Heuristics, thinking about others, and strategic management:

Insights from behavioral game theory

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Abstract

The outcome of strategic decisions (such as market entry or technology adoption) depends on the decisions made by others (such as competitors, customers, or suppliers). To anticipate others' decisions managers must form beliefs about them and consider that others also form such higher-order beliefs. In this paper we draw on insights from behavioral game theory —in particular the level-k model of higher-order reasoning— to introduce a two-part heuristic model of behavior in interactive decision situations. In the first part the decision maker constructs a simplified model of the situation as a game. As a toolbox for such formulations, we provide a classification of games that relies on both game-theoretic and behavioral dimensions. Our classification includes aggregative games in an extended Keynesian beauty contest formulation and two-person 2x2 games as their most simplified instances. In the second part we construct a two-step heuristic model of anchoring and adjustment based on the level-k model, which is a behaviorally plausible model of behavior in interactive decision situations. A key contribution of our article is to show how higher-order reasoning matters differently in different classes of games. We discuss implications of our arguments for strategy research and suggest opportunities for further study.

Keywords: Behavioral game theory, beauty contest games, bounded rationality, heuristics in strategic Interaction, strategy, level k model, anchors.

1. Introduction

"To change the metaphor slightly, professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; [. . .] It is not a case of choosing those which, to the best of one's judgment, are really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practice the fourth, fifth and higher degrees." (Keynes, 1936, Chapter 12.V).

A key characteristic of strategic decisions (such as market entry or technology adoption) is that their outcomes depend on the decisions taken by other "players" in the situation, such as competitors, customers, or suppliers (Leiblein, Reuer, & Zenger, 2018). Consequently, the beliefs managers have about these other players affect their behavior in strategic decision situations. Yet, surprisingly, in the field of strategic management,[1] only few scholars (e.g., Levine, Bernard, & Nagel, 2017; Menon, 2018; Zajac & Bazerman, 1991) have explicitly and systematically examined how beliefs about others affect behavior in such situations. Understanding how managers reason about others is particularly important because beliefs about other players have consequences that are qualitatively different from the consequences of beliefs about other aspects of a situation: Beliefs about others are beliefs about players who may also think strategically and who thus may similarly have beliefs about the other players from their perspective. Managers who consider others' beliefs engage in higher-order reasoning, and such reasoning may be of second or higher order (e.g., considering beliefs about beliefs about beliefs and so on; Nagel, 1995; Camerer, Ho, & Chong, 2004; Crawford, Costa-Gomes, & Iriberri, 2013). As the introductory quote by John Maynard Keynes suggests, engaging in higher-order reasoning can substantially affect behavior and outcomes in interactive decision situations and may even be a source of competitive advantage.

Interactive decision situations have been analyzed using game theoretic tools, but the kind of higher-order reasoning suggested by Keynes in the above quote is at odds with standard assumptions in game theory: he claims that players who play the same game with the same perspective and

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[1] Camerer (1991) defines the field of strategic management as "the study of the sources (and creation) of efficiencies which make firms successful" (p.137). As van den Steen (2018) notes, the meaning of the concept of strategy used by researchers in the field of strategic management only partly overlaps with the game-theoretic meaning of a strategy as a "complete contingent plan that specifies how a player will act at every decision node where she is the decision-maker" (p. 581). Our contribution is to the field of strategic management.

information can still exhibit different beliefs about others and therefore potentially choose different actions. If players were fully rational in such a given game, they could anticipate the actions by other rational players (often based on iterative reasoning) and thus calculate the (expected) value of each action. When each player thus best replies to each other's action, a Nash equilibrium is reached. Outcomes can be different, however, if not all players are rational and some know that not all players are rational.

At least since Selten's (1978) description of the chain store paradox, behavioral theorists have argued that it is implausible that humans actually engage in the type of (iterative) reasoning that the rationality assumptions imply. During the past 25 years, a large literature has developed in behavioral game theory which examines bounded rationality and the heuristics people use for higher-order reasoning in interactive decision situations (see the recent surveys by Crawford et al., 2013, and Mauersberger & Nagel, 2018). A hallmark of behavioral game theory is that it combines rigorous experiments with the analytic tools of game theory to generate insights into how individuals act when the outcome of their actions are affected by the actions of others and, in particular, into how they think about one another in such settings (for a comprehensive review of the field of behavioral game theory, see Camerer, 2003). In this article, we draw on this literature to propose a two-part heuristic model of behavior in interactive decision-making and to demonstrate its applicability to typical strategic decision situations.

Our proposed model builds on and connects two fundamental points Keynes makes using the beauty contest metaphor. First, he shows how a complex real-life situation (a stock market situation) can be reduced into a game as a simplified representation that captures the essential features of the real-life situation while leaving others out of the picture. Second, he suggests that humans exhibit heterogeneity in terms of their depth of strategic reasoning and that an enhanced depth of reasoning may constitute a source of advantage in interactive decision-making situations. Behavior in interactive decision situations is thus guided by two types of simplification: First, as in individual decision-making situations (Simon, 1955; Levinthal, 2011) managers will construct a simplified representation of the interactive decision environment they are acting in, which determines the premises for their subsequent strategic considerations. Here our model builds on analytical game theory, from which (as

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already suggested by Camerer, 1991) a useful taxonomy of interactive decision situations can be constructed. Second, how they think about others (i.e., how they engage in higher-order reasoning) affects the decisions they make. Here, our model builds on the "level-k" model, which is a simple and parsimonious model of higher-order reasoning in interactive decision situations based on the idea of iterated best reply to beliefs about other players.

The level-k model of strategic reasoning has been conceived to explain actual behavior in interactive decision situations. It draws from one of the most representative examples of behavioral investigations from this literature, i.e., the "guessing game" or "beauty-contest game" (Nagel, 1995).[2] This game provides a simple and intuitive illustration of how heterogeneity in higher-order reasoning affects outcomes and mimics Keynes' ideas about levels of reasoning. The experimental setup involves a number of participants who are instructed to guess a number between 0 and 100 with the aim that one's number is the closest to a target, commonly set as two thirds of the average of all chosen numbers. To perform well on this task, participants must realize not only that they need not only anticipate the numbers other participants will choose (and calculate an average and multiply that by two thirds), but also that others will in turn engage in a similar reasoning. The game has a unique Nash equilibrium: all players guess exactly zero.

But this is not the behavioral outcome in an experiment. Instead, a clear pattern emerges when the numbers actually chosen are analyzed, which Nagel (1995) explains by assuming that individuals engage in different levels of reasoning. A naïve (or level-0) player, who does not think about what others may play would randomly choose a number in the interval [0, 100], maybe with 50 being a reference point, or simply his favorite number. On the other hand, a player who would think that all others would (uniformly) randomly choose any number in the interval [0, 100], would estimate the average of the other players' stated numbers to be 50 and consequently guess 33. Thus, guessing 33 characterizes level-1 reasoning, whereas choosing randomly or guessing 50 corresponds to level-0 reasoning. Consequently, level-2 reasoning would lead to stating 22 (i.e., 2/3 of 33). That is, a level-2 reasoner assumes all others to be level-1 reasoners, believing to be one step ahead of the others. This

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[2] The experimental game was originally conceived by Ledoux (1982) and Moulin (1986). The first experimental lab implementation was done by Nagel (1995). See Nagel, Bühren, and Frank, (2017) for a historical account.

logic can be continued for level- 3 and higher and thus be generalized into a "level-k model" of reasoning where a player at level- k believes that the other players are at level k-1 and he consequently best responds to such level k-1 players.

The first part of our heuristic model offers a new taxonomy of games combining analytical game theory and the level-k model.[3] Our taxonomy classifies games according to two game-theoretic dimensions: symmetry (symmetric vs. asymmetric games) and strategic interdependence (choice variables are strategic substitutes or complements depending on the direction of best reply, but in certain games a player may have a dominant strategy in which case his best reply is independent of other players' choices). Our taxonomy includes both an extended beauty contest game formulation (a formulation of games in terms of iterated best reply to beliefs about other players; see Mauersberger & Nagel, 2018 for a generalizing, connecting to more complex situations) and six 2x2 games (Corts, 2011, mimeo). This combination contains the main simple features of strategic interaction in a concise way.

