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Strategic sophistication of individuals and teams. Experimental evidence

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ABSTRACT

Many important decisions require strategic sophistication. We examine experimentally whether teams act more strategically than individuals. We let individuals and teams make choices in simple games, and also elicit first- and second-order beliefs. We find that teams play the Nash equilibrium strategy significantly more often, and their choices are more often a best response to stated first order beliefs. Distributional preferences make equilibrium play less likely. Using a mixture model, the estimated probability to play strategically is 62% for teams, but only 40% for individuals. A model of noisy introspection reveals that teams differ from individuals in higher order beliefs.

1. Introduction

In this paper, we examine the strategic sophistication of individuals and teams. Strategic sophistication refers to the extent to which players consider the structure of a game and the other players' incentives in the game before deciding on their strategy (Crawford et al., 2013). There are many important contexts where strategic sophistication plays an important role for organizations, such as in decisions on market entry, technology races, company takeovers, or how to optimally intervene through monetary policy instruments in financial markets during a crisis. Examining the strategic sophistication of teams is warranted because many economically important decisions are taken by teams rather than by individuals. One can think of company boards, management teams, committees, or central bank boards as relevant economic agents that make strategic decisions with far-reaching consequences.

By now, there is a large literature that examines the strategic sophistication of individuals by means of experimental normal-form games (see, e.g., Stahl and Wilson, 1994, 1995; Haruvy et al., 1999; Costa-Gomes et al., 2001; Weizsäcker, 2003; Bhatt and Camerer, 2005; Crawford and Iriberri, 2007; Costa-Gomes and Weizsäcker, 2008; Rey-Biel, 2009; Danz et al., 2012). In a nutshell, the main insight from this literature is the fact that strategic sophistication is often limited, such that

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many subjects ignore the incentives and the rationality of other players (e.g., Costa-Gomes et al., 2001, Weizsäcker, 2003) or fail to best reply with their choices to their own beliefs (Costa-Gomes and Weizsäcker, 2008).[1] By examining how teams make strategic decisions we can contribute both to the literature on strategic sophistication and the literature on team decision-making in the following ways.

We let teams and individuals make choices in 18 different, one-shot normal-form games that have been designed by Costa-Gomes et al. (2001) to study the strategic sophistication of individuals. In addition to asking for choices of individuals and teams, we elicit their first order beliefs about their opponent's most likely strategy, and their second-order beliefs about the opponent's most likely first order belief. Hence we elicit point beliefs rather than a probability distribution over all strategies. We examine the differences between individual and team decision making by analyzing the following aspects of strategic sophistication: (i) the relative frequency of equilibrium play and beliefs about equilibrium play, (ii) the degree of a decision maker's consistency and the consistency expected from the opponent, where we define consistency in the sense that choices are a best reply to stated point beliefs, (iii) the factors that make behavior more or less likely to comply with standard textbook-rationality (by which Fudenberg and Tirole, 1991, mean that a player's strategy is a payoff-maximizing best response to the opponent's forecasted strategies, given that forecasts are correct), (iv) the distribution of eight different strategic and non-strategic types which is estimated separately for teams and individuals by an econometric mixture model (Costa-Gomes et al., 2001) where each decision maker's type is drawn from a common prior distribution over the eight types and remains constant for all 18 games, and (v) the relation of choices and higher order beliefs in a model of noisy introspection (Goeree and Holt, 2004).

Our estimations on the determinants of textbook-rationality examine how the complexity of a game and how the distribution of payoffs in equilibrium affect the likelihood of a decision maker playing Nash and expecting the opponent to do the same. This adds to the literature on strategic sophistication by shedding more light on which factors of a game promote or hinder equilibrium choices and beliefs. Rey-Biel (2009) has investigated the influence of constant-sum games vs. variable-sum games on the predictive power of Nash equilibrium, finding that the likelihood of observing Nash equilibrium choices is higher in constant-sum games than variable-sum games. We contribute to this issue by focusing on the role of the decision maker (being either an individual or a team).

We also contribute to the flourishing research on team decision making. While the basic bottom-line of team decision making-research seems to be that teams are “more rational” than individuals in strategic games – meaning that team behavior is in the aggregate typically closer to standard game theoretic predictions than individual behavior (see, e.g., Bornstein and Yaniv, 1998; Bornstein et al., 2004; Cooper and Kagel, 2005; Kocher and Sutter, 2005; Charness and Jackson, 2007)[2] – we are not aware of any research on team decision making that classifies single teams as of a particular strategic or non-strategic type and compares the distribution of different types across individuals and teams. We analyze the strategic sophistication of teams by considering not only choices, but also their first- and second-order point beliefs. Eliciting beliefs allows us to check whether teams are more likely to best reply to their own first-order beliefs, and whether teams expect their opponents to be best responding as well (by matching first-order beliefs with second-order beliefs). Furthermore, we estimate a model of noisy introspection (Goeree and Holt, 2004) where a player's choice probabilities are given by a logit best response that is a function of the player's first order beliefs, and where beliefs are again a function of one level higher order beliefs.[3] None of this has been studied in the team decision-making literature before.[4] Our paper can therefore provide a fine-grained picture of the (bounded) rationality and strategic sophistication of teams and how this compares to individual decision making.

Based on a total of 192 experimental participants, we find that teams play Nash-strategies in about 50% of cases, while individuals do it significantly less often in only about 40% of cases. The choices of teams are also significantly more often a best response to their own first order point beliefs. We denote such behavior as consistent, and teams are more often consistent than individuals. Moreover, teams expect their opponents to be more often consistent, i.e., first-order point beliefs are more often a best reply to second-order point beliefs. In the noisy introspection model we find that teams differ significantly from individuals in the estimated higher order beliefs (of order two and higher), indicating that the differences between individuals and teams are largely driven by differences in beliefs, although there is also a difference in the likelihood of best responding to beliefs.

Addressing the determinants of textbook-rationality (of playing and expecting equilibrium strategies) we note that the complexity of a game and the distributions of payoffs in equilibrium have an important impact. A game's complexity is interpreted as the required number of rounds of iterated pure-strategy dominance a row or column player needs to identify

[1] Strategic reasoning is not only limited in normal-form games, but also in a wider variety of games, such as auctions (Gneezy, 2005) or information cascades (Kübler and Weizsäcker, 2004).

[2] The paper by Cason and Mui (1997) is often misinterpreted as showing that teams are more generous than individuals in a dictator game. However, Cason and Mui (1997) did not find that teams in general are more generous than individuals, but only reported more other-regarding team choices when team members differed in their individual dictator game choices.

[3] As in Goeree and Holt (2004), the error rates follow a geometrical progression that is specified using two parameters: the error rate of actions and a “telescoping” parameter that determines how fast error rates are increasing for higher order beliefs. Using the estimates of these parameters we compute the error rates for beliefs with the standard errors computed using the delta method.

