

# BEHAVIORAL INFLUENCES ON STRATEGIC INTERACTIONS OUTCOMES IN GAME THEORY MODELS

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**Abstract:** Traditional decision-making models assume full rationality of all actors. Nevertheless, the practice has shown that the behavior and choices of actors are influenced by many factors such as motives, beliefs, opinions, personal and social preferences, as well as cognitive biases. Moreover, it has already been proven that people have limitations in their ability to collect relevant information and respond to them, i.e., they are bounded rational. All this has contributed to the development of behavioral models in many disciplines including game theory. This paper provides a detailed review of the literature regarding behavioral models of strategic decision making. Bounded rationality and other cognitive biases in the strategic interactions are illustrated through the findings of numerous experimental studies.

**Keywords:** Behavioral Game Theory, Cognitive Biases, Social Preferences, Bounded Rationality, Experimental Games.

**MSC:** 91A26, 91A90.

## 1. INTRODUCTION

Most of the theoretical models in management science and economics are based on the assumption of perfect rationality, which means that all actors have a full understanding of their environment and can think infinitely at any given moment. A perfectly rational decision maker has all the information that can be collected and uses it to make a perfectly logical deduction, which he then uses to make the best decision, usually to maximize profits or benefits. Other assumptions underlying most traditional decision-making models are that decisions are not affected by decision makers' emotions and as well as their environment, that their

preferences are consistent, and that they are able to react to relevant information and discard the irrelevant ones.

Nevertheless, the practice has shown that the behavior and choices of decision makers and other actors are influenced by many factors including motives, beliefs, opinions, risk attitudes, personal and social preferences, as well as by collective behavior. Moreover, it has already been proven that people have limitations in their ability to collect relevant information and respond to them. This is a type of cognitive bias known as bounded rationality. Biases arise from cognitive limitations and represent systematic errors that influence people's decisions and beliefs [39]. Some other decision-making biases are: confirmation bias, anchoring, decoy effect, time discounting, endowment effect, framing effect, overconfidence effect, reciprocity, among others. Confirmation bias is the tendency to seek, interpret, focus, and memorize information in a way that confirms one's prejudices; anchoring is the tendency to focus on one, initial piece of information that influences valuation and making subsequent decisions. The endowment effect occurs when people additionally value the items they own, while decoy effect arises when people's preference for one option over another changes due to the addition of a third, less attractive option. The framing effect involves drawing different conclusions from the same information, depending on how or who presented the information. Loss aversion refers to people's preference for avoiding loss rather than gaining equivalent profit.

Bounded rationality is the term introduced by Simon [88, 89] that refers to the concept of rational principles related to non-optimizing adaptive behavior of people, so-called satisfactory solution concept. Simon argues that the ability of decision makers to act rationally is limited by the information they have access to, as well as by the computing ability they possess. Later on Simon proposed the concept of procedural rationality, which involves the effectively managing the trade-off between costs and quality of decision [90]. Instead of rationalizing the decision, procedural rationalization demonstrates the rationality of the processes used to make the decision. Procedural rationality assumes that choice can be based on a distorted set of information, as a result of the various mental elements that process information. Two main classes of bounded rationality models focus on the heuristics that people use in decision making and the processes of learning.

In 1979, Kahneman and Tversky [52] developed a prospect theory, a behavior model that explains how people choose between options that involve risk and uncertainty. The theory assumes that individuals evaluate choices differently depending on how the options are framed; namely they do not make decisions based on absolute outcomes, but based on a heuristic estimate of the potential value of losses and gains. Heuristics are mental shortcuts that allow for quick decision making and deduction without spending a lot of time researching and analyzing information [23]. In order to better reflect the decision makers' subjective risk preference, Tversky and Kahneman [97] proposed a cumulative prospect theory (CPT) with the weighting of the cumulative probability distribution function instead of the probability of individual outcomes.

At the same time, a discrete multicriteria method based on nonlinear CPT

was formulated, called the TODIM method [43]. Other models have also been developed that take into account human behavior and cognition, and (all) are closely related to the social and cognitive psychology. Social psychology deals with understanding the nature and causes of an individual's behavior, while cognitive psychology is about studying how people respond to new information and how this response affects their behavior and emotions.

All this has contributed to the development of behavioral models and their application in many areas such as economics [16, 51, 96], game theory [15], finance [93], accounting [6], marketing [44, 67], operations management [39], and more recently in operations research [34, 46].

This paper provides an overview of the literature related to the behavioral aspects of decision-making models in Game theory. Bounded rationality and effects of certain cognitive biases in models of strategic interactions are illustrated through the findings of numerous experimental studies.