By adding the level-k model as a behavioral dimension to our classification system, we can show that games differ in terms of whether and how higher-order reasoning matters to behavior and outcomes in particular games. A key insight of our study is that a distinction can be made between games in which at most level-1 reasoning matters and those in which reasoning at level 2 and higher matters (when we say that "reasoning at level k matters" we mean that a player who reasons at a level higher than k will make the same decision as a level-k player for all levels higher than k). If reasoning at level 2 or higher matters to outcomes then thinking about others involves *thinking about what others think* instead of merely thinking about others's actions. If thinking about others' thinking does not matter (if at most level-1 reasoning matters) a situation may be reduced to a "game against nature," assigning, e.g., a probability distribution over strategies of other players..

The second part of our model develops a heuristic model of anchoring & adjustment (see related ideas in Tversky & Kahneman, 1974) with the level-k model as its main underlying concept. The

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[3] Several taxonomies have been proposed in the game-theoretic literature. The taxonomies of games proposed by Rapoport and Guyer (1976) and Robinson and Goforth (2005) only considered two-person 2x2 gamers; Camerer and Fehr (2006) classify games into those where choices are strategic substitutes and those where they are strategic complements as we do, but their classification does not include 2x2 and BC games.

actual behavior and outcomes are contingent on the constructed representation of the decision environment. Here we assume that all players have available the information of the same game. Yet, they might use those details in different ways. We present and discuss different anchors as starting points together with higher order reasoning. Anchors serve as representations of choices by naive agents who think about the situation without engaging in strategic reasoning (e.g., choosing randomly or using a focal point). Adjustments are deviations from such reference points which in strategic situations are (iterated) best replies.

Overall our paper provides a novel perspective on game theory to strategic management scholars. We provide a structure for classifying games together with a behavioral model and demonstrate its relevance to key questions of strategic management, thereby reiterating Camerer's (1991) argument that game theory, although often misunderstood, has much to offer to strategy researchers. We conclude our paper by discussing the implications of our heuristic model for strategic management, thereby highlighting research opportunities and possible extensions.

2. Keynesian Beauty contest games, best replies and the level k model

Our two-part heuristic model builds and connects the two fundamental points Keynes makes with his beauty contest metaphor and thus the two types of simplification that affect behavior in interactive decision situations. Before we can develop our model, we first need to provide the analytical and behavioral foundations our model builds on, which we do in this section.

2.1. Higher-order reasoning and behavior in the Keynesian Beauty Contest game

In order to be able to translate Keynes' beauty contest metaphor into a model of behavior in interactive decision situations, we need to make two important qualifications concerning the game-theoretic structure of the game and the suggested reasoning procedure for the participants. First, it must be noted that the beauty contest game, as formulated by Keynes, has multiple equilibria (namely all players selecting the same face, which means that any of those can form an equilibrium). The players thus have to solve a coordination problem in addition to "outguessing" each other. This coordination problem exists even for rational players. To see this, let us take a version of Schelling's (1960) coordination game of meeting in New York city. Two (or n > 2) people want to meet in the same place, without being able to communicate with each other, one of the possibilities being the

Central Station (CS), and the other the Empire State Building (ESB). Not getting to the location selected by the other person (or the larger crowd in the case of n players) results in a payoff loss. The game has two equilibria: All meeting in either location is obviously an equilibrium as any unilateral deviations from these two possible locations yields a loss. From a game theoretical point of view, rational reasoning will not solve the problem, as Keynes suggests. But Schelling proposes a way out by introducing a behavioral component: focal point reasoning. Focal points can serve as behavioral rules for reasoning about others: if it were well-known that New Yorkers prefer to meet at, say, CS, then knowing about meeting with a New Yorker, one will head to CS. In analytical game theory, the problem of equilibrium selection is still an open question, and several refinements of the equilibrium notion have been proposed in the attempt to solve it (see, for example, Selten, 1975, on subgame perfection, and Selten's, 1978, the chainstore paradox). A behavioral model of strategic reasoning can solve the problem, but such a model must account for the behavioral rules used by players when thinking about what others will do.

Second, there is an inherent limit to how higher-order reasoning matters to outcomes in Keynes' original formulation. Here, the behavior implied by beliefs of higher order is the same as the behavior implied by first-order beliefs. Using our example, if Bob thinks that Ann wants to meet at CS (this is level-1 reasoning), then he will go there. If Bob thinks that Ann thinks that Bob thinks that Ann will get to CS (this is level-3 reasoning), then he should also go there. Whereas different beliefs result in different choices, higher-order beliefs beyond level-1 with the same starting belief will collapse to the same belief and choice as that of a level-1 thinker. This means that participants in the beauty contest as formulated by Keynes do not have an advantage from engaging in higher levels of reasoning. But there are many games in which reasoning at level 2 or higher does make a difference. It is therefore important to understand in which game situations it makes a difference and in which it does not. The taxonomy of games that we provide below clarifies in which games different levels of reasoning matter to outcomes.

2.2 The p-Beauty Contest game formulation and the level-k model of strategic reasoning

To be able to focus on the role of higher order reasoning in games and avoid issues of multiplicity of equilibria it is sufficient to make a small change to Keynes' beauty contest formulation, namely by

introducing a discount factor of the mean different than one. This yields a family of games called p-Beauty Contest games, in which players win if their guess is p times the average of all submitted guesses. For example, setting p = ⅔ yields the "guess the ⅔ of the average" popular game described in the introduction (with either the fixed or distance payment scheme). This game has a unique Nash equilibrium in which all players choose zero (so rational agents who solve for the equilibrium solution do not face a coordination problem).

In this game, iterated dominance reasoning leads to the equilibrium. That is, the equilibrium is the strategy that survives the infinite process of iterated elimination of strictly dominated strategies. This reasoning can be illustrated as follows. If all players would choose 100, then the guess of ⅔ of 100 (66.67) dominates all guesses above it, as they would yield a lower payoff. Therefore, all rational players would submit the guess of 66.67. However, a player that anticipates this reasoning would best reply to it by submitting a guess of ⅔ of 66.67 (44.44). After infinite repetitions of this process, all possible guesses but that of zero are eliminated.

Nagel (1995) was the first to implement the guessing ⅔ game in a laboratory experiment (we provided an overview of the experiment and results in the introduction). The most important insight of Nagel's (1995) study is that the observed heterogeneity in behavior could be explained by a very simple and parsimonious behavioral model: the level-k model of reasoning, which is based on the idea that players best reply to beliefs about the other players and that these beliefs are potentially formed through multiple steps of iteration. A player at level-k believes that he is one step ahead of all other players: he assumes they are all at level k-1 and he consequently best responds to such level k-1 players. A player at level 1 assumes others to be level-0 players who use some simple rule for making a choice (e.g., random choice or a focal point). This simple rule serves as an anchor for a level-1 player. In the guessing ⅔ game the number 50 is as an obvious focal point, as it is the average assuming all other players choose a random number or some other favorite number. Level-1 players would choose 33, level-2 players 22 and level-3 players 15, which is a clearly visible pattern in Nagel's (1995) data.

Levels of reasoning have been examined in a variety of games over the last 30 years, and there is a clear-cut answer about the depth of strategic sophistication of decision makers. In most situations,

the depth of strategic reasoning does not exceed level 2, and rarely level 3 and 4 are observed (Bosch-Domenech et al., 2002, Arad & Rubinstein, 2012, Kneeland, 2015, Camerer, 2003, Crawford et al., 2013, and Mauersberger & Nagel, 2018). Results also vary across types of subjects: Figure 1 illustrates the results from subsequent experiments by Bosch-Domenech et al. (2002) with participants from different populations, where A, B, and C correspond, respectively, to level-1, level-2, and level-3 reasoners, respectively. In particular, level-1 and level-2 reasoners are clearly visible, independent of the subject pool, but the frequencies can be quite different (obviously, game theorists' choices are close to the equilibrium while undergraduate only rarely do so).

<div align="center">*** Insert Figure 1 about here ***</div>

The level-k model was subsequently extended (e.g., according to Stahl & Wilson, 1995, level-2 players form probability distributions over level-1 and 0 players), and a more sophisticated "cognitive hierarchy" model was proposed by Camerer, Ho, and Chong (2004) with a one-parameter model in which level-k players best respond to a Poisson distribution of lower level k-1, k-2, …, 0. Furthermore, Alaoui and Penta (2019) introduce an axiomatic theory with costs and bounds of thinking in which the reasoning level is determined endogenously. Goeree and Holt (2004) add noise to each level k rule, similarly as Bosch-Domenech et al. (2011) who construct a mixture model of different beta distributions for each level k. These models have been used to explain observed behavior in a variety of contexts, including the explanation of market entry decisions as a function of the firms' CEOs depth of reasoning (Goldfarb & Xiao, 2011) and recently in behavioral macroeconomics (see, e.g., Garcia-Schmidt & Woodford, 2019). To develop our heuristic model, however, we use the simpler level-k model.