[4] Second-order beliefs in normal-form games have been studied with individuals as decision makers by Bhatt and Camerer (2005) and in the working paper version of Costa-Gomes and Weizsäcker (2008). The role of second-order beliefs on actual behavior (of individuals) in extensive form games (such as a lost wallet-game or a trust game) is studied in Dufwenberg and Gneezy (2000) or Charness and Dufwenberg (2006), for instance.

the own equilibrium choice. Teams and individuals differ in their behavior in particular when the game has an intermediate complexity (of requiring two rounds of iteration). If payoffs are more unequal in equilibrium, equilibrium play and beliefs get less likely, suggesting that players are somewhat inequality averse (Fehr and Schmidt, 1999).

game # 3 (*D*) [1R, 2R]

	1	2
1	72, 93	31, 46
2	84, 52	55, 79

game # 13 (*D*) [1R, 2R]

	1	2
1	94, 23	38, 57
2	45, 89	14, 18

game # 1 (*D*) [2R, 1R]

	1	2
1	75, 51	42, 27
2	48, 80	89, 68

game # 12 (*D*) [2R, 1R]

	1	2
1	21, 92	87, 43
2	55, 36	16, 12

game # 7 (*D*) [2R, 1R]

	1	2	3
1	59, 58	46, 83	85, 61
2	38, 29	70, 52	37, 23

game # 11 (*D*) [2R, 1R]

	1	2
1	31, 32	68, 46
2	72, 43	47, 61
3	91, 65	43, 84

game # 9 (*D*) [1R, 2R]

	1	2
1	28, 37	57, 58
2	22, 36	60, 84
3	51, 69	82, 45

game # 16 (*D*) [1R, 2R]

	1	2	3
1	42, 64	57, 43	80, 39
2	28, 27	39, 68	61, 87

game # 6 (*ND*) [3R, 2R]

	1	2
1	53, 86	24, 19
2	79, 57	42, 73
3	28, 23	71, 50

game # 15 (*ND*) [3R, 2R]

	1	2
1	76, 93	25, 12
2	43, 40	74, 62
3	94, 16	59, 37

game # 14 (*ND*) [2R, 3R)

	1	2	3
1	21, 26	52, 73	75, 44
2	88, 55	25, 30	59, 81

game # 2 (*ND*) [2R, 3R]

	1	2	3
1	42, 45	95, 78	18, 96
2	64, 76	14, 27	39, 61

game # 8 (*ND*) [∞R, ∞R]

	1	2	3
1	87, 32	18, 37	63, 76
2	65, 89	96, 63	24, 30

game # 10 (*ND*) [∞R, ∞R]

	1	2	3
1	67, 91	95, 64	31, 35
2	89, 49	23, 53	56, 78

game # 5 (*ND*) [∞R, ∞R]

	1	2
1	72, 59	26, 20
2	33, 14	59, 92
3	28, 83	85, 61

game # 4 (*ND*) [∞R, ∞R]

	1	2
1	46, 16	57, 88
2	71, 49	28, 24
3	42, 82	84, 60

game # 17 (*D*) [1R, 2R]

	1	2
1	22, 14	57, 55
2	30, 42	28, 37
3	15, 60	61, 88
4	45, 66	82, 31

game # 18 (*D*) [2R, 1R]

	1	2	3	4
1	56, 58	38, 29	89, 62	32, 86
2	15, 23	43, 31	61, 16	67, 46

Fig. 1. The 18 normal-form games.

Using a mixture model, the estimated probability for teams to play strategically is 62%. The modal type of team decision making is a strategic $D1$-type that applies one step of deleting strategies that are dominated by pure strategies and then plays best reply to a uniform prior over the opponent's remaining strategies. Individuals are classified as strategic significantly less often, i.e., in only 40% of cases. Their modal type is a non-strategic *optimistic* type (which chooses the strategy that maximizes the maximum possible payoff, thus implicitly assuming that the opponent plays randomly).

The rest of the paper is organized as follows. In Section 2 we present the experimental design. Section 3 reports the results. Section 4 discusses our results and concludes the paper.

2. Experimental design

2.1. The 18 normal-form games

Fig. 1 presents the 18 normal-form games that we used in our experiment. They are taken from Costa-Gomes et al. (2001), because these games are very well designed to study strategic thinking and behavior. Out of the 18 games, 16 games are pairs of isomorphic games (which are identical for row and column players except for transformation of player roles and small, uniform payoff shifts). We applied the same order of games as in Costa-Gomes et al. (2001). This is indicated in Fig. 1 as "game # x", with $x\in\{1, \ldots, 18\}$. In brackets after the game number we refer to two different types of games. "***D***"-games ("***ND***"-games) are those in which one (none) of the two players has a strictly dominant strategy. In total, there are 10 ***D***-games and eight ***ND***-games. Note that in all games the unique, pure strategy Nash equilibrium is Pareto-dominated by another strategy combination of row and column players, which creates a tension between equilibrium play and efficiency concerns.

The number of rows (columns) indicates the number of available strategies for row (column) players. The 18 games have different levels of complexity, interpreted as the required number of rounds of iterated pure-strategy dominance a row or column player needs to identify the own equilibrium choice. The notation [xR, yR] refers to the number of rounds needed for the row (x) and column player (y) to identify the equilibrium. In ***D***-games, we have $x, y\in\{1, 2\}$, while in ***ND***-games $x, y\in\{2, 3, \infty\}$, where [∞R, ∞R] denotes non-dominance solvable games.

2.2. Treatments, decisions and payments

We have implemented three different treatments which are distinguished by which types of decision makers are interacting with each other in the normal-form games. Note that the treatment – and thus the type of decision maker in the opponent's role – was common knowledge in the experiment (see the experimental instructions in Supplementary material).

- *Ind*: In the individual treatment both row and column players were individuals.
- *Team:* In the team treatment both row and column players were teams of three subjects each. Team members sat together in a sound-proof cabin and could communicate with each other in order to reach a team-decision. There were no restrictions on communication and no regulations how a team should reach an agreement, except that only one decision could be entered by a team on the computer.
- *Mixed*: In the mixed treatment a team of three subjects was interacting with an individual. In half of the *Mixed*-sessions the team was in the role of the row-player and the individual in the role of the column-player, while the reverse order applied in the other half of sessions.

The *Mixed* treatment has been included because it allows examining whether individuals and teams condition their choices and beliefs on the type of decision maker (individual or team) in the opponent's role. To avoid any influence of the kind of presentation on the data, we presented all games to all players in a way that they saw themselves as a row player. In each single game each player (either individual or team) had to make three different decisions:

- *Choice*: This was a player's choice of a row in a given game.
- *First-order belief* (*FOB*): Each player had to indicate the action expected from the opponent.
- *Second-order belief* (*SOB*): Players stated a belief about their opponent's first-order belief.