Following the introductory part, Section 2 provides an overview of the various modeling frameworks that have been used to capture the bounded rationality and social preferences in game theory models. In Section 3, a level- $k$  reasoning model is presented through the experimental results of the  $P$ -beauty contest game. Section 4 provides literature overview of social preference models in experimental Ultimatum bargaining game, while Section 5 gives insight into the experimental results of the trust game. Behavioral effects in social dilemmas of the prisoner's type dilemma are presented in Section 6.

## 2. BEHAVIORAL MODELS IN GAME THEORY

Game theory is a branch of mathematics that models social interactions between intelligent rational decision-makers. It is a multiplayer decision theory based on the assumption that rational players form their beliefs based on what they think other players will do (strategic thinking), after which they make the decision that best fits those beliefs (optimization). Players then tune their decisions and beliefs until they become mutually consistent, that is, until equilibrium is reached [7]. In non-cooperative games, Nash equilibrium is a set of strategies, one for each player, such that they are each other's best response, and no player can benefit by unilaterally deviating from the equilibrium strategy.

More formally, in the game with  $n$  players where  $S_i$  is strategy set for players  $i$  ( $i = 1, \dots, n$ ), a Nash equilibrium is a set of strategies  $(s_i^*, s_{-i}^*)$  such that

$$\Pi_i(s_i^*, s_{-i}^*) \geq \Pi_i(s_i, s_{-i}^*), \quad \forall s_i \in S_i,$$

where  $s_i$  is a strategy for player  $i$ ,  $s_{-i}$  is a vector of strategies for all players other than  $i$ , and  $\Pi_i(s_i, s_{-i})$  is player  $i$ 's payoff for given combination of strategies for all players.

Nevertheless, in reality players are not always as rational as theory predicts, because their behavior is influenced by a number of psychological, situational and other factors [58]. Moreover, there is heterogeneity among them in terms of different cognitive reference points, different ways and intensity of reasoning.

To overcome shortcomings of traditional game theory, and to explain how people actually play games (behave in strategic interactions), behavioral game theory (BGT) has been developed, extending analytics to include emotions, mistakes, limited foresight, as well as people's doubts about how smart other players are. The origins of behavioral game theory can be found in the works of Allais in 1953 and Ellsberg in 1961 who addressed the phenomenon that the choices made by players do not reflect the expected benefits [40]. The various modeling frameworks have been further constructed to capture bounded rationality and social preferences of players in game theory models.

The two most common models of bounded rationality are the Quantal response model [68], and the Cognitive hierarchy model [75]. *Quantal response equilibrium* (QRE) is a solution concept where players are assumed to make mistakes in choosing a strategy to play. The probability that a player will choose a particular strategy is proportional to the payoff for a given strategy. The QRE approach has been applied in various situations, including analysis of overbidding in private-value auctions [41], study of behavior in ultimate bargaining games [104], capacity allocation games [22] and public good games [55]. *Cognitive hierarchy theories* (CHT) assume that players belong to different discrete levels of rationality and have different beliefs about the level of rationality of other players [92]. In CHT, every player believes that he/she understands the game better than other players. In particular, CH models represent non-equilibrium thinking models that set decision rules to reflect the iterative process of strategic reasoning. CH models are widely used to predict equilibrium in various one-shot games, such as stag-hunt, prisoners' dilemma, *P*-beauty contest game, centipede game, market entry games, and strategic voting games.

Behavioral equilibrium has been proposed by Esponda [27] as a solution concept in the situations where some players fail to explain the relationship between other players' actions and their own uncertainty. According to him, behavioral equilibrium implies that players have no incentive to deviate given their beliefs about the effects of deviating whereby those beliefs are consistent with information obtained from the actual equilibrium.

Social preference models are related to the concepts of altruism, inequity aversion, reciprocity, and fairness, and can be self-regarding or other-regarding [73]. Self-regarding preferences refer to preferences for one's own payoffs, while other-regarding preferences refer to preferences over other individual's payoffs, in addition to one's own, and could be distributive and reciprocal [62]. Distributive social preferences assume that individuals have a preference for finite payments and are analyzed by inequality aversion models proposed by Fehr and Schmidt [32], while reciprocal preferences mean that individuals have a preference for fairness and tend to reward or punish others depending on their intentions [1, 5, 31, 77, 81].