2.3 The extended Beauty Contest game

In the p-beauty contest formulation, each player's best reply is based on his beliefs about the average of the numbers chosen by all other players. Calculating and replying to an average of other players is one way to aggregate the choices of other players. But there are other ways in which other players can be aggregated into a "representative opponent," such as average, minimum, maximum, and other order statistics. More generally, there is a class of aggregative games, which are n-player games (with

n ≥ 2) in which the actions of the n-1 opponents can be aggregated into the action of one representative player (Selten, 1970).[4]

Formally, *an extended beauty contest game*[5] is a game with N players $i = 1, ... N$, each of which chooses an action $y^i \in Y$ (where Y is the set of available actions), and player i's optimal action (best reply) given his beliefs about the actions of others, which is given by:

$$y^i = c + p \cdot E_i[f(y^1, ..., y^N)], \tag{1}$$

where $p, c \in R$, with p being a discount or multiplication factor and c representing some exogenous value (e. g , a fundamental value); E_i is player i's subjective belief about the actions of the other players, and $f(\cdot)$ is an aggregation function. The aggregation function $f(\cdot)$ can be the average, minimum, maximum, mode, action chosen by at least $h \leq N$ players, etc. The parameter p determines the direction of a player's best reply in reaction to other players' choices (as we explain in more detail below). It determines whether choices are strategic substitutes ($p < 0$) or strategic complements ($p > 0$). The parameter c is an added constant, e.g., representing a large player acting before everybody else, or a fundamental value or endowment, exogenously determined. The resulting y^i is a generic reaction function which determines player i's optimal action given his beliefs about the actions of other players and some other exogenous components which characterize the game. The formulation here can be extended to include more components (see, for example, Mauersberger & Nagel, 2018, and Angeletos & Lian, 2016).[6]

Aggregation can be seen as a simplification step that collapses a multiplicity of opponents into a representative one. Many well-known games are specific instances of the generic beauty contest game as defined in (1), with specific values for the parameters p and c, the set of available actions Y and the aggregation function $f(\cdot)$. For example, the guessing two thirds game is given by setting $p = 2/3$,

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[4] Games in which the different players cannot be aggregated into one "representative opponent" are not considered here. Examples of these games and their importance to strategy management are illustrated in Brandenburger and Stuart (1996), in which the authors analyze three-person games (input firm, supplier, and buyer). The authors build their investigation on the so-called cooperative game theory (coalition formation with unstructured decision procedures as free bargaining).

[5] See Mauersberger and Nagel (2018) for a more generic formulation of beauty contest games, which also includes a consideration of time (thus allowing for dynamics and learning about others) as well as parameters that are relevant in applications beyond the strategy context (such as macroeconomics).

[6] Benhabib, Wang, and Wen (2015) and Mauersberger and Nagel (2018) show how these BC games are extendable to more dimensions and even up to simplified general equilibrium models, which is the most general way of modeling economic interaction in a high dimension.

$c = 0$, $Y = [0; 100]$ and $f(\cdot) = \frac{1}{N}\sum_{j=1}^{N} \quad y^j$ and in a Cournot game firms best reply to the expected

aggregate quantity chosen by all other firms. Two-person games with two (discrete) actions (2x2

games) available to each player can also be considered as aggregative games in the sense that the

aggregation of the other players has already taken place or there is only one opponent[7].

3. A two-part heuristic model of behavior in interactive decision situations

The generalized beauty contest formulation of games in terms of a best reply function to beliefs about

others' choices together with the level-k model of strategic reasoning form a two-part heuristic model

of behavior in interactive decision situation, which we present in this section. In the first part of the

model, the decision-maker constructs a simplified representation of the decision situation he faces,

which determines the premises for his strategic considerations. In order to guide the formation of such

simplified representation, we provide a classification of games that relies on both the game-theoretic

and behavioral dimensions of analysis. We will show how this "toolbox" includes building blocks for

constructing a wide set of decision-making scenarios that capture the underlying motives of common

real-life strategic situations. The second part of the model identifies the behavioral strategies

contingent on the constructed representation of the decision environment. We present and discuss a

model of anchoring & adjustment, with the level-k model as its main underlying concept.

3.1 Part 1: Constructing a game

3.1.1 Games as simplified representations of interactive decision situations

The first step in making decisions in an interactive decision situation is to construct a simplified

representation of the situation as a game that captures the essential features of the situation just as

Keynes did in transforming the stock market investment situation into a beauty contest game. The

process of mapping an interactive decision situation into a game requires the recognition of the

relevant actors, their available choices and payoffs, and how the payoffs depend on each of the actor's

choices. The transformation of an interactive decision-making situation into a game can be simplified

if one is able to recognize which game best represents the situation one faces. For example, a market

entry decision is the more profitable the fewer other firms enter the market. At the simplest, this is

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[7] There is a large variety of experiments on (extended) versions of beauty contest game which are surveyed in
Mauersberger & Nagel, 2018.

akin to a game of chicken where a firm would prefer to enter if others stay out but prefer to stay out if others enter (Camerer & Lovallo, 1999). The decision to adopt a standard can be likened to a battle of the sexes, which has two equilibria but requires coordination. The decision whether or not to engage in an R&D alliance could be captured by a stag hunt, which also has two equilibria but one is strictly superior to the other (we will explain these games in more detail below). Throughout we assume that all players correctly identify the game that best represents the situation they face and that all players identify the same game.[8]

The game as a simple representation of the situation determines not only each player's best reply (that is, what he should do given others' choices) but also how he should think about others (and whether he should at all). This means that it determines both the parameters of each player's best response function (here we make use of the formulation of the game as a extended beauty contest) and the levels of reasoning that matter to each of the players' choices. In the following two sections we provide an overview of the structural and behavioral dimensions that we then use to build a classification of games.

3.1.2 Structural dimensions for classifying games

A more systematic way to think of different games and, in particular, to identify relevant structural aspects by which different games can be compared is suggested by analytical game theory. In our classification we distinguish between strategic dependence, strategic substitutes and complements, and symmetric vs. asymmetric games.

Symmetric and asymmetric games. Players may differ in a number of aspects that affect their behavior and the outcome of their choices. Such differences include choice alternatives, pay-off consequences, initial endowments, information, or power. Therefore, it is important to distinguish between symmetric and asymmetric games. The asymmetries we account for in our classification only relate to choice alternatives and payoff consequences. We leave out other ways in which they may differ, such as initial endowments or information (these can in principle be added to our games). Therefore, in our classification in a symmetric game all players have the same choice alternatives and

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[8] Players can have inaccurate representations of the decision problem, and the representations can vary across players (e.g., see Devetag & Warglien, 2008, and Oechssler & Schipper, 2003). We abstract from this because it would introduce an additional level of complexity into our model.

payoff consequences given other players' choices, whereas in an asymmetric game there are differences between the players in terms of alternatives and payoff consequences. There is also an asymmetry between players in terms of how they think about each other, which we capture in our behavioral dimension in terms of levels of reasoning.

Strategic independence and dominance. In interactive decision situations a player's payoffs typically depends upon what other participants do. But this need not be always the case. For example, in a prisoner's dilemma a rational player will prefer to defect no matter what the other player chooses to do. In this case, a player has a dominant strategy. In particular, it is independent of other players' actions and therefore also independent of his beliefs about other players. Therefore, the existence of a dominant strategy essentially turns an interactive decision problem into an individual one for such a player. However, even though the concept of strategic dominance is simple from a theoretical point of view, behavioral studies have shown that being able to actually detect a dominant strategy can be a non-trivial, cognitively difficult exercise. This can even be the case for sophisticated reasoners: Nagel et al. (2017) shows that in an experiment on a two-person BC game with fixed payoffs, not even game theorists can easily detect that they have a dominant strategy. Furthermore, cooperation may be preferred if the situation is better characterized as a repeated prisoner's dilemma; Axelrod, 1981).