Each player had to make all three decisions in each of the 18 games, yielding a total of 54 decisions to be taken during the experiment. We proceeded game by game with all three decisions, but the order of the three decisions for a given game was randomly determined.[5] In order to suppress learning, partners changed after each game (random matching) and there was no feedback until the experiment was finished. All details of this procedure were common knowledge to participants.

In order to keep the per-capita incentives constant for individuals and teams the payoffs described in the following were paid to each member of a team, and participants knew this. At the end of the experiment each player needed to draw a card

[5] Note that Costa-Gomes and Weizsäcker (2008) do not find order effects depending on whether to elicit beliefs before choices or the other way round.

from a deck of cards which were showing numbers from 1 to 18. This card determined the game that was relevant for payment. Players then received full information about their own and their opponent's choices and beliefs in this game. Afterwards, players were asked to draw another card from a deck of cards showing numbers 1 (for choice), 2 (for first-order belief), or 3 (for second-order belief). If a player was paid for her choice, the player received 30 Euro Cents for each experimental point earned in the game as a consequence from the own and the opponent's choice (as shown in Fig. 1). Players who were paid for their first-order or second-order belief received 15 Euros if their belief was correct, but nothing if it was wrong. The all-or-nothing feature for paying beliefs was intended to make the decisions on first- and second-order beliefs as salient as possible.[6]

Eliciting point beliefs – instead of a probability distribution of beliefs over different actions – may be criticized because it may make it difficult to check the consistency of actions and beliefs. While eliciting a probability distribution of beliefs over actions may look like a remedy to this problem, asking for a probability distribution requires full understanding of participants and auxiliary assumptions that subjects maximize expected payoffs. It has also potential problems with checking consistency when first- and second-order beliefs (one of our central design-features) are involved. It is possible that a subject's first-order belief (in the form of a probability distribution) fails to be a best response to his second-order belief (also in the form of a probability distribution), although both beliefs are optimally stated.[7] For these reasons, and in order to keep the experiment simple, we have opted for asking for point beliefs.

2.3. Experimental procedure

In each treatment we conducted four sessions that were run in the video-lab of the Max Planck Institute of Economics in Jena. This lab has eight sound-proof cabins which are connected via a computer network (using z-Tree by Fischbacher, 2007). The cabins provide teams with an opportunity to talk to each other without other teams hearing what they say. We ran also the sessions with individuals as decision makers in the video-lab in order to keep the conditions of individual and team decision making as identical as possible. Participants were never videotaped, and they were told so at the beginning of the experiment. This design choice was motivated to minimize the possibility that potential differences between individuals and teams might have been driven by the fact that team discussions were taped.

In each session we had eight decision makers. Four of them were row players and four column players. Depending upon the treatment, a decision maker was either an individual subject or a team of three subjects. When recruiting subjects with the help of ORSEE (Greiner, 2004), assignment to treatments was randomly determined. In the treatments with team decision making, subjects were randomly assigned to a particular team at the beginning of the experiment. Teams stayed together for the entire experiment. The matching of row and column players was random and changed after each game. Note that for a particular game (with its three decisions) the matching was kept constant. To make sure that participants understood the instructions and the experimental tasks, they needed to answer a questionnaire before the experiment in which they were tested how choices and first- and second-order beliefs mapped into outcomes and payoffs. These questions had to be answered individually, and all participants gave correct answers.

In sum, we had a total of 192 participants, recruited from the undergraduate student population of the University of Jena. For each game in each treatment we obtained 32 different observations. No subject was allowed to participate in more than one session. On average, a session lasted 2 h and subjects earned 16.5 Euro, including a show-up fee of four Euro.

3. Experimental results

In the first Section 3.1 we analyze whether the players' decisions are dependent on their roles as row and column players and whether playing against the same type of decision maker (individual or team) or against the other type makes a difference. This section is followed by an examination of strategies and point beliefs (Section 3.2). The corresponding analysis mainly focuses on the influence of a decision's complexity. Based on our chosen definition of consistency, Section 3.3 analyzes consistency in the general sense that a consistent decision is a best reply to a certain point belief. Section 3.4 focuses on the frequency of playing and expecting the Nash equilibrium to be played by the opponent. The result-section concludes with two econometric estimations. One allows us to test for the likelihood of nine different decision maker types (Section 3.5), the other one to explore whether behavioral differences are driven by differences in rationality or beliefs (Section 3.6).

[6] Since subjects were either paid for their choice or for one of their beliefs, the issue of hedging choices and beliefs (see Blanco et al., 2010) is of no concern in our case.

[7] We would like to thank Georg Weizsäcker for drawing our attention to the problems of inconsistency between first- and second-order beliefs even for situations in which probability distributions are elicited. To illustrate the main intuition, consider the two following cases: (i) Subject A expects subject B to have two different first-order beliefs such that with a 50% probability subject B expects subject A to play his first strategy for sure and with a 50% probability he expects subject A to play his second strategy for sure. (ii) Subject A expects subject B to think that subject A plays any of his first two strategies by 50%. In both cases an optimally reported second order belief assigns a 50% probability to both strategies. Depending on situation (i) or (ii) prevailing, it is possible that subject B's best reply differs between (i) and (ii). As a consequence, subject A's first-order belief can differ, and if case (i) is the true second-order belief, it is possible that the optimal first-order belief for subject A is not a best reply to the optimal second-order belief (if we implicitly assume case (ii)).

3.1. Pooling of data

In the following analysis we pool the data of row and column players, because 16 out of 18 games are isomorphic games which are practically identical for row and column players expect for small payoff shifts and the transformation of player roles (see Costa-Gomes et al., 2001, for details). All analyses presented below are based on all 18 games.[8]

We have also examined whether players' choices and beliefs depend on the opponent's type being a team or an individual. In other words, we tested whether the distribution of choices and first- and second-order beliefs differs for individuals between treatments *Ind* and *Mixed*, respectively for teams between treatments *Team* and *Mixed*. In a total of 216 tests, we find four significant differences (at the 5%-level) for individuals (between individual behavior in *Ind* and *Mixed*) and five significant differences (at the 5%-level) for teams (between team behavior in *Team* and *Mixed*). Hence, the statistical tests (see Table S0 in Supplementary material) yield rejection rates that are within the limits of chance. From this we conclude that decision makers do not condition their behavior and their beliefs on the type of decision maker in the opponent role (see also the discussion of Table 4 in Section 3.4). This is most likely due to giving no feedback until the end of the experiment, which prevents teams or individuals to learn about the decision patterns of their opponents and thus calibrate their decisions on the experienced decision patterns of their opponents. We summarize as our first result:

Result 1: Neither individuals nor teams condition their choices and point beliefs on the type of decision maker (individual or team) in the opponent role.