According to Schmidt [86], there are three major classes of models of social preferences: (1) outcome-based models, (2) intention-based models, and (3) type-dependent models. In outcome-based social preference models, the utility of each player directly depends on the payoff of other players belonging to a given reference group. Unconditional altruism theory implies that the utility of players does

not depend on their own payoffs, but increases monotonically with the payoff of other players. Charness and Rabin [21] point that individuals are more concerned about increasing social welfare, but to reduce the difference in payoffs. Intention-based models attempt to capture the consequences of intentions and assume that players benefit from reciprocal actions that are attributed good or bad intentions ([76]. These models include beliefs as to why the player has chosen certain action and successfully explain retaliation and altruistic behavior [62]. Finally, in type-dependent models, players behave nicely to the person they consider to be good, and unfriendly to the person they consider to be bad [86].

The concept used to describe and categorize people according to their personal preferences about the distribution of outcomes between self and others in situations of interdependence is known as social value orientation – SVO [69]. Several different measurement methods have been developed for measuring individuals’ SVO thus far, including Ring 24 measure [63], Triple-Dominance Measure [99], SVO Slider Measure [74]. Within the SVO framework, individuals can be categorized as altruistic, cooperative, equality-seeking, individualistic or competitive type.

Recently, Rand *et al.* [84] proposed a framework for understanding pro-sociality from the perspective of two processes, so-called Social Heuristics Hypothesis (SHH). According to SHH, intuition encourages behavior that is generally in line with maximizing the payoff in the long run, while deliberation leads to behavior that maximizes the current payoff. In one-shot anonymous interactions in which future benefits are not sufficient to outweigh the costs of pro-sociality, it is always rational to be self-interested, so reasoning is predicted to encourage selfishness in those situations. Intuition, in contrast, requires understanding which behaviors are optimal in situations that involve consequences of repeated interactions [83].

Several experimental games have been developed to measure the impact of cognitive biases and social preferences on decision-making in strategic interactions, including *p*-beauty contest game, ultimatum game, trust game, prisoners’ dilemma, and public goods game among others.

### 3. *P*-BEAUTY CONTEST GAME AND LEVEL-*K* REASONING MODEL

The “*p*-beauty contest” is the game based on a concept developed by John Maynard Keynes [56], to illustrate how investors make decisions in stock markets. A Keynesian beauty contest is based on a fictional newspaper contest, where readers (competitors) are expected to select the six most attractive faces within a hundred photographs. The winner is a player who chooses a face that is the most attractive to majority of the competitors. A strategic competitor, instead of choosing according to his own preferences for physical attractiveness, could try to predict which faces in the general opinion will be the most attractive. Some competitors could even try to anticipate what the general opinion about the faces might be, and so on. In other words, in this game “a player has to form beliefs

about average choices of others and about what average beliefs expect average beliefs to be”.

Moulin [72] introduced an experimental version of the game, the so called  $p$ -beauty contest game ( $p$ -BCG), in which participants should simultaneously choose a number in the range from 0 to 100. The winner is the player who chooses the number closest to the average of all selected numbers multiplied by the parameter  $p$ , which typically takes the value  $2/3$  or  $1/2$ . The winner receives a fixed prize that does not depend on either the number chosen or the value of parameter  $p$ . If there is a tie, the prize is distributed equally to the winners. A rational player would resonate as follows: ”Even if all other players choose 100, I should choose no more than 67 ( $= 100 \times 2/3$ ). Assuming that other players reason similarly, however, I should choose no more than 45 ( $= 67 \times 2/3$ )...“, and so on.

More formally, in the  $p$ -beauty contest, a rational player does not pick numbers higher than  $100p$ , as they are dominated by  $100p$ . Besides, if a rational player believes that other players are also rational, then he will not choose a number above  $100p^2$  and so on. Thus, assuming a common knowledge of rationality, a process of iterated elimination of weakly dominated strategies will lead to the game’s unique equilibrium in which everyone chooses zero.

However, when a game is played in an experimental setting, the average of all picked numbers is typically in the range of 20 and 40 [14]. The reasons for deviating from equilibrium are numerous. In fact, some players are unable to reason in a way that leads to an equilibrium or assume that others are unlikely to do so. According to Nagel [75], players exhibit different, limited rational levels of reasoning, so  $p$ -BCG can be used to measure the reasoning steps an individual goes through in their thought process. He describes the thought processes of players with varying degrees of strategic sophistication as follows: ”A player is strategic of degree 0 if he chooses the number 50. A player is strategic of degree  $k$  if he chooses the number  $50p^k$ “. Nagel suggested 50 as reference point because it can be anticipated either as the expected value from guessing randomly over a symmetric distribution, or as a focal point that draws the player’s focus to the midpoint of the interval. Higher values of  $k$  indicate both a higher degree of player sophistication and a belief that opponents also think more strategically [54]. This model of marking the level of player sophistication is also known as the “level- $k$  reasoning model”. According to standard level- $k$  model, level-0 type is nonstrategic player which might choose number at random, or a number may have some special meaning to the player. A level- $k$  type, for any  $k \geq 1$ , behaves to respond best to the belief that other players are level  $k - 1$  type.

