimentalists with a convenient way to quantify (ex-ante) strategic abilities (Levitt et al., 2011; Palacios-Huerta and Volij, 2009). We follow this previous work by interpreting Elo as a measure of strategic skills.

Second, even if strategic and analytic reasoning skills are separable, we would still expect GO players to be above average at both. Indeed, GO professionals must excel at the strategic ability to model an opponent. Other abilities, like suppressing heuristic reasoning, applying deduction and induction, accessing memory, and focusing attention all involve in-game reasoning that doesn't necessarily incorporate the goals or abilities of an opponent. So if analytic and strategic skills are separable within GO professionals, any non-Nash behavior they exhibit is unlikely to be due to errors or reasoning failures.

To elicit the analytic skills of our subjects, we use an incentivized version of the cognitive reflection test (CRT) (Frederick, 2005). We use these two measures to show that the exceptional analytic and strategic skills of GO players (CRT scores and Elo ratings) predict different behaviors. We suggest that these two measures reveal at least two kinds of reasoning.

We examine the behavior of our subject pool in Traveler's Dilemmas and Centipede games. We also elicit our subjects' choices in Kreps and Matching Pennies games. The first two games allow us to explore the relationship between choices and different cognitive skills in games which evoke the Prisoner's Dilemma's conflict between cooperative and individually rational behavior. We propose that strategic skill predicts Nash behavior and explore whether analytic skill correlates with cooperative behavior in these decision-making environments.

The last two games, in particular the Kreps game, serve as robustness checks. If our subjects tend to play Nash equilibrium strategies in these games, in which standard subject pools regularly fail to behave rationally (Goeree and Holt, 2001), then limited reasoning abilities would be less likely to explain observed deviations from Nash in the first two.

Our main results can be summarized as follows. In games which evoke a conflict between cooperative and individually rational choices (Traveler's Dilemma and Centipede game), strategic skill correlates positively with a greater likelihood of Nash behavior. Greater analytic skill, on the other hand, correlates positively with more efficient and cooperative play. Our results from the Kreps and Matching Pennies games suggest that deviations from Nash equilibrium play in Traveler's Dilemma and Centipede game are not generated by limited reasoning skills. Where Nash behavior is efficient, as in the Kreps game, our subjects outperform standard subject pools in coordinating on efficient equilibrium outcomes.

The remainder of the paper is organized as follows. Section 2 briefly introduces the game of GO. Section 3 describes the one-shot games we used in our experimental design. Section 4 describes the design and Section 5 presents our results. Section 6 provides a discussion and Section 7 concludes.

2. The game of GO

GO is an East Asian board game noted for its strategic complexity. Two players place black and white "stones" on intersections of a 19 by 19 grid-board. The goal of the game is to encircle a larger total area of the board than the opponent. When a game ends, captured stones are subtracted from the number of controlled intersections to determine who has more points (Bozulich, 2001).

Although GO, in contrast to chess, has only two kinds of game pieces, it is more complex than chess from a strategic point of view. More specifically, the number of legal positions in chess is estimated to be between 10^{43}–10^{47}, with a game-tree complexity of approximately 10^{123}. By comparison, the upper bound on the number of legal board positions in GO is approximately 10^{170}, with a game-tree complexity between $10^{10^{48}}$–$10^{10^{171}}$. While in chess the average number of legal moves per turn is 37 (Keene and Levy, 1991), the average number of moves per turn throughout most of a GO game exceeds 150.

If game skills, like backward-induction and iterated elimination of dominated strategies, should emerge from expertise in searching game trees (Palacios-Huerta and Volij, 2009), then GO will provide at least as compelling a training ground as chess.

GO players can be ranked based on their Elo ratings (see Table A.7 for details). The larger the Elo-score of a player, the higher his ranking. Since the ability to model other strategic reasoners is central to GO proficiency, we treat a player's Elo rating as his "strategic skill" in the remainder of the paper.

3. Reflection test, games, and model predictions

In our experimental design we administered one logic test and four different game classes that vary in terms of the properties of their underlying Nash equilibria.[1]

3.1. Cognitive reflection test (CRT)

The Frederick CRT is a simple, powerful, and well-validated measure consisting of three questions (Frederick, 2005). Each question has an incorrect answer that immediately suggests itself and a less obvious correct answer. It was originally designed to measure the dominance of a subject's logical, analytic reasoning processes relative to automatic, heuristic processes. The questions are as follows

- A bat and a ball cost $1.10 in total. The bat costs $1 more than the ball. How much does the ball cost?
- If it takes five machines five minutes to make five widgets, how long would it take 100 machines to make 100 widgets?
- In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?[2]

Frederick (2005) ran a series of experiments and tested the performance of 3428 students on these questions. He showed that the number of correct answers, 0–3, is strongly correlated with the results from other measures of analytic reasoning, like the Wonderlic Personnel Test (WPT), the "need for cognition scale" (NFC; Cacioppo et al., 1984; 1982), the SAT, and the American College Test (ACT).[3] We introduce the CRT as a measure for "analytic skills".

3.2. Centipede and Traveler's Dilemma

The first class of games we consider is a normal-form representation of a Centipede game, following Nagel and Tang (1998) (see Table 1). In this version of the game, agent A selects an odd number between 1 and 13 and agent B selects an even number between 2 and 14. The unique Nash equilibrium outcome of this game is (1, 2) for the choices of players A and B, respectively. The Nash equilibrium is Pareto dominated by various other outcomes, in particular (13, 14), which corresponds to the cooperative and efficient (sum-of-utility-maximizing) outcome. Standard subject pools playing the Centipede

[1] For the games we used the designs and materials of Goeree and Holt (2001) and Nagel and Tang (1998) with random matching and no feedback.

[2] The correct answers are 5, 5, and 47. Very frequently subjects jump into the conclusion that the correct answer to question one (for example) is 10 cents.

[3] Oechssler et al. (2009) show that individuals with low CRT scores are more likely to be subject to the conjunction fallacy (Kahneman and Tversky, 1983) and to conservatism with respect to probability updating. Bergman et al. (2010) demonstrate that anchoring effects Kahneman and Tversky (1974) decrease with higher CRT scores.