This result allows us to pool individual decisions in treatments *Ind* and *Mixed*, as well as team decisions in *Team* and *Mixed*. Hence, when we talk of individual (team) decisions in the following, we refer to all decisions made by individuals (teams) in the different treatments. Due to the circumstance that we had 16 individuals and 16 teams as decision makers in *Mixed*, we obtain 48 observations for individuals, and 48 for teams, after pooling the data.

3.2. Choices, first- and second-order beliefs of individuals and teams

In Table 1 we report the relative frequency of different strategies – chosen either by teams or individuals – across all games, and separately for ***D***-games and ***ND***-games.[9] We distinguish between the strategy that leads to the Nash-equilibrium ("Nash"), the strategy that could yield an outcome that Pareto-dominates the Nash-equilibrium ("Pareto"), and other strategies ("Other"). The upper panel reports relative frequencies for own choices, the middle and lower panel for first-order, respectively second-order, beliefs.

We compare the relative frequencies of the different strategies chosen by individuals and teams by considering for each single decision maker the relative frequency of choosing a particular strategy across all games (or across ***D***- and ***ND***-games separately) and then apply a two-sided Mann–Whitney *U*-test to the resulting data. We see from the upper panel of Table 1 that teams are significantly more often playing the Nash-strategy than individuals (49.30% vs. 40.97%; $p<0.05$).[10] Individuals choose more often what we call the "Pareto"-strategy of trying to improve on the Nash-equilibrium choice (53.47% vs. 45.72%; $p<0.05$). These differences between individuals and teams are mainly driven by the 10 games with a dominant strategy. Only in ***D***-games teams are significantly more often playing Nash, and less often playing Pareto, while there is no significant difference between individuals and teams in the ***ND***-games where neither player has a dominant strategy. This indicates that the presence or absence of a dominant strategy for one of the players has an impact on how the type of decision maker influences behavior.

The middle panel in Table 1 considers first-order beliefs. Although teams expect their opponents to play Nash more often, respectively Pareto less often, than individuals, none of these differences is significant according to conventional levels. As seen in the lower panel, however, individuals and teams differ in their second order beliefs in the set of ***D***-games. Similar to the choice data, teams think that their opponents expect them to play Nash more often, respectively Pareto less often, than individual decision makers.[11]

Comparing across panels in Table 1, while holding the type of decision maker constant, we find that the relative frequency of playing Nash decreases from top to bottom, i.e., it is highest for own choices, intermediate for first-order beliefs and lowest for second-order beliefs. This holds true both for individuals and teams and the descending order is significant

[8] If we excluded the two non-isomorphic games, all results would remain qualitatively the same.

[9] Tables S1–S6 in Supplementary material present the relative frequencies of each single strategy in each single game, both for individuals and teams, and for choices, first- and second-order beliefs.

[10] If players chose their strategies randomly, then the expected relative frequency of observing Nash equilibrium choices would be 43%. In Fig. F1 of Supplementary material we show that players' choices of both individuals and teams are significantly different from random, though. In this Fig. F1 we plot the relative frequency of playing Nash in x out of 18 games (with $x \in \{1, 18\}$) and compare the distributions of actually observed relative frequencies and theoretically expected ones in case of random play. The upper panel of Fig. F1 plots choices, first- and second-order beliefs for individuals, and the lower panel for teams. In all six cases we find that the actually observed distribution is significantly different from a random one (Kolmogorov–Smirnov one sample test, $p<0.05$ in all cases).

[11] In Supplementary material we provide in Tables S7–S10 the relative frequency with which individuals and teams were correct in their first- and second-order beliefs. On average, teams were slightly more often correct in their beliefs (62.7% vs. 61.0% for first-order beliefs; 69.1% vs. 68.6% for second-order beliefs), but the different accuracy of beliefs is far from being significant.

Table 1
Choices and beliefs of individuals and teams (relative frequencies in %).

			All games	*D-games*	*ND-games*
Choice	Nash	Individuals	40.97**	57.71**	20.05
		Teams	49.30	70.42	22.92
	Pareto	Individuals	53.47**	41.25**	68.75
		Teams	45.72	28.96	66.67
	Other	Individuals	5.56	1.04	11.20
		Teams	4.98	0.62	10.41
First-order beliefs	Nash	Individuals	37.26	55.63	14.32
		Teams	40.04	60.62	14.32
	Pareto	Individuals	57.06	43.33	74.22
		Teams	55.21	38.75	75.78
	Other	Individuals	5.68	1.04	11.46
		Teams	4.75	0.63	9.90
Second-order beliefs	Nash	Individuals	30.55	47.71**	9.11
		Teams	33.79	53.96	8.59
	Pareto	Individuals	62.62	50.21*	78.13
		Teams	61.11	45.42	80.73
	Other	Individuals	6.83	2.08*	12.76
		Teams	5.10	0.62	10.68

* Significant difference between individuals (in a given row) and teams (in the next row) at $p < 0.1$; two-sided Mann–Whitney U-test.
** Significant difference between individuals and teams at $p < 0.05$; two-sided Mann–Whitney U-test.

for both types of decision makers ($p < 0.05$; Page tests). Hence, equilibrium play is less likely according to beliefs than according to own choices and less likely the higher the order of beliefs.[12]

In Table 2 we examine the influence of a game's complexity on choices and beliefs. For both ***D***- and ***ND***-games we report the relative frequencies of chosen strategies, contingent on the number of rounds of iterated pure-strategy dominance a player needs to identify the own equilibrium choice. The first column shows that in games with a dominant strategy those players with the dominant strategy play Nash in about 80% of cases. There is no significant difference between individuals and teams, neither for choices nor for first- or second-order beliefs.

However, the second column reveals a very strong difference between individuals and teams when they are in the role of the player without the dominant strategy (when the opponent has one). While teams choose the Nash-strategy in almost 60% of cases then, individuals play Nash in less than 40%. The reverse holds true for the Pareto strategy. The differences in choices between individuals and teams (when they need two rounds of iterated pure-strategy dominance to identify the own equilibrium choice) is mirrored in second-order beliefs. Teams also think that their opponents expect them to play Nash almost double as often as individuals think of their opponents (25.42% vs. 13.75%). The differences in first-order beliefs are qualitatively similar, but fail significance at conventional levels.