Strategic substitutability and complementarity. If a player does not have a dominant strategy his preferred choice depends on what others do. Then one needs to consider whether one prefers to move in the same direction and follow others' choices or instead move into the opposite direction and counteract other agents' behavior. In the former case choices are strategic complements and in the latter case they are strategic substitutes (Topkis, 1979; Bulow, Geanakoplos, & Klemperer, 1985). These define the direction in which a player will best reply based on his beliefs about the choices of other players and is given by the parameter p in the extended beauty contest game formulation, where a game with $p > 0$ is a game of strategic complements while a game with $p < 0$ is a game of strategic substitutes. For example, in a Bertrand game pricing choices are strategic complements because players find it optimal to respond to a reduction in price by another player by themselves reducing price (until prices reach marginal costs), and vice versa. In a Cournot game quantity choices are

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strategic substitutes because it is optimal to increase one's own output quantity if another player decreases his output quantity, and vice-versa.[9]

Strategic substitutability and complementarity are important features of the game structure that lead to different behaviors under the same levels of strategic reasoning. This can be illustrated using the guessing game and comparing that game with $p = \frac{2}{3}$ and $Y \in [0; 100]$ and the same game with $p = -\frac{2}{3}$ and $Y \in R$ (it is necessary to allow participants to choose negative numbers in the latter case). In the game with $p = \frac{2}{3}$ and no boundaries, complementarity implies that the higher the choices of other players, the higher one's own choice. On the other hand, in the game with $p = -\frac{2}{3}$ a very different pattern emerges, with choices clustering around zero. Here, substitutability will lead participants to "jump back and forth" between positive and negative numbers, which leads to much more homogeneous behavior than in the traditional guessing two thirds setup (see figure 2), from Buehren & Nagel, 2019). This is in fact a more general result: As noted by Camerer and Fehr (2006), when actions are strategic substitutes actual choices are closer to the analytic solution (i.e., Nash equilibrium), because less rational behavior is mitigated by more rational players; instead, in games where actions are strategic complements, actual choices are further from the analytic solution due to the absence of any balancing effect from having opposite incentives.

<center>*** Insert Figure 2 about here ***</center>

3.1.3 Levels of reasoning and behavior in different games

Recall that when we say that "reasoning at level k matters" in a game we mean that a player who reasons at a level higher than k will make the same decision as a level-k player for all levels higher than k. Adding level k into in the game structure therefore means that it is predetermined whether and what extent higher order beliefs matter or not in a given game. Levels of reasoning matter differently in different games, and therefore using level-k reasoning as a behavioral dimension in our classification of games provides guidance about how thinking about others affects one's own preferred choice. The behavioral dimension can be simplified into three different cases.

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[9] Mauersberger & Nagel, 2018 show how Bertrand and Cournot reaction functions are special cases of general BC games.

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Level k and strategic independence. If a player has a dominant strategy his preferred choice is independent of what others do. Consequently, thinking about others will not affect what one will do. For example, if the situation one faces is best characterized as a one-shot prisoner's dilemma where defecting is a dominant strategy it does not make sense to think about what the other player will do. This of course assumes that one has correctly classified the situation (cooperation may be preferred if the situation is better characterized as a repeated prisoner's dilemma; Axelrod, 1981) and realizes that one has a dominant strategy (which may be cognitively challenging in some games, as noted above).

Level 1. A level-1 player assumes all other players are level-0 players who choose myopically based on some anchor (e.g., randomly or focal point) and best replies to his beliefs about such level-0 players. He thus forms a very simple representation of others. In particular, he may consider how they view the situation (e.g., he may ponder about the "types" of players, which may give some indication about their preferred choice). But he will *not* consider how others think about others, i.e., a level-1 player ignores that other players may have beliefs about other players and that these beliefs may affect their actions. This means that the games in which at most level-1 reasoning matters to outcomes thinking about others' thinking plays no role in outcomes. The New York coordination game introduced above is such a game: Merely thinking about which focal point others may use is sufficient to identify one's preferred action but thinking about how others think about oneself has no effect on one's choice.

Level 2 and higher. Games in which reasoning at level 2 and higher matters to outcomes differ from games with strategic independence and games in which at most level 1 matters in an essential way: Players at level 2 or higher form beliefs about how other players think, and these beliefs affect their preferred actions. For example, in Nagel's (1995) guessing game with p = ⅔ (in the general beauty contest formulation) higher-order beliefs make a difference whereas in Keynes' original formulation with p = 1 only beliefs at level 1 matter. As a consequence games with reasoning at level 2 and higher are qualitatively different from other games, though how these higher-order beliefs affect choices will be different in different games. Basically games in which at most level 1 matters are equivalent to games against nature, where beliefs about others can be represented by a probability distribution. On the other hand, games in which reasoning at level 2 and higher matters cannot be

reduced in this way. There is also evidence that the latter are cognitively more difficult than games in which at most level 1 matters (Cherchia, Nagel & Coricelli, 2018).

Levels of reasoning in asymmetric games. In asymmetric games, the level of reasoning that matters for different players may be different. For example, asymmetric games include games in which one player has a dominant strategy and the other needs to (iteratively) best reply (and is thus at most at level 1).

3.1.4 A classification of games as a toolbox

Here we provide a classification of simple aggregative games as a toolbox that guides and supports the process of abstraction and simplification of a concrete decision problem. This classification is based on the structural dimensions we introduced above. That is, we classify games by their payoff symmetry, and whether choices are independent, strategic substitutes or strategic complements. The classification also includes the levels of reasoning that matter as a behavioral dimension. Together, these dimensions result in eight different subclasses of games, and each of these subclasses can include multiple canonical games.

To populate the eight subclasses, we build on the extended beauty contest formulation from the previous section. We include two types of games in our classification: (1) beauty contest games with with continuous strategies (henceforth BC games) and (2) discrete 2x2 games. Continuous BC games are a stylized representation of well-known games, such as Cournot or Bertrand. Discrete 2x2 games capture situations in which one of multiple available options (here two) must be chosen (e.g., technology standards in a coordination game). Mauersberger and Nagel, 2018, show that 2x2 games are simplified versions of generalized Beauty Contest games.

*** Insert Table 1 about here ***

2x2 games. 2x2 games are the simplest type of games that capture key aspects of strategic interaction. In addition, as noted above, 2x2 games can be interpreted as the simplest version of aggregative games, in which a number of other players are collapsed into a representative one. Although the set of 2x2 games is vast even when only considering ordinal payoffs (see the classification by Rapoport et al., 1976), it can be reduced to six games that encompass most of the strategic interactions that are relevant to the strategy field (see also the appendix for an overview of

the six games and how they are derived). These six 2x2 games are representative of five of the eight subclasses in our classification. For each of the six 2x2 games, there exists a basic BC game with the same game-theoretic features but with a continuous strategy set. The proposed combination of BC and 2x2 games therefore allows for a comprehensive analysis of the theoretical features that underlie a large set of interactive decision situations.

There are two symmetric 2x2 games with strategic independence: prisoner's dilemma and prisoner's delight. In both games, both players have a dominant strategy (i.e., defect), but the difference is that in the prisoner's dilemma the outcome from playing dominant strategies is inferior whereas in the prisoner's delight the dominant strategy leads to the mutually preferred outcome.

A stag-hunt game is a 2x2 coordination game in which one of the two available actions leads to high pay-offs if both players choose it and zero otherwise (the "risky" option) whereas the other action leads to a low pay-off (the "safe" option). This is characteristic of situations in which cooperation is risky but potentially rewarding, such as when engaging in an R&D alliance or when managers form firm-internal coalitions to pursue a strategic initiative. The actions in a stag hunt game are strategic complements, because both players prefer to choose the same action. In such a game, reasoning matters only at level 1 for the same reason as in the New York coordination game explained above. This means that if a situation is best characterized as a stag hunt game then a decision whether or not to cooperate should only be affected by what one thinks about the other player (e.g., his general willingness to cooperate or his risk preferences) but not by what one thinks about what the other player thinks about oneself.

The entry game (and chicken and battle of the sexes as variants) is a 2x2 game that depicts a situation in which both players are better off if they coordinate on opposing actions, but they have contrasting preferences on which action to coordinate. The game captures the strategic tension underlying a situation in which two competing firms have to decide whether to enter a given market and each prefers the situation in which one firm enters and the other does not (Camerer & Lovallo, 1999). An example for battle of the sexes is a situation where two firms each promote their technology for a common standard, where both prefer that their own technology is chosen as standard but will want to avoid a situation in which they don't agree on one or the other (Besen & Farrell,

1994). The actions in an entry game are strategic substitutes, because each player prefers to choose a different action. In such a game reasoning at levels 2 or higher matters, because one additional step of reasoning will change the best reply (in principle players at higher levels would alternate their best replies indefinitely). As Crawford et al. (2013) show, in entry or battle-of-the-sexes coordination games, thinking about what others think helps players to tacitly coordinate on mutually beneficial actions.[10]

There are also two asymmetric 2x2 games. In the one-sided (incumbent-challenger) game one player (the "incumbent") has a dominant strategy while the other player's (the "challenger") preferred action depends on what the incumbent does. Knowing that the incumbent has a dominant strategy the challenger will select the action that best replies to the incumbent's dominant strategy. While the incumbent will not need to think about the challenger (as he has a dominant strategy) the challenger will have to think about what the incumbent will do. For the challenger reasoning at level 1 but not higher matters because he simply has to see (in a sequential game) or imagine that the incumbent will do the same (choose his optimal strategy) no matter what the challenger will do (and what he would believe the challenger to do). Therefore, neither of the players can make himself better off by thinking about what the other thinks.