Following Nagel’s level- $k$  model [75], Stahl and Wilson [92] introduced taxonomy of player types for one-shot games, based on which each player is assumed to belong to one of several types: type level 0, 1 or 2; Naive Nash type, worldly type, and rational expectation type. A “naive Nash” type chooses Nash strategy, assuming that all other players will also play Nash strategy. A “worldly” type believes that some players are naive Nash types, while other players are level 0, 1, or 2. A “rational expectations” type is aware that some opponents are also unboundedly rational, and responds to a mixture of all the types.

A variety of experiments on the  $p$ -BCG have been conducted to study iterated dominance and learning both in one-shot [10, 12, 94] and repeated [36, 37, 87] versions of the game. Burnham *et al.* [12] found that in a one-shot game, individuals with higher scores on the cognitive test were choosing numbers closer to the Nash equilibrium. Similarly, Brañas-Garza *et al.* [10] found that players with higher scores on CRT test for measuring intelligence are more likely to choose a strategy from Nash's equilibrium. However, Schnusenberg and Gallo [87] suggest that cognitive ability is important only when players are faced with a new situation, while in subsequent rounds of the game variability of responses are not significantly related to CRT scores and cognitive ability is subordinated to a learning effect and players' responses. Gill and Prowse [37], find that both cognitive ability and personality affect behavior and learning in repeated  $p$ -beauty contest game, and that more emotionally stable subjects learn to play equilibrium faster. Galavotti *et al.* [36] analyzed the bidding behavior of firms and found that more sophisticated firms are the better strategic thinkers are able to acquire more accurate beliefs about the behavior of other firms and act optimally.

We conducted experiments on  $p$ -BCG among fourth year undergraduates at University of Belgrade, Faculty of Organizational Sciences, over the years. Students were required to choose a number in the range 0 to 20, with the winning number being the one closest to  $2/3$  of the average of all numbers chosen. Table 1 provides data on average values, standard deviation and winning numbers for all experiments, as well as data on the number of participants involved in each experiment.

	Exp.1 2013 ( $n = 28$ )	Exp.2 2014 ( $n = 47$ )	Exp.3 2015 ( $n = 38$ )	Exp.4 2016 ( $n = 54$ )	Exp.5 2018 ( $n = 51$ )
Mean	6.93	8.15	8.18	7.02	7.14
SD	2.48	3.72	3.45	3.01	3.18
$2/3$ of mean	4.62	5.43	5.46	4.68	4.76
Winning number	5	5	5	5	5

Table 1: Mean, standard deviation and winning number in experiments

Figure 1 shows the dispersion of choices in experiments. It can be seen that in all experiments, the majority of participants chose number 7, so the winning number was 5.

Based on experimental data, we calculated the level of player rationality using Nagel's approach [75] as follows. A participant has a level  $k$  of depth of reasoning if the number he has chosen belongs to the interval:  $[10 \times 2/3^{k+1/4}; 10 \times 2/3^{k-1/4}]$ , for  $k = 0, 1, 2, \dots$ . We take number 10 as an initial reference point, as it is the expected choice value for the  $[0, 20]$  interval. The percentage of participants by level of strategic reasoning in this study is given in Table 2.

Although the distributions of participants by type vary from experiment to experiment, the most participants are Level 1 players in all experiments, followed by Level-2 (or more) in experiments 1, 4 and 5, and Level-0 in experiments 3 and 4.