The third column in Table 2 considers games without a dominant strategy for either of the players, and it clearly confirms the findings from the second column. When two rounds of iterated dominance are needed, teams play significantly more often Nash – and less often Pareto – than individuals. The same pattern is found for first- and second-order beliefs (with the differences being weakly significant for first-order beliefs). The final two columns in Table 2 show that for more complex games (with more than two rounds of iterated dominance) there are no significant differences in strategy choices between individuals and teams. Thus, the evidence from Table 2 suggests that for very straightforward decisions (when a player has a dominant strategy) and for more complex decisions (with more than two rounds of iterated dominance) there are no differences between individuals and teams. Yet, for decisions with two rounds of iterated dominance teams choose (and think that they are expected to choose) more often the equilibrium-strategy.[13]

Result 2: Overall, teams play the equilibrium strategy significantly more often than individuals. Taking a game's complexity into account we find that individuals and teams do not differ in the likelihood of playing equilibrium when they have a dominant strategy or need more than two steps of iterated dominance. In situations where two steps are required, though, teams play equilibrium much more often. These differences in choice-patterns of individuals and teams are also reflected in their point beliefs, in particular in second-order point beliefs.

[12] This pattern is consistent with a model of noisy introspection by Goeree and Holt (2004) in which they predict more noise (and less equilibrium play) the higher the order of beliefs. Section 3.6 gets back to this point.

[13] The pattern observed in Table 2 is reflected from a different perspective in Table S11 in Supplementary material. It reports the relative frequency of equilibrium play in the different types of games, classified by the available number of strategies for row and column players and the presence or absence of a dominant strategy for a player or its opponent. Table S11 also reveals significant differences between individuals and teams in the games where the opponent has a dominant strategy.

Table 2
Complexity of the game, choices and beliefs (relative frequencies in %).

		Complexity (game type)[a]	**1R (D)**	**2R (D)**	**2R (ND)**	**3R (ND)**	**∞R (ND)**
Choice	Nash	Individuals	76.67	38.75**	31.25*	14.58	17.19
		Teams	81.67	59.17	44.79	10.42	18.23
	Pareto	Individuals	22.50	60.00**	68.75*	56.25	75.00
		Teams	17.91	40.00	55.21	57.29	77.08
	Other	Individuals	0.83	1.25	0.00	29.17	7.81
		Teams	0.42	0.83	0.00	32.29	4.69
First-order beliefs	Nash	Individuals	88.75	22.50	21.87*	7.29	14.06
		Teams	87.92	33.33	33.33	6.25	8.86
	Pareto	Individuals	10.42	76.25	78.13*	56.25	81.25*
		Teams	10.83	66.67	66.67	57.29	89.58
	Other	Individuals	0.83*	1.25*	0.00	36.46	4.69
		Teams	1.25	0.00	0.00	36.46	1.56
Second-order beliefs	Nash	Individuals	81.67	13.75**	9.37	9.37	8.85
		Teams	82.50	25.42	17.71	4.17	6.25
	Pareto	Individuals	16.25	84.17**	90.63	50.00	85.94
		Teams	17.08	73.75	82.29	57.29	91.67
	Other	Individuals	2.08*	2.08*	0.00	40.63	5.21
		Teams	0.42*	0.83	0.00	38.54	2.08

*Significant difference between individuals (in a given row) and teams (in the next row) at $p < 0.1$; two-sided Mann–Whitney *U*-test.
**Significant difference between individuals and teams at $p < 0.05$; two-sided Mann–Whitney *U*-test.
[a] The columns separate behavior according to (i) the different number of rounds (***R***) of iterated pure-strategy dominance a player needs to identify the own equilibrium choice, and (ii) the presence (***D***) or absence (***ND***) of a dominant strategy in the game.

3.3. Consistency of choices and beliefs

Our design allows us to check not only the consistency of choices and beliefs but also the opponents' expected consistency. We denote a player's choice as consistent with beliefs if the choice is a best reply to the player's own first-order point belief. Likewise, we define the opponent's expected consistency as to whether the first-order point belief is a best reply to a player's second-order point belief. The latter determines basically a player's first-order belief about the opponent's consistency. Moreover we can distinguish the two most frequent types of consistency. One type is a straightforward combination of playing Nash and expecting the opponent to play Nash as well. We call this the "Nash-consistency" (Nash-CON). The other type is when the combination of a player's choice and first-order belief would yield the maximal payoff that is available for the player in a specific game. We call this the "Maximax-consistency" (Max-CON). Note that Max-CON cannot coincide with the Nash-equilibrium in our games. The relative frequency of these two consistency types can be examined not only for a player himself, but also for the player's expectation about the opponent's consistency type.

Table 3 reports in the upper part the relative frequency of average own consistency and in the lower part the average expected consistency of the opponent player.[14] Moreover, in each part of the table the relative frequency of Nash-CON and Max-CON is reported. We find that only about one half of the individual decisions (55.79%) are a best-reply to the individual's own first-order (point) belief, confirming the earlier findings by Costa-Gomes and Weizsäcker (2008) or Danz et al. (2012).[15] However, we find that teams play best-reply significantly more often (65.63%; $p < 0.05$, two-sided Mann–Whitney *U*-test). We see from the column "***D***-games" that this difference is predominantly driven by the games where one party has a dominant strategy. The lower part of Table 3 indicates that teams also expect their opponents to be more often consistent by playing best reply. Due to the circumstance that point beliefs, which are the basis for our consistency-check, might actually be based on probability distributions over different actions, a lack of consistency described in this subsection does not necessarily imply irrationality. In Section 3.6 we estimate a model of noisy introspection (Goeree and Holt, 2004) in order to explore whether the differences between individuals and teams are driven by differences in rationality or beliefs.

Next, we examine the consistency of choices and beliefs in more detail by having a look at the two types of consistency described above. For the player's own consistency we find a very strong difference between individuals and teams with

[14] In Fig. F2 of Supplementary material we plot the theoretically expected relative frequency of being consistent in x out of 18 games under the assumption of random play (with $x \in \{1, 18\}$) versus the actually observed relative frequency of being consistent. We note a clear rightward shift – in particular for teams – of the actually observed distribution, clearly rejecting the null-hypothesis of randomness in consistency ($p < 0.01$ for individuals and teams, both for own consistency and the opponent's expected consistency; Kolmogorov–Smirnov one-sample tests).

[15] Danz et al. (2012) show that the relative frequency of best responses to own beliefs increases with repetition *if* feedback is given after each game. However, in their study it also starts out with slightly more than 50% in the first of twenty rounds – which is comparable to the level we observe without feedback – and it converges to only around 75% in the final round of their experiment.

Table 3
Consistency of decisions (relative frequency of best reply in % of total choices).