This is different for the second asymmetric 2x2 game, matching pennies (or hide-and-seek games as a variant). In such a game, one player's choice is a strategic complement to the other's choice, whereas for the other player choices are strategic substitutes. That is, one player wants to choose the same action and the other one a different action than the respective other. An example is an innovator (who wants to differentiate) competing against an imitator (who wants to be similar). In such a game reasoning at levels 2 and higher matters. In fact, matching pennies is a game in which the asymmetry between players leads to benefits from being able to outguess the other player. Just like in the guessing ⅔ game, where players are most likely to win if they are ahead of others by just one but no more steps of reasoning, in matching pennies a player's payoffs depend on his level of reasoning relative to the other player's level of reasoning (see Crawford et al., 2013).

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[10] See also Camerer and Fehr (2006) for a description of the n-player entry game. Heterogeneity in higher-order reasoning helps to achieve tacit coordination.

Continuous BC games. Due to their extreme structural simplicity, the six 2x2 games only fill

five of the eight cells of Table 1. Variants of the BC game can be constructed to fill all cells in our

classification scheme, and the reasoning behind whether and how higher-order reasoning matters in

these different games can be done analogously to the 2x2 games described above.[11] The BC game

with $p > 0$ is a game of strategic complements in which reasoning at level 2 or higher matters (as

illustrated in the guessing ⅔ game as the canonical case). The BC game with $p = 1$ is the exception as

then only level 1 matters (as discussed above, this was Keynes' original formulation of the game). The

BC game with $p < 0$ (where any number or a number from a symmetric interval centered around 0

can be chosen) is a game of strategic substitutes in which only level-1 reasoning matters. There is,

however, an interesting difference between the two symmetric 2x2 games (stag hunt and entry game)

on the one hand and the continuous BC game with $p > 0$ and $p < 0$ on the other hand: in the former

reasoning at level 2 and higher matters when choices are strategic substitutes and level 1 when choices

are strategic complements, whereas in the latter this is reversed. This shows that whether and how

higher-order reasoning matters in a specific game critically depends on structural characteristics of the

game. For example, when choices are strategic complements and there are only two possible choices,

it is not possible to outguess other players and therefore only level 1 matters. Once more choices are

introduced, for example by making them continuous (as in the guessing ⅔ game) outguessing

becomes possible and therefore engaging in more levels of reasoning than others potentially leads to

an advantage.

Extensions of the 2x2 and BC games. The games we selected for inclusion in our classification

are simple and capture some essential features of strategic interaction. Extensions and generalizations

are possible, and these generalizations can also be classified and analyzed according to the theoretical

and behavioral features that inform our classification. Moreover, the proposed 2x2 games can easily

be extended to n-person games with more than two discrete choices. Many of these games have been

studied extensively in the behavioral game theory literature. For example, the public good game is the

n-player extension of the prisoner's dilemma (depicting the tragedy of the commons situations,

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[11] For the three empty cells which are not filled by 2x2 games, one could also construct games with more than two discrete strategies. Yet, they have no prototypical easy correspondence of games discussed in the applied game theory literature.

Hardin, 1968), the minimum effort (or weak-link) game extends the stag-hunt game (see Camerer 2003, for review of experimental results on this game), and the n-player entry game extends the two-person entry game (see, for example, Rapoport et al., 1998).

Other two-player situations often encountered in negotiation and strategy contexts are the ultimatum game (Güth et al., 1982) the trust game,   and some principal-agent games, which are all extensions of the one-sided game. In these games one player moves first but must anticipate the reaction of the other. In the ultimatum game, the responder has to accept or reject the offer made by the proposer, with rejection leading to zero payoffs and acceptance to the payoffs suggested by the proposer. In the trust game, the amount offered increases and the responder can return an amount to the proposer. In both games, the second player has a dominant strategy, but it is the proposer who is in an advantageous position.

The n-player Cournot and Bertrand games of competition (where $n > 2$) are special cases of the generalizations of the extended BC game (see Mauersberger & Nagel, 2018). For the former, the reaction function depends on the sum of the quantities produced by the other n-1 firms, and $p < 0$ (game of strategic substitutes); for the latter, the reaction function depends on the minimum of the prices asked by the other n-1 firms, and $0<p<1$ (game of strategic complements).

3.2 Part 2: Anchoring & adjustment heuristics for playing the game

3.2.1 Level-k as a heuristic model based on anchoring & adjustment

When a game has been constructed, the second step in making decisions in an interactive decision situation is to consider which action one prefers given one's beliefs about what other players will prefer to choose. The level-k model can be translated into a heuristic model based on anchoring and adjustment. As above, we assume that all players correctly identify the game that best represents the situation they face and that all players identify the same game.

The level-k model is based on the idea that players use simple heuristics to form beliefs about (construct representations of) other players and that they will best reply to these beliefs. These beliefs are formed based on a logic of anchoring and adjustment similar to that proposed by Tversky and Kahneman (1974). Specifically, decision makers are assumed to define an anchor (or reference point),

which means forming beliefs about the behavior of level-0 players. Based on such an anchor, decision makers iteratively reconstruct the behavior of their opponent(s). However, not all players will think about other players and therefore not engage in the process of anchoring and adjustment suggested by the level-k model. They may have a good reason to do so. For example, a player may have a dominant strategy, which means that his preferred choice is independent of what others choose. If (as assumed) the player correctly understands the game, then he will play the dominant strategy.

The level-k model is based on the assumption that players' choices are rational responses to their beliefs about others. If the standard assumptions of rationality are not met, a player's beliefs about others need not be correct or consistent with other players' beliefs. Thus, these choices are allowed to systematically deviate from equilibrium in a way that accounts for out-of-equilibrium pay-offs its predictions are often more accurate than equilibrium or other solution concepts that assume more rationality (Crawford et al., 2013; Camerer & Fehr, 2006).

3.2.2 Defining the anchor

Players who do think about others need to define an anchor as the starting point. The anchor is the belief about what a level-0 player will choose. Level-0 players do not think about other players to decide what to do. A level-1 player best replies to his beliefs about level-0 players. Note that level-0 players need not exist: level-1 players may best respond to purely fictitious level-0 players. Defining an anchor is a crucial step in the decision process, as different anchors can imply different behaviors also for strategically more sophisticated players by propagating through the chain of iterated reasoning. The following is an overview of possible anchors.

- *Random play*. Players may simply assume that level-0 players select their actions randomly. Such naive play may be reasonable when one is confronted with other players about which he knows nothing, or when he is totally ignorant about the incentive structure of the game. For example, in the guess ⅔ of the mean game introduced above, participants in experiments seem to use (uniform) random play as anchor, which leads them to expect level-0 players to submit an average guess of fifty.

- *Focal point or salient point*. Players may use focal points as an anchor if they have reason to believe that level-0 players are likely to make their choices non-randomly. For example, one

may believe that others choose the option with the highest possible payoff. In the original Keynes' beauty contest this means assuming others to choose a face that is very different from all other faces (e.g. if there was only one male face and otherwise all women faces).

- *Own favorite choice.* Players may approach the game and search for their own favorite choice as an anchor (e.g., submitting one's own birth date in the guess ⅔ of the average game; see Brandenburger & Li, 2015).

- *Social preferences and cultural norms.* Players can use knowledge about how others' choices are affected by social preferences or cultural norms as an anchor. Especially in two-player games, social preferences could suggest players select the action that corresponds to the largest sum of the payoffs, or, if the player is a competitive type, the action that maximizes the difference in payoffs in a matrix.

- *Minimax.* One way to make a good decision without having to think and forming beliefs about others is to use minimax, which means choosing the action that has the highest minimum payoff across all potential choices by others (i.e., this pay-off is guaranteed independent of what others do). A level-1 thinker may thus use minimax as an anchor.