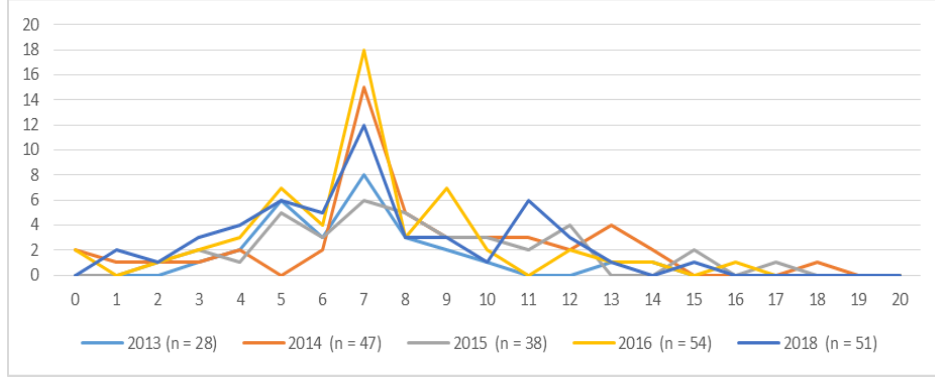


Figure 1: Distribution of selected numbers in p-beauty contest experiments

	Interval	Exp. 1 (2013)	Exp. 2 (2014)	Exp. 3 (2015)	Exp. 4 (2016)	Exp. 5 (2018)
Naïve Nash	0	0.00%	4.26%	0.00%	3.70%	0.00%
Level-4	1-2	0.00%	4.26%	2.63%	1.85%	5.88%
Level-3	3	3.57%	2.13%	5.26%	3.70%	5.88%
Level-2	4-5	28.57%	4.26%	15.79%	18.52%	19.61%
Level-1	6-7	39.29%	36.17%	23.68%	40.74%	33.33%
Interim *	8	10.71%	10.64%	13.16%	5.56%	5.88%
Level-0	9-11	10.71%	19.15%	21.05%	16.67%	19.61%
Interim *	12-13	3.57%	12.77%	10.53%	5.56%	7.84%
Irrational	14-20	3.57%	6.38%	7.89%	3.70%	1.96%

Table 2: Percentage of participants by level of strategic reasoning

In each experiments 2 and 4, two players showed rationality by choosing number 0. According to [92], these players could be considered naive Nash as they understand the equilibrium but do not imply that other players are bounded rational or do not recognize equilibrium. Strictly dominated strategies were chosen differently through experiments, from 1.96% in Experiment 5 to even 7.89% in Experiment 3.

The results obtained in this experiment are consistent with those of many other studies. It should be noted that in such strategic interactions, it is critical to make good judgments about the types of other players when it comes to the level of strategic reasoning in order to increase the chance of winning the game.

#### 4. ULTIMATUM BARGAINING GAME AND SOCIAL PREFERENCES

For the purpose of modeling take-it-or-leave-it bargaining situations, Güth et al. [45] introduced the so-called Ultimatum Game (UG). It is a sequential two-person game where one player (the proposer) is endowed with the amount of money



( $S$ ) and is tasked to propose the second player (the responder) how to divide a given prize. Responder then decides to either accept an offer, or reject it. If the proposal is accepted, the proposer's and responder's payoffs are  $S - x$  and  $x$  ( $0 \leq x \leq S$ ), respectively. Otherwise, neither of the players receive any money (see Figure 2). The fully rational responder who is totally driven by self-interest should accept whichever non-zero (positive) offer, as something is better than nothing at all. Anticipating that, the proposer should offer the smallest possible positive amount to the responder. This outcome is a subgame perfect equilibrium of the game [57].

However, the results of experimental studies show that offers typically range between 20% and 40% of the total prize, and the most offers below 30% usually are perceived as unfair and are rejected [18]. This findings are seen as evidence that people are bounded rational or driven by some social preferences, such as aversion to guilt [25], inequity aversion [32, 100], preference for fairness [30, 95], as well as social value orientation [33, 53].

It has also been observed that identical offers in the ultimatum game may have different rejection rates, depending on the alternative offers available to the proposer. In particular, experimental results indicate that responders rarely reject offers that are considered unfair if those do not reflect the proposer's bad intentions [4, 13, 49]. As pointed out by Falk and Fischbacher [28], two types of fairness are considered in an ultimatum game: fairness based on outcome, comparing one's own and others' gains/losses, and intention-based fairness that takes into account standing motives behind the chosen action [103]. Falk *et al.* [29] consider a mini-ultimatum game that directly addresses these issues. In this form of the game, the proposer has to choose between two predefined 10-unit allocation strategies: (8:2) or (5:5) in the first treatment, (8:2) or (2:8) in the second treatment, and (8:2) or (10:0) in the third one (see Figure 3). In the first treatment the choice (8:2) could be considered greedy, because there was also a fair allocation option (5:5), while in the third treatment the same choice might be considered generous. In the second treatment, the choice (2:8) may be considered acceptable since the only alternative would be extremely undesirable for the proposer (8:2).