		All games	*D-games*	*ND-games*
Player's own consistency of which:	Individuals	55.79**	60.00***	50.52
	Teams	65.63	75.21	53.65
Nash-CON	Individuals	18.75**	27.71***	7.55
	Teams	27.66	45.00	5.99
Max-CON	Individuals	32.52	31.67	33.59
	Teams	31.37	29.58	33.59
Expected consistency of the opponen of which	Individuals	59.38	62.29	55.73
	Teams	63.08	68.54	56.25
Nash – CON	Individuals	10.65**	15.63**	4.43
	Teams	17.25	28.75	2.86
Max-CON	Individuals	44.56	44.79**	44.27
	Teams	41.09	37.71	43.49

** Significant difference between individuals and teams at $p < 0.05$; two-sided Mann–Whitney *U*-test.
*** Significant difference between individuals and teams at $p < 0.01$; two-sided Mann–Whitney *U*-test.

respect to Nash-CON. Again, the difference is mainly driven by our ***D***-games. While only 27% of individual choices and beliefs can be classified as Nash-CON, it is 45% of team choices and beliefs in the 10 ***D***-games where one player has a dominant strategy ($p<0.01$, two-sided Mann–Whitney *U*-test). Moreover we note that while in ***ND***-games more than 60% of the consistent choices of teams and individuals coincide with Max-CON definition, in the ***D***-games teams and individuals display a very different distribution across consistency types: more than 60% of consistent choices of teams coincide with Nash-CON while less than 50% of consistent choices of individuals coincide with Nash-CON. From the lower part of Table 3 we also note that teams expect their opponents significantly more often to be of the Nash-CON-type than individuals, while individuals expect opponents more often to be of the Max-CON-type.[16]

Result 3: Teams make more often consistent choices than individuals, such that the choices of a team are more frequently a best reply to their first-order point beliefs about the opponent's behavior. Also, teams play the Nash-strategy and expect it from the opponent much more often than individuals do. Individuals' choices and point beliefs more often focus (optimistically) on the maximum available payoff.

3.4. *The determinants of textbook rationality*

As a final step in analyzing the consistency of decisions we examine the determinants that increase the likelihood of “Nash-consistency”. Note that this is precisely the type of consistency standard game theory would predict for rational and payoff-maximizing decision makers (i.e., playing Nash and expecting the opponent to do the same). Hence, estimating the factors that make “Nash-consistency” more likely does not only reveal which factors promote this type of consistency, but also which ones prevent decision makers from playing the equilibrium strategy and expecting their opponent to do the same. In Table 4 we report a probit estimation of a player's Nash-CON on various factors that are explained in the following. Since each decision maker had to make decisions in 18 different games, we cluster the standard errors on the decision maker.

Panel [A] of Table 4 shows that the consistency type Nash-CON is more likely if players have a dominant strategy themselves (“dominant strategy”) or if their opponent has one (“opponent dominant strategy”). The next three independent variables are all insignificant. Making decisions in a team (“team player”), having a team as opponent player (“opponent=team”) or playing as a team against another team (“team ∗ opponent=team”) does not influence the likelihood of “Nash-consistency”. The latter two terms confirm that the type of decision maker in the opponent role does not matter for decision making. However, the interaction terms of team decision making with dominant strategy for oneself (“team ∗ dominant strategy”) or for the opponent (“team ∗ opponent dominant strategy”) have a significantly positive effect each. This is in line with our previous findings that decisions in the ***D***-games mainly drive the differences between individuals and teams.

The final four variables in panel [A] of Table 4 consider the magnitude and distribution of payoffs in a game in different ways. The variable “risk with maxstrategy” measures the absolute difference between the decision maker's payoff in the Nash-equilibrium and the decision maker's payoff in case he chose the strategy in which the game's highest payoff is possible while the opponent played Nash. In other words, this variable indicates how much money is at risk when a decision maker tries (unsuccessfully) to reach his maximal possible payoff instead of playing Nash. The estimation shows that Nash-CON gets weakly significantly more likely the more money is at risk if a player wants to deviate to the strategy that could

[16] In Fig. F3 of Supplementary material we compare the relative frequency of Nash-consistency if players' choices were random to the actually observed relative frequencies. Again, the actually observed distributions are significantly different from random both for individuals and teams as well as for the own Nash-consistency and the opponent's expected Nash-consistency ($p<0.01$; Kolmogorov-Smirnov one-sample tests).

Table 4
Determinants of a player's consistency-type Nash-CON.

Variable	*Coefficient*	*Standard error*		
[A] Probit regression				
dominant strategy	1.313	0.281**		
opponent dominant strategy	0.935	0.257**		
team player	−0.145	0.287		
opponent=team	−0.053	0.242		
team ⁎ opponent=team	0.053	0.329		
team ⁎ dominant strategy	0.508	0.209**		
team ⁎ opponent dominant strategy	0.703	0.221**		
risk with maxstrategy	0.011	0.007*		
risk with maxstrategy opponent	0.000	0.007		
advantageous inequality in Nash	−0.013	0.012		
disadvantageous inequality in Nash	−0.038	0.013**		
Constant	−1.339	0.405**		
[B] Marginal effects of team decision making contingent on binary independent variables				
Dominant strategy	Opponent dominant strategy	Opponent=Team	*Marginal effect*	*Standard error*
Yes	No	Yes	0.163	0.100
Yes	No	No	0.143	0.102
No	Yes	Yes	0.221	0.089**
No	Yes	No	0.204	0.090**
No	No	Yes	−0.009	0.025
No	No	No	−0.014	0.029

$N=1.728$; standard errors clustered for the 96 decision makers (48 individuals, 48 teams).
Marginal effects evaluated at the mean of independent variables (risk with maxstrategy, risk with maxstrategy opponent, advantageous inequality in Nash, disadvantageous inequality in Nash) and contingent on the three binary variables indicated in the top row (and their interaction effect with team decision making).
* Coefficient significant at $p<0.1$.
** Coefficient significant at $p<0.05$.

maximize his payoff.[17] The variable “risk with maxstrategy opponent” is constructed like “risk with maxstrategy”, but measures the opponent's potential losses from deviating from Nash. This variable has no significant influence on a player's likelihood to be Nash-consistent.

Since subjects have been shown to respond in an asymmetric way to advantageous and disadvantageous inequality (Fehr and Schmidt, 1999), we consider two separate variables to measure payoff inequalities in the Nash equilibrium: “advantageous inequality in Nash” (defined as *max* {own payoff – opponent's payoff in Nash, 0}) and “disadvantageous inequality in Nash” (defined as *max* {opponent's payoff – own payoff in Nash, 0}). Table 4 shows that advantageous inequality does not influence a player's likelihood to be Nash-CON. However, if disadvantageous inequality increases in the Nash equilibrium, a player is less likely of the Nash-CON-type. Hence, distributional preferences such as inequality aversion have a significant influence on consistent behavior in our experiment. It is important to note that interacting any of the final four variables in Table 4 with the variable “team player” does not yield any significant effects. Hence, payoff distributions affect the Nash-consistency of individuals and teams to the same extent.