- *Equilibrium.* Equilibrium considerations can be anchors. Assuming others will choose an equilibrium would be reasonable if a player knows that his opponent is trained in game theory (but neglects findings from behavioral game theory).

- *Play observed in the past.* Cournot (1838) proposes that firms consider the action of others in the past as an anchor.

Players will often use their knowledge about others for choosing an anchor. But different players may also choose different anchors in the same situation. For example, a game theorist will form a different anchor than a player who is not familiar with game theory. The level-k model does not specify which anchor will be used. It has therefore sometimes been sometimes criticized as being arbitrary, as any anchor can be chosen (e.g., Colman, 2003). However, (as in the case of multiplicity of equilibria) it is an empirical question which level-0 anchors are selected by (boundedly) rational players.

3.2.3 Adjustment

Once an anchor has been defined, the decision-maker adjusts his decisions by best replying to that anchor and, for higher levels of reasoning, by iteratively best replying to the respective lower level. Adjustment can be thought of as a "stopping rule": a player (deliberately or intuitively) chooses a level, which is the number of iterations one goes through until the adjustment process stops. As we argued above, there is a critical difference between level-1 reasoning and reasoning at levels 2 and higher.

A level-1 player best responds to the behavior of a (possibly fictitious) level-0 player. He understands the structure of the game but he assumes that the other players are not engaging in strategic reasoning, so the interactive game can in principle be reduced to an individual decision against nature. Possible behavioral heuristics that can be labelled as level-1 reasoning are the following.

- *Choose the strategy with the highest expected payoff.* In its simplest case, this strategy relies on the premise that all other players select their strategies according to a uniform distribution. In 2x2 games this strategy trivially implies the selection of the dominant strategy, if it exists.

- *Best reply to previously observed data.* Also, a Cournot best response (Cournot, 1838) can be classified as a level-1 strategic approach, when a firm just best replies to the quantity observed in the previous period, conjecturing that the other player will make the same choice in the next trial. This means that the player ignores that other players may in fact act strategically and thereby lead to over- or underinvestment.

- *Best reply to "fair" behavior."* When a level-1 reasoner ponders about social preferences of his opponent(s), he might first consider some fairness norms he needs to best reply to. For example, he will offer more in an ultimatum game if he believes that low offers will be rejected. This heuristic may avoid rejections, which occur if the equilibrium strategy of offering incrementally more than 0 is chosen but the offer is rejected because it is socially unacceptable.

- *Playing the (nearly) same or opposite action.* When choices are strategic complements, a simple heuristic is to choose the same or nearly the same action as other players. On the other hand, when choices are strategic substitutes, a simple heuristic is to choose the opposite of

what other players choose. For example, in games with thresholds (an n-player entry game where payoffs are only positive when no more than 50% enter; Camerer & Lovallo, 1999) this simple heuristic suggests entry if one believes that less than 50% of the others will enter and no entry if one believes that more than 50% enter. This simple heuristic is based on treating other players as an aggregate and can lead to surprisingly good coordination (Camerer & Fehr, 2006).

Level-2 players assume that all other players are level 1. Players that perform two or more iterations of strategic reasoning are strategic in the sense that they consider how other players think about others (including themselves) to anticipate their decisions.

Evidence from experiments shows that there is substantial heterogeneity among individuals in the levels of reasoning they employ, both within and between populations. One possible reason for the observed heterogeneity in individual strategic sophistication and levels of reasoning may be differences in individual cognitive skills. Empirical literature has shown that the degree of strategic sophistication correlates with the cognitive capabilities of an individual (sometimes referred to as "strategic IQ"; see, for example, Carpenter, Graham, & Wolf, 2013; Gill & Prowse, 2016, Devetag & Warglien, 2003).

There is evidence that individuals by default tend to represent the other players as strategically naive decision makers that are unable to anticipate others' moves, and that this default model is continuously revised as new evidence about the behavior of others is accumulated (Hedden & Zhang, 2002). That is, while players may be initially at level 1 they may move to higher levels based on learning about others. This suggests that strategic sophistication is not a fixed trait of individuals but can develop over time as managers learn about other players over time.

However, from a firm perspective, and possibly from an individual one, individuals and firms can choose endogenously their level of sophistication based on some cost-benefit considerations (see Alaoui & Penta, 2015). In addition, the choice of a level of strategic sophistication by a firm also depends on the beliefs about the level of sophistication of the other firms involved. As noted earlier, in situations that can be modeled through an n-player BC game, just being one step ahead of the others is sufficient to get the prize (Nagel, 1995, Levine et al., 2018; Agranov et al., 2012). For example, as

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displayed in Figure 1, playing against different populations of agents can suggest different beliefs about the average level of sophistication, and thus trigger different best responses. In the entry game, instead, higher order reasoning suggests a switching between the two possible actions, on each next level. However, in a stag-hunt game, a player with level-k, with k > 1, would choose the same action as the level 1 player.

4. Discussion

We discuss the implications of our arguments for research in the field of strategic management, and highlight opportunities for further study and limitations.

4.1 Simplified representations of others, heuristics and characteristics of the situation

Strategy researchers seek to build their theories on realistic assumptions about human cognition and behavior (Powell, Lovallo & Fox, 2011). They have thus embraced and built on Simon's (1947; 1955) pioneering work on bounded rationality and simplification. Surprisingly, however, they have largely ignored the interactive component of bounded rationality, namely that managers also entertain simplified representations of others. As we have shown, when decision outcomes are interdependent there is a difference between simplifying one's representation of other players and simplifying one's representation of other aspects of a situation. But this difference only matters in certain games: if reasoning at level 2 or higher matters to outcomes then thinking about others involves thinking about what others think instead of merely thinking about others actions. If thinking about others' thinking matters, a decision situation cannot be reduced to a "game against nature." Established models of bounded rationality do not capture this difference.

The level-k model of strategic reasoning is the key building block in our simple heuristic model that explains how individuals simplify how they see others. It is based on realistic assumptions about human cognition and behavior. In fact, the level-k model can also accurately explain observed behavior in a wide range of interactive decision situations. It not only predicts when behavior will deviate from equilibrium outcomes but, in addition, it also predicts the distribution of players (their expected heterogeneity) and how characteristics of the situation (the game being played) affect behavior (Crawford et al., 2013). The studies by Levine et al. (2017) and Goldfarb & Xiao (2011) show that the level-k model is predictive of behavior in competitive settings.

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When combined with analytic game theory (which provides a taxonomy of relevant games; Camerer, 1991) the level-k model allows distinguishing between situations in which thinking about others' thinking matters and those in which it does not, and this is what we have shown in our table above. The advantage of this approach is that it does not require that managers actually engage in the kind of reasoning assumed by equilibrium analysis, which often relies on cognitively implausible assumptions (Camerer, 1991). Instead, what emerges from combining the level-k model with the taxonomy of games is a kind of "ecological rationality" analogous to what has been proposed by Gigerenzer and Selten (2002) in the context of situations of individual decision-making or prediction. Their argument was that simple heuristics "work" because they exploit the structure of a given environment. A corollary to their argument is that the same heuristics will lead to different outcomes in different environments. Our taxonomy of games can be seen as a taxonomy of relevant environments.

The fact that some situations cannot be reduced to a "game against nature" (because thinking about others' thinking matters) implies that ecological rationality in interactive decision situations also has to take into account what others think. This point is clear when recalling that in the guessing two thirds game the winning number depends on the kind of reasoning everybody else engages in. For example, if one plays against economists and—critically—knows that one plays against economists it is ecologically rational to choose a smaller number. More generally, in interactive decision situations where one plays a game against other players who are not "rational" (in the sense of the rationality definition in game theory) and one knows that they are not rational then the "ecologically rational" choice must account for how others are thinking about the situation and each other (at the simplest, in terms of anchoring and adjustment and as illustrated in the guessing ⅔ game at what point to optimally stop adjusting depends on where others stop). This introduces a type of complexity that strategy scholars have not accounted for.

4.2 Levels of reasoning and strategic sophistication as a managerial cognitive capability

The level-k model of reasoning captures a source of heterogeneity among individuals that matters to strategic outcomes. Strategic sophistication as measured by the depth of thinking about others can therefore be thought of as a managerial cognitive capability (Helfat & Peteraf, 2015; Levine et al.,

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2017). Levine et al. (2017) show in an experiment that participants' distance to the winning number in the guessing game (which they use as a measure for what they call "strategic intelligence": the ability to anticipate the actions of others) is associated with superior returns in so-called bubble experiments, in which subjects assume the role of traders who buy and sell assets. The study by Goldfarb & Xiao (2011), which uses a variant of the level-k model, shows that firms whose CEOs exhibit higher levels of reasoning outperform firms that have CEOs with lower levels of reasoning.