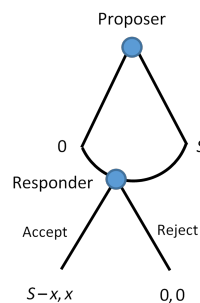


Figure 2: Classic ultimatum game

In order to research impact of intention-based fairness on the game outcome,

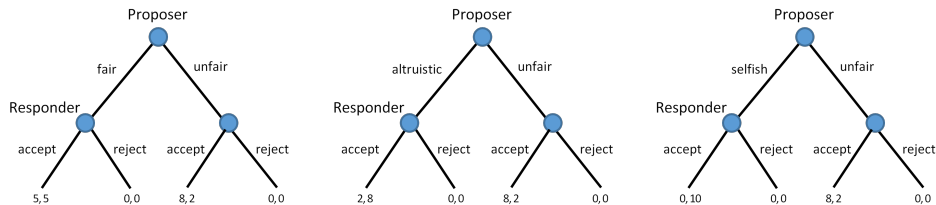


Figure 3: Mini ultimatum games

we conducted an online mini-ultimatum game experiment containing the first two treatments in the above described game. The experiment was carried out in 2018 and it was attended by 543 subjects from Serbia, of which 391 (72%) were female and 152 (28%) were male. All participants were first in the Proposer role and then in the Responder role. In treatment 1, as many as 76.4% of proposers chose a fair strategy. When placed in the position of the responder who was offered the allocation (8:2), 66.5% of them were ready to accept such an offer (with rejection rate of 33.5%). Only 10% of participants were choosing a fair distribution when they were in the proposer role and were accepting exactly the same offer when they were in the responder role. In the second treatment, the percentage of those who offered allocation (8:2) increased as much as 80.8%, while the percentage of those who would reject such an offer was lower than in the first treatment and amounted to 24.5%.

Another reason why people are more likely to accept unfair offers is either delaying responder's decision [78] or turning the game into a multi-stage negotiation game. Harbaugh *et al.* [47] suggest that in practice, people make optimal offers in terms of proposing the amounts that are most likely to be accepted, providing a sufficiently payoff for the bidder himself. Wittig *et al.* [103] state that a fair offer is indeed a rational choice because it is highly likely to be accepted.

Capraro [19] observes that while people recognize morally right things, moral preferences do not have causal influences on behavior in UG. The experimental results of his research indicate that high UG offers are motivated by aversion to inequality and, to a lesser extent, by self-interest.

Through numerous experimental studies, various sociodemographic and situational factors influencing decisions in the Ultimatum game have been examined, e.g. gender [24], cultural differences [48, 79], religious identity [9, 42], stake size [17, 61], punishment etc.

## 5. RATIONALITY OF TRUST WITHIN THE TRUST GAME

The trust game was introduced by Berg *et al.* [5] as part of a study on trust and reciprocity. By facilitating the transactions and reducing transaction costs between trading partners, the trust can promote economic growth and development. The game is also known as Investment game and has become a standard laboratory experiment for measuring trust in decisions with measurable economic

consequences. In the experiments, the game is sequentially played by two anonymously paired players (investor and trustee) both endowed with \$10. The game has two stages. In the first stage, the investor decides whether and how much money to pass to the trustee (to invest). All the money passed is multiplied by some parameter  $m$ , after which in the second stage the trustee decides whether and how much of the multiplied money to return to the investor. The basic form of the trust game is given in Figure 4.

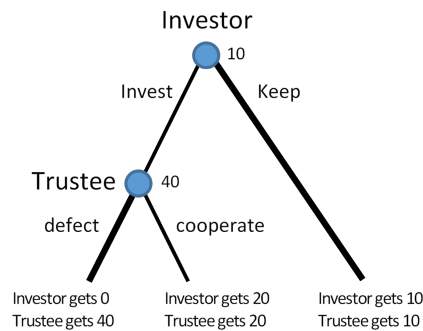


Figure 4: Basic trust game

A rational trustee will choose to keep the entire amount of money for himself, thereby maximizing his own payoff without any risk of either revenge of the investor or any other type of penalty. With that in mind, a rational investor, who possesses a common knowledge of the game, should not invest any money. In this subgame perfect equilibrium, the investor deprives the trustee of the opportunity to make the move.

However, the results of numerous experiments show large and frequent deviations from this theoretical solution. In an experiment conducted by Berg *et al.* [5], 91% of investors sent just over 50% of the money to the trustee, showing behavior that deviates from rational expectations. Similar results were obtained in the experiment conducted by Brulhart and Usunier [11]. The behavior of the trustees, in response to the zero investment in the above experiments, was more liable to variation. Specifically, in Berg's experiment, the proportion of money that was returned to the investor depended heavily on the level of information the experimenters gave to the trustee about the investor. However, regardless of the information received, the average value that the trustees returned to the investors was greater than the amount that the investor decided to pass on to the trustee in the first stage of the game. In an experiment conducted by Brulhart and Usunier [11], only 20% of trustees keep all the multiplied capital to themselves.

Experiments showed that there are many factors affecting players' non-rational behavior in trust game. Cognitive biases such as overconfidence [66], reciprocity [65, 64], guilt and inequity aversion [98], but also risk preference [50, 101], social value orientation [11, 59, 85], anonymity [50], and reputation [2] are especially emphasized.