Panel [B] of Table 4 reports the marginal effects of team decision making (compared to individual decision making) for specific combinations of the binary variables from panel [A], evaluated at the means of the four ultimate variables in panel [A]. If a decision maker has no dominant strategy, while the opponent has one, the likelihood of observing Nash-consistency is more than 20 percentage points higher when teams instead of individuals make choices and state their first-order beliefs. If a decision maker has a dominant strategy, while the opponent does not, then teams are also more likely to be Nash-consistent, however, the effect fails significance.

Table 5 reports a similar probit regression as Table 4, but takes as the dependent variable a player's expectation about the opponent being a Nash-CON-type. The variables used in Table 5 are defined from the point of view of the player who states first- and second-order beliefs. Basically, we find very similar results as in Table 4, with a few noteworthy exceptions. Most strikingly, “opponent dominant strategy” is not significant in itself, while “teams ⁎ opponent dominant strategy” is significantly positive. Taken together, this shows that individuals fail to recognize that if an opponent has a dominant strategy then the opponent is more likely to be Nash-consistent (as it has become clear from Table 4). On the contrary, teams expect (correctly) opponents who have a dominant strategy to be more often Nash-consistent. These implications are fully in line with our previous findings on the differences between individuals and teams when the degree of complexity is intermediate (i.e., requiring two steps of reasoning). The variable “advantageous inequality in Nash” is significantly negative in Table 5, indicating that players expect their opponents to be less often consistent even when the Nash-equilibrium would

[17] The estimation presented in Table 4 remains qualitatively identical if we used the relative – rather than the absolute – losses from deviating from the Nash strategy. In fact, “risk with maxstrategy” becomes significant even at the 5%-level, while all other significant variables in Table 4 keep their significance level with the alternative specification. We have opted for absolute losses since this fits better to the final two independent variables.

Table 5
Determinants of the opponent's expected consistency-type being Nash-CON.

Variable	*Coefficient*	*Standard error*		
[A] Probit regression				
dominant strategy	1.594	0.369**		
opponent dominant strategy	0.414	0.289		
team player	−0.196	0.364		
opponent =team	−0.023	0.256		
team ∗ opponent=team	0.045	0.340		
team ∗ dominant strategy	0.581	0.269**		
team ∗ opponent dominant strategy	0.720	0.229**		
risk with maxstrategy	0.020	0.007**		
risk with maxstrategy opponent	−0.007	0.006		
advantageous inequality in Nash	−0.036	0.013**		
disadvantageous inequality in Nash	−0.037	0.014**		
Constant	−1.465	0.417**		
[B] Marginal effects of team decision making contingent on binary independent variables				
Dominant strategy	Opponent dominant strategy	Opponent=Team	*Marginal effect*	*Standard error*
Yes	No	Yes	0.108	0.048**
Yes	No	No	0.099	0.052*
No	Yes	Yes	0.169	0.095*
No	Yes	No	0.151	0.107
No	No	Yes	−0.008	0.015
No	No	No	−0.011	0.022

N=1.728; standard errors clustered for the 96 decision makers (48 individuals, 48 teams).
Marginal effects evaluated at the mean of independent variables (risk with maxstrategy, risk with maxstrategy opponent, advantageous inequality in Nash, disadvantageous inequality in Nash) and contingent on the three binary variables indicated in the top row (and their interaction effect with team decision making).

* Coefficient significant at $p<0.1$.

** Coefficient significant at $p<0.05$.

be to their (i.e., the opponent's) advantage – something which players themselves do not consider as far as their own consistency is concerned (see Table 4). Panel [B] of Table 5 reports the marginal effects of team decision making (compared to individual decision making) on the likelihood of expecting the opponent to be Nash-consistent. The results are very similar to those discussed above for Table 4 and hence we dispense with a detailed discussion.

Result 4: Teams are more likely than individuals to be a Nash-consistency type – and expect their opponents to be of this type also more often – when the game has a dominant strategy. Inequality in payoffs in the Nash equilibrium makes consistent decisions (of choices and first-order beliefs, respectively of first- and second-order beliefs) less likely. Hence, distributional preferences affect the degree of standard game-theoretic rationality.

3.5. Econometric estimation I: strategic and non-strategic types

Next, we present a maximum likelihood error-rate analysis of players' choices following the econometric model used in Costa-Gomes et al. (2001). This econometric model is a mixture model in which each player's type is drawn from a common prior distribution over eight types and remains constant for all 18 games. The nine types that we consider can be classified into non-strategic and strategic types and are defined as in Costa-Gomes et al. (2001)[18] :

Non-strategic types: (1) An *altruistic* type tries to maximize the sum of payoffs to himself and the opponent, implicitly assuming that the opponent is also *altruistic*.[19] (2) A *pessimistic* type chooses the strategy that secures the best of all worst outcomes. Hence, a *pessimistic* type plays maximin. (3) An *optimistic* type chooses the strategy that maximizes the maximum possible payoff, thus ignoring the incentives of the opponent player. (4) A *naïve* type best responds to beliefs that assign equal probabilities to its partner's decisions.[20]

Strategic types: (5) Type *L*2 plays best response to *optimistic* (*naïve*) types. (6) Type *D*1 applies one step of deleting strategies that are dominated by pure strategies and then plays best reply to a uniform prior over the opponent's remaining strategies. (7) Type *D*2 applies two steps of deleting dominated strategies and then best responds to a uniform prior over the opponent's remaining strategies. (8) An *equilibrium* type makes equilibrium choices (which are unique in our games). (9) A

[18] The definition of types used in Costa-Gomes et al. (2001) is largely based on earlier work by Stahl and Wilson (1994, 1995).

[19] In keeping with the literature (see Costa-Gomes et al., 2001) we denote this type *altruistic*, although *efficiency-loving* would probably be a more appropriate term. Note that efficiency-loving has been identified to be an important factor in shaping subjects' behavior in non-strategic allocation tasks (Charness and Rabin, 2002).

[20] Even if a *naïve* type might reflect strategic decision making with diffuse beliefs, we follow Costa-Gomes et al. (2001) who describe *naive* types as non-strategic.

Table 6
Estimated types of individuals and teams – own choices, first- and second-order beliefs.