The level of reasoning employed in a situation affects the payoffs one gets. It can be a source of advantage in games where it is possible to outthink others, such as the guessing ⅔ game. In these games players have an advantage if they realize that they have to outguess others but not by too much. Because the levels of reasoning used by others matter it is important to be able to correctly assess others' depth of reasoning. But as our classification shows this is not the case in all situations. In some situations, levels of reasoning matter because they affect the ability to coordinate (for example, in entry games where outcomes depend on how many others also enter). That is, rather than outguessing others engaging in higher-order reasoning allows coordinating on a mutually beneficial outcome. But in some situations, levels of reasoning don't matter to outcomes, or they only matter to a certain degree (e.g., only up to level 1). This means that whether and how one can benefit from thinking about others depends on the specific characteristics of the situation.

The implication for strategic sophistication as a managerial cognitive capability is that its application requires understanding the characteristics of the situation. This means that a key part is to correctly assess the situation, which we have conceptualized as forming a simplified representation of a situation in terms of a game that captures its essential features. Therefore, being able to recognize and categorize situations in terms of games is important and the classification we have suggested can be seen as a toolbox that managers can use for assessing situations. Given limits to managerial attention (Ocasio, 1997) our classification allows managers to employ higher levels of reasoning selectively as it also includes the behavioral dimension which tells managers whether and to what extent higher-order reasoning matters in a situation.

4.3 Further research and limitations

Prior empirical research on levels of reasoning and strategic sophistication has focused on competitive contexts (Goldfarb & Xiao, 2011; Levine et al., 2017). Further research can examine the role of individual managers' levels of reasoning in other strategic decision contexts, using both field and laboratory studies. In addition, as research in behavioral game theory has shown, the level of strategic sophistication is not necessarily fixed but can be affected, for example, by experience and learning (Hedden & Zhang, 2002) or cost-benefit considerations (Alaoui & Penta, 2015). An interesting avenue for future research would be to study how strategic sophistication employed by managers varies across strategic decision-making situations and how it changes over time.

We finally note that in this article we have excluded a number of important aspects that have been examined by behavioral game theorists and that are relevant for business strategy. For example, we have largely abstracted away from the fact that individuals who are repeatedly exposed to the same or a similar situation or the same other players will engage in learning over time. Learning effects have been established in experiments and various learning models have been proposed to explain these learning effects (see, for example, Erev & Roth, 1998, Camerer, Ho, & Chong, 1999, and Marchiori & Warglien, 2008).

In addition, we have excluded the large area of studying social preferences (except for their potential role as level-0 anchors), which are also based on refining assumptions about rationality (see, for example, Cooper & Kagel, 2016). For example, individuals may care about the distribution of pay-offs instead of merely wanting to maximize their own pay-offs. Issues of fairness, trust or reciprocity have been examined in a large number of studies. Finally, we have mentioned only laboratory experiments and analytical game theory. However, behavioral game theorists have also examined how participants think and make decisions using brain studies (fMRI) (e.g., Coricelli & Nagel, 2009), which thus complements the other type of studies (Camerer, Ho, & Chong, 2015). .

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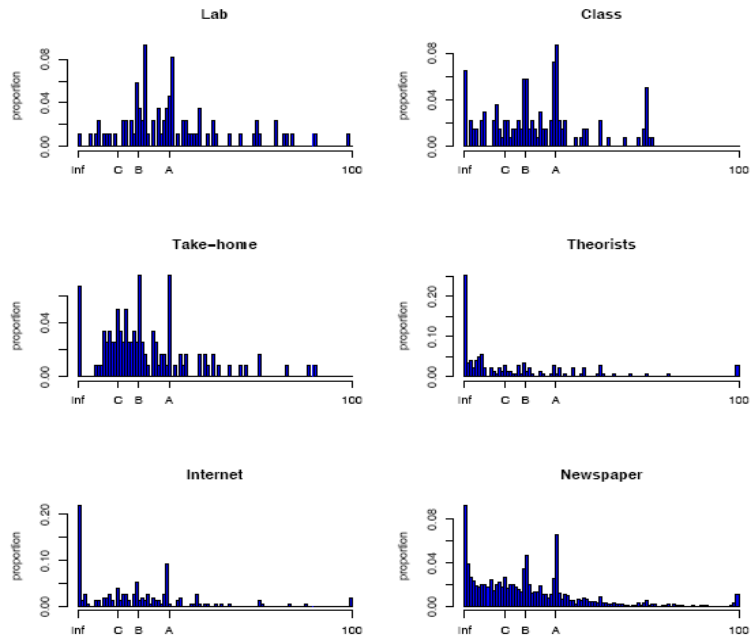
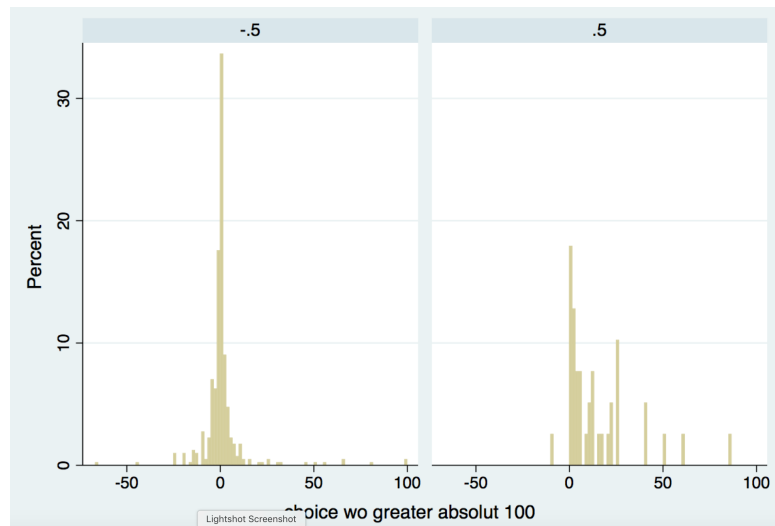***FIGURE 1. Experimental results in the guessing 2/3 game for different types of participants.***

FIGURE 2. Experimental results in the guessing 2/3 game (strategic complements, right side) and the guessing -2/3 game (strategic substitutes, left side) with numbers to choose from all numbers (negative, positive, zero), thus without boundaries. Data source: Benhabib, Duffy, & Nagel (2019).

TABLE 1. A classification of games (2x2 games are indicated in bold)

	Strategic substitutes	Strategic complements
	Symmetric games	
Strategic independence of other players' behavior (dominant strategy)	What other players do or think is irrelevant to one's own choice ● **Prisoner's dilemma** (one Pareto-inferior equilibrium in dominant strategies) ● **Prisoner's delight** (one Pareto-optimal equilibrium in dominant strategies) ● Two-person BC game, fixed prize payoff function, one Pareto-optimal equilibrium in dominant strategies)	
Level-1	● BC game with $p < 0$ and any number or symmetric interval around 0, e.g. [-100, 100]	Players want to choose the same action ● **Stag-hunt game** ● Continuous strategy games and $n > 2$: Keynes's beauty contest metaphor with $p = 1$ (Pareto ranking in minimum effort game)
Level-2 or higher	Players want to choose different actions ● **Entry game** (or **chicken game**; **Battle of the Sexes game**) ● BC game "guess (p) * the average + c", $p<0$	● BC game (positive guesses, close interval, and $p > 0$)
	Asymmetric games	
Mixture of Strategic independence and level-1	● **Incumbent-challenger game (or one-sided game)** ● Two-person BC game with $p < 0$; fixed-price for one player, distance payoff function for the other.	● Two-person BC game with $p > 0$; fixed-price for one player, distance payoff function for the other.
Level-2 or higher	Some players want to choose the same action as others, others want to do the opposite. ● **Matching pennies** also **Hide and seek games** (inspection games) ● BC game "guess (p) * the average + c" with positive guesses and close interval, with $p < 0$ for some players, and $p > 0$ for others	

Appendix: The six 2x2 games reported in Table 1

As explained, one of the dimensions that characterizes our analysis of the possible game situations (cf. Table 1) is the symmetry of a game. Starting from their general form (illustrated in Figure A1), the large set of symmetric 2x2 games can be firstly reduced by assuming a > d. Without any loss of generality, this assumption only implies that both the row and column players prefer to coordinate on *Action A* rather than on *Action B*. Although 12 possible orderings of the four distinct payoffs are consistent with the constraint a > d, these can be summarized by only four types of games, obtained by combining the ordering of a with respect to b, and c with respect to d. This because in a 2x2 simultaneous-move game, what matters for a player is only the ranking of his actions given the choice of the other player.