Figure 5 shows a game tree where the Investor has certain beliefs regarding the type of Trustee. By mutual cooperation, the Investor and Trustee each earns a reward of  $r$  that is significantly higher than the amount available to them before the interaction,  $s$  ( $r > s$ ). The Investor does not know whether trustee is nice or greedy, but assigns  $p$  and  $(1 - p)$  probabilities to these options respectively. Greedy trustee will always defect ( $r < 1$ ), while nice trustee will always cooperate ( $r > 1 - \epsilon$ ). In this setting, the trustee cannot manipulate investor's beliefs about whether or not to invest, but the results of previous interactions and the reputation can be credible signal of the type of trustee.

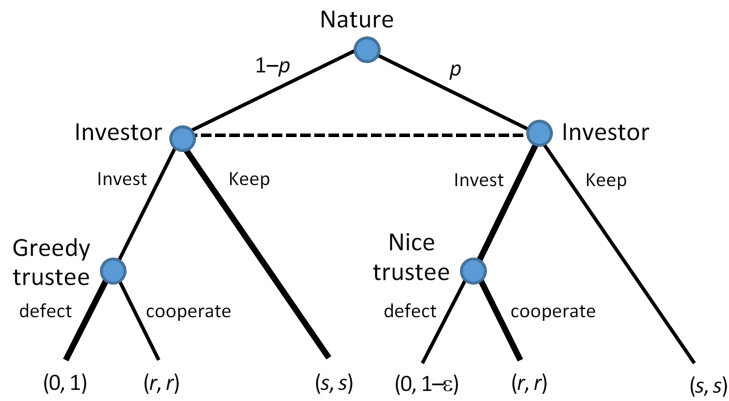


Figure 5: Bayesian trust game

This is a sequential trust game with incomplete information (Bayesian trust game) where solution concept called Perfect Bayesian Equilibrium (PBE) has two components: set of strategies and set of beliefs. PBE is defined as a strategy profile that maximizes the expected payoff for each player given their beliefs and given the strategies played by the other players. The expected payoff vary depending on the probability distribution, which directly affects the investor's decision. However, Investor beliefs are subject to numerous factors including cognitive biases such as overconfidence, confirmation bias, framing effect, loss aversion and a like. It has already been proven that reputation is a factor that drives players to cooperate more. In the multi-stage version of the trust game, the interaction between investors and trustee is repeated  $n$  times ( $n$  rounds), where the number of rounds is usually known in advance. Investors have the opportunity to receive greater rewards by investing money, while, at least until the last round, the trustee has an incentive to maintain a reputation of trustworthiness in order to persuade the investor to invest more.

## 6. BEHAVIORAL DRIVERS OF COOPERATION IN PRISONER'S DILEMMA GAME

The Prisoner's Dilemma (PD) game was introduced by Flood and Dresher in 1950, to research a global nuclear strategy. Since then, the game has been used to explain the behavior of individuals in a number of social dilemmas. Social dilemmas occur when individuals have to choose between strategies that optimize their personal benefits and those that maximize the well-being of the group (society). An individually rational strategy in social dilemmas is non-cooperation, but if no one cooperates, the payoffs will be lower than if all cooperates.

When a PD game is played in experimental settings, players can choose to either cooperate (C) or defect (D). Neither of the players knows the choice of the other player as long as both of them make the choice, and the payoff for each player depends on the combination of their choices. Payoff matrix for the one-shot PD game is given in Figure 6, where  $T > R > P > S$  and  $2R > T + S$ . The highest individual payoff is made by the player who defects when the other cooperates ( $T$ ), with the cooperator earning the lowest individual payoff ( $S$ ). If both players defect, each get a punishment payoff that is less than a reward payoff which they would get if both had cooperated ( $P$  and  $R$ , respectively). In this setting, defecting is the dominant strategy, and a rational solution to the game, so-called Nash equilibrium, is a set of strategies (defect, defect).

		Player 2	
		C	D
Player 1	C	$R, R$	$S, T$
	D	$T, S$	$P, P$

Figure 6: One-shot prisoners' dilemma

In repeated version of the game (RPD), where players play the Prisoner's Dilemma  $k$  times, the unique equilibrium is also Defect. Namely, in the last round, the dominant action is defect; therefore, in the last but one round there is no possibility of influencing what will happen, so it is optimal to defect in this round as well, and so on.

However, in reality, people deviate from a rational self-interested solution by cooperating much more, as confirmed by the results of numerous empirical studies. Striving for a socially optimal solution to social dilemmas, researchers are interested in understanding the dynamics of choosing a cooperative strategy as well as the factors influencing it. Numerous incentives were found for cooperation ranging from the socio-demographic variables to individuals' cognitive biases. Social preferences for fairness, altruism or efficiency as well as personal preference and reputation, can also generate (drive) cooperation in this game. This is especially noticeable in the multistage variant of the game with long-term consequences.