Figure A1. Representation of 2x2 symmetric games in the matrix form.

Prisoner's dilemma. This game, obtained by setting a < b and c < d (Figure A2), depicts a situation in which two players can choose between two actions, namely cooperate (i.e., invest in a common good) and defect (i.e., free ride on the other's investment). In this game, which has been primarily used to study the evolution of cooperative behavior (e.g., Axelrod, 1980, and McNamara, Barta, & Houston, 2004), defecting is a dominant strategy for both players, so that the unique Nash equilibrium is the profile (defect, defect). Thus, the socially desirable action profile in which both players cooperate is not stable, at least in the one-shot game.

Entry game. This game, obtained by setting a < b and c > d (Figure A2), is usually referred to as a coordination game with mixed motives. This game depicts a situation in which both players are better off coordinating on one of the two available actions, but have contrasting preferences on which action to coordinate. For example, this game captures the strategic tension underlying a situation in which two competing firms have to decide whether to enter a given market. Whereas both firms prefer the situation in which one firm enters and the other does not, each firm prefers to be the monopolist of the market. The entry game is an instance of the Battle of the Sexes games, in which the players' preferences on the two Nash equilibria are conflicting.

Stag-hunt game. The Stag-hunt game is obtained by setting a > b and c < d (Figure A2). In this game, players have to coordinate their efforts. Two players select between two possible levels of effort to exert (high and low), and the payoff from coordinating on the high effort is larger than that from coordinating on the low one. Coordination on high and low efforts are the two pure-strategy Nash equilibria of the game. Although, high-effort coordination (also referred to as the payoff dominant equilibrium) is more desirable, it is also associated with considerable strategic uncertainty. Indeed, if one player selects the high effort action, he is exposed to the risk of getting the lowest possible payoff if the other player chooses, for whatever reason, the low effort action. Conversely, the low-effort action is safer, as the player who selects it secures a positive payoff independent from the choice of the other. Coordination on the low-effort action is also indicated as the risk-dominant equilibrium.

Prisoner's delight. This game is obtained when a > b and c > d (Figure A2). In this game both players have a dominant strategy, leading to a unique Nash equilibrium associated with the superior outcome for both players.

Asymmetric 2x2 games form a comparatively much broader set, as relaxing the symmetry constraint leads to 8! possible orderings of the eight distinct payoffs.[12] Nonetheless, asymmetric 2x2 games only lead to two conceptually new game structures, with respect to the four classes of best response dynamics highlighted earlier. In the first, neither of the two players has a dominant strategy,

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[12] Without loss of generality, this number of combinations can be halved by normalizing the ordering of actions, similarly as done for symmetric games, yielding 20,160 different games.

without the presence of equilibria in pure strategies. In the second, one player has a dominant strategy and the other does not, and the ensuing equilibrium is the strategy profile that survives the process of iterated elimination of strictly dominated strategies (also referred to *iterated dominance*).

Matching pennies. This game (Figure A2) is an instance of the family of zero-sum games, in which the payoffs corresponding to every combination of choices by the row and column player sum up to zero. This game does not have any Nash equilibria in pure strategies, but only one mixed-strategy equilibrium in which players are supposed to randomize their actions. In the case illustrated, players are supposed to select each action with probability 0.5. Any strategy in which a player selects deterministically one of the two actions is going to be exploited by the other one. It is important to notice that in these games, for a player, equilibrium probabilities are computed solely based on the payoffs of the opponent.

Incumbent-challenger game. One incumbent firm (row player) and a challenger firm (column player) are considering whether to invest in a new technology (Figure A2). If neither of the two decides to invest (the status quo), the incumbent will keep its position of monopolist of the market earning a payoff of three, and the challenger will get a payoff of zero. If both decide to innovate, competition will lower profits and the cost of the investment will result in a loss for both firms. If one firm decides to invest and the other does not, the innovator will become the monopolist of the new market technology, whereas the other will get a payoff of zero. In this game, only the incumbent has a dominant strategy, namely not to innovate, as this strategy will yield the largest payoff no matter what the challenger will do. In turn, the challenger's best response is that of investing in the innovation, thus taking over the incumbent.
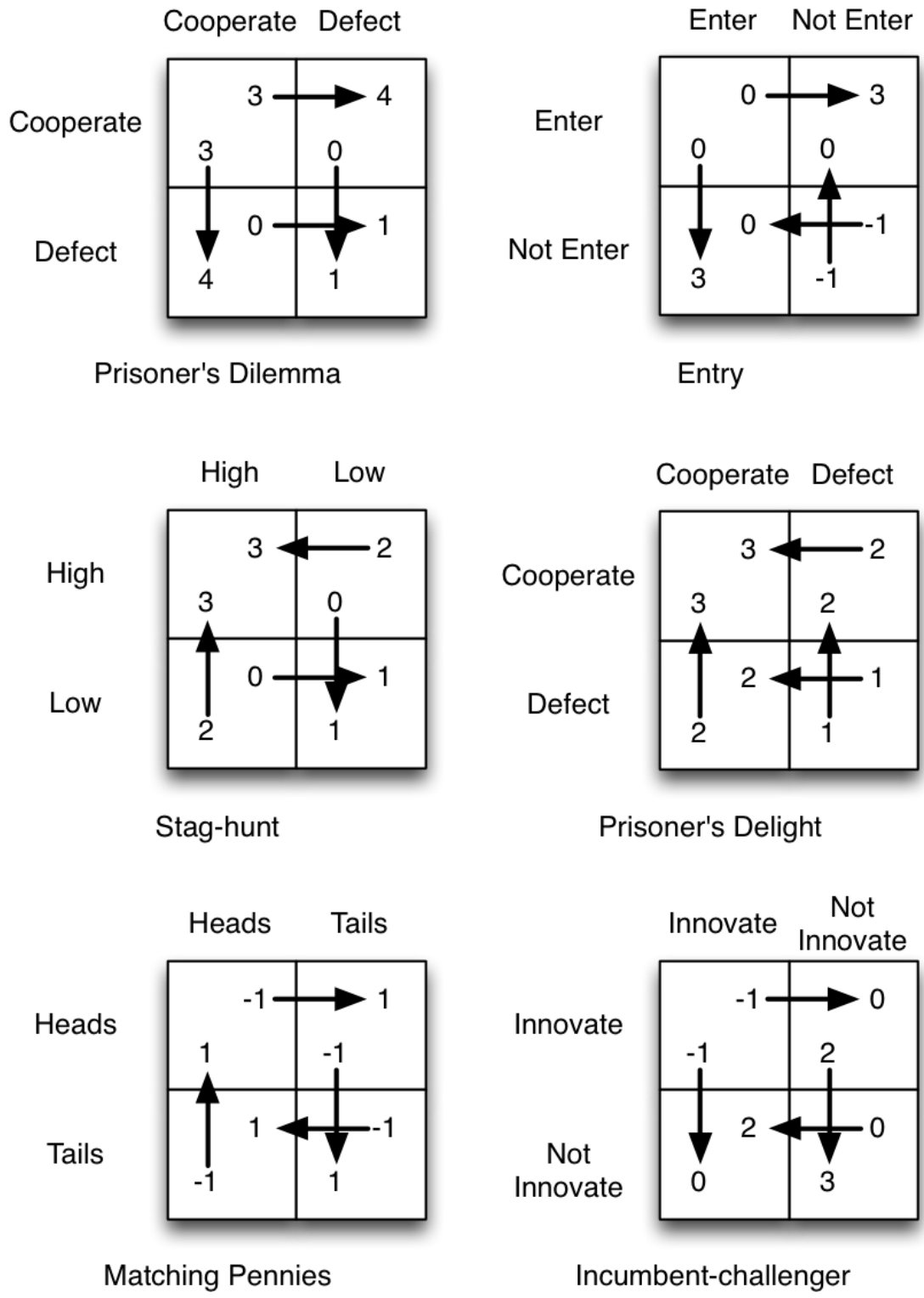
FIGURE A2. Illustration of the 2x2 games reported in Table 1 and discussed in the main text. In the game matrices, the first number in each cell is the payoff for the row player, and the second the payoff for the column player.