Rand [82] states that cooperation rates in the one-shot PD game is determined by both social surplus and cognitive skills of players. He has experimentally demon-

strated that higher cognitive skills are associated with higher rates of cooperation. Many experimental studies confirm that cooperative behavior in PD-type games could also be affected by differences in the consistency of players' SVO [60, 80]. Smeesters *et al.* [91] found that the behavior of individuals depend on what they think of the other player as if being competitive or cooperative. To explain the emergence of cooperation in repeated social interactions, Moisan *et al.* [71] presented an integrated framework that looks at individual social preferences in social dilemmas such as the prisoner's dilemma. The authors identified patterns of high and low rates of cooperation resulting from both different incentive structures and individual SVOs among players.

Using computer simulation and four experiments, Ginberg *et al.* [38] researched group biases in the PD game. The authors suggest that people obtain a greater incentive to cooperate when their choices correlate with an exogenous factor, which is a consequence of the so-called Simpson's paradox. In addition, the results of the experiments showed that communication significantly increases cooperation rate, but the effectiveness of communication depends on whether promises or threats are used [70] and whether communication is face-to-face or not [35]. Charness and Dufwenberg [20] conclude that people usually keep their promises because of aversion to guilt.

Using one-shot PD game Kuzmanovic *et al.* [60] sought to reveal whether and to what extent individuals behave rationally, whether their behavior is affected by gender and/or social value orientation and whether the effects of these factors on the cooperation rate remain the same if the stake value is changed or if the opponent is known in advance. The authors experimentally confirmed that if there was an external stimulus, neither gender nor SVO had significant influences on the players' behavior. Repeating the experiments over the next few years, these findings were continually confirmed.

Player's expectations about the opponent's behavior in PD affecting own behavior, as suggested by Pletzer *et al.* [80]. Contrary to pro-self players, pro-socials are predicted to increase their cooperation when they expect the opponent to cooperate [8]. Recently, Engel and Zhurakhovska [26] conducted an experiment to explain effect of five motives (payoffs from cooperation, expectations about cooperativeness in given population, and the degree of aversion to risk, loss and inequity) on cooperation level in PD games. By manipulating payoffs in case of both players defect, they found that all five factors are significant only if one factor controls all the others.

It was found that individuals cooperate more in finitely repeated PD than in on-shot PD games. Axelrod [3] proposes tit-for-tat as a strategy that effectively train opponent to play cooperatively in repeated PD games. Wang *et al.* [102] studied the impact of decoy effect on the level of cooperation in repeated PD game. The decoy effect or asymmetrically dominated choice is a cognitive bias that occurs when people's preferences for one option change to another as a result of adding a third, less attractive option. The authors extended the classic PD game by introducing new "rewarding" action in addition to the existing two actions (Cooperate and Defect). They have shown that the existence of a decoy

option significantly increases the overall cooperativity in multistage PD game and improves the success rate of individuals who cooperate in this game.

## 7. CONCLUSIONS

Neglecting the influence of human behavior in decision-making models and methods has received a lot of criticism. Actually, there are numerous behavioral influences, from cognitive biases to the personal and social preferences of individuals, all undermining the assumption of rationality on which traditional models are based.

This paper provides a comprehensive overview of the various modeling frameworks that have been used to capture social preferences, bounded rationality, and other cognitive biases in game theory models. The findings of experimental studies regarding the factors that influence behavior in both one-shot and repeated social interactions are presented.

The concept of bounded rationality is illustrated by the example of a p-beauty contest game. A presented k-level model identifies the depth of reasoning of individuals. The model was applied to the data of multiple experimental studies in order to explain the levels of rationality of players in the decision-making process. Most of the participants turned out to be level-1 type, although there were irrational or naive Nash ones. In addition, a review of the literature on the influence of social and personal preferences on player behavior in the experimental ultimatum bargaining game, trust game and prisoners' dilemma game is given. A number of other factors affecting players' behaviors that are inconsistent with the assumption of rationality, have also been pointed out.

Although the paper provides a detailed review of the literature, much has not been touched upon. Strategic interactions such as negotiation, contracting, market entry and the like are also influenced by many behavioral factors that can be researched through experimental games such as coordination games and collective actions games. However, it has been shown that mathematical models together with behavioral experiments could significantly improve game theory and provide a better basis for decision-making. Therefore, it is not surprising that scientists are strongly interested in behavioral aspects of modeling and analysis of strategic interactions. So, further development of this sub-discipline with applications in a number of fields is to be expected.

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