Type	Individuals			Teams		
	Choices	First-order beliefs	Second-order beliefs	Choices	First-order beliefs	Second-order beliefs
Altruistic	0.122 (0.051)**	0.086 (0.042)**	0.109 (0.050)**	0.123 (0.070)*	0.073 (0.040)*	0.107 (0.046)**
Pessimistic	0.070 (0.047)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.001)
Optimistic	0.407 (0.082)***	0.666 (0.074)***	0.848 (0.053)***	0.251 (0.067)***	0.573 (0.078)***	0.648 (0.076)***
Equilibrium	0.021 (0.021)	0.021 (0.021)	0.021 (0.021)	0.019 (0.028)	0.000 (0.001)	0.000 (0.000)
Sophisticated	0.058 (0.051)	0.102 (0.065)	0.000 (0.000)	0.020 (0.021)	0.000 (0.000)	0.042 (0.040)
*D*1	0.223 (0.080)***	0.122 (0.071)*	0.000 (0.000)	0.473 (0.087)***	0.281 (0.073)***	0.203 (0.068)***
*D*2	0.062 (0.042)	0.000 (0.001)	0.022 (0.028)	0.006 (0.047)	0.000 (0.001)	0.000 (0.000)
*L*2	0.038 (0.049)	0.002 (0.011)	0.000 (0.001)	0.108 (0.060)*	0.073 (0.043)*	0.000 (0.002)
Sum Strategic	0.402 (0.076)***	0.248 (0.068)***	0.043 (0.035)	0.626 (0.082)***	0.353 (0.074)***	0.245 (0.068)***
Log likelihood	−507.03	393.08	−371.7	−481.8	−410.2	−421.1

* Standard errors in parenthesis, significant at 10% level.
** Standard errors in parenthesis, significant at 5% level.
*** Standard errors in parenthesis, significant at 1% level.

sophisticated type plays best reply to the probability distribution of opponents' strategies by taking the actually observed distribution of strategies in the experiment's subject pool as the estimated probability distribution.[21]

Given that, as noted by Costa-Gomes et al. (2001), it is impossible to distinguish an *optimistic* type from a *naïve* type in the 18 games used here. In the following estimation we therefore consider eight types so that *optimistic* and *naïve* are collapsed in a single type, named *optimistic*.

For the estimation of the mixture model let $i=1,\ldots, N$ index the different players (individuals or teams), let $k=1,\ldots, K$ index our types, and let $c=2$, 3, or 4 be the number of a player's possible decisions in a given game. We assume that a type-k player normally makes a type k decision, but in each game he makes an error with probability $\varepsilon_k \in [0,1]$, type k's *error rate*, in which case he makes each of his c decisions with probability $1/c$. For a type-k player, the probability of a type k decision is then 1-εk (c-1)/c. Hence, the probability of any single non-type-k decision is ε_k/c. We assume errors are independently and identically distributed across games and players.

The likelihood function can be constructed as follows. Let T^c denote the total number of games in which a player has c choices; in our design we have $T^2=11$, $T^3=6$, and $T^4=1$. Then let x_k^{ic} denote the number of player i's decisions that equal type k's in games in which he has c choices with $x_k^i=(x_k^{i2}, x_k^{i3}, x_k^{i4})$, $x^i=(x_1^i, \ldots, x_K^i)$, and $x=(x^i, \ldots, x^N)$. Let p_k denote players' common prior k-type probability, and $\sum_{k=1}^{K} p_k = 1$ and $p=(p_1,\ldots,p_K)$. Let ε_k denote the k-type error rate and $\varepsilon=(\varepsilon_1,\ldots,\varepsilon_K)$. Given that a game has one type-k decision and c-1 non-type-k decisions, the probability of observing a particular sample with x_k^i type-k decisions when player i is type k can be written as

$$L_k^i(\varepsilon_k|x_k^i) = \prod\nolimits_{c=2,3,4} \left[1-\frac{(c-1)}{c}\varepsilon_k\right]^{x_k^{ic}} \left[\frac{\varepsilon_k}{c}\right]^{T^c - x_k^{ic}} \quad (1)$$

Weighting the right-hand side by p_k, summing over k, taking logarithms, and summing over i yields the log-likelihood function for the entire sample:

$$\ln L(p, \varepsilon|x) = \sum\nolimits_{i=1}^{n} \ln \sum\nolimits_{k=1}^{K} p_k L_k^i(\varepsilon_k|x_k^i) \quad (2)$$

We provide two separate estimations of Eq. (2), one with individuals as decision makers and one with teams. In the analysis of the results we interpret the estimated probability p_k as the probability to find a player of type k in the population under observation.

Table 6 presents the main estimation results. Under the heading "individuals" ("teams") we show the estimated probabilities for choices, first- and second-order beliefs of individuals (teams).[22]

Concerning actual choices, we can see from the bottom row of Table 6 that individuals are estimated as strategic types in only 40% of cases, while 62% of teams are classified under any of the strategic types, and the difference is significant.[23] There are three types with a significantly positive probability, both for individuals and teams, and a fourth type which is only significant for teams. The three significant types common to both types of decision makers are the non-strategic types

[21] The best responses in each game for each type are indicated in Fig. F4 in Supplementary material.

[22] We have also run estimations with five types only where types (4)–(6) introduced above have been omitted (like in the initial approach of Costa-Gomes et al., 2001). The results with respect to the estimated frequencies of strategic, respectively non-strategic, play remain practically the same as those reported in Table 6.

[23] At first sight it might seem surprising why the *equilibrium* type is so rare, while Table 1 has shown about 50% of equilibrium play by teams across all games. For the classification of types it is important what a decision maker chooses when, for example, *D*1 and *equilibrium* do not suggest the same choice (as is the case in 6 of our games). In these games, the large majority of teams opt for the *D*1-strategy rather than the *equilibrium*-choice, which explains why the *equilibrium* types are rare.

altruistic (alias efficiency-minded) and *optimistic* (alias naïve) and the strategic type $D1$. While the probability to find an *altruistic* type does not differ significantly between individuals and teams, there are clear differences concerning the other two types. Individuals are significantly more often than teams of the non-strategic *optimistic* type, while teams are significantly more likely to be of the strategic $D1$-type. The fourth (weakly) significant type – which applies only to teams – is the strategic type $L2$.

Looking at first- and second-order beliefs in Table 6, we note that teams are much more often classified as a strategic type. This result shows that teams are more likely to expect their opponents to be strategic, and expect their opponents to have strategic expectations as well.

Result 5: The likelihood of teams to be of any of the five different strategic types (equilibrium, sophisticated, $D1$, $D2$, $L2$) is about 62%, while it is only 40% for individuals. Most of the individual decision makers are classified as optimistic types. First- and second-order beliefs are also more often classified as strategic for teams than for individuals.

3.6. Econometric estimation II: choices and higher order beliefs

In this final results section we provide a joint estimation of choices and beliefs in order to explore if the behavioral differences between teams and individuals are driven by differences in rationality or beliefs. For this purpose, we estimate a model of "noisy introspection" as introduced by Goeree and Holt (2004).

In this model a player's choice probabilities are given by a logit best response that is a function of the player's first order beliefs. Moreover the first-order beliefs are given by a logit best response that is a function of the player's second order beliefs. More generally speaking, the beliefs of order z are given by a logit best response that is a function of the player's beliefs of order z+1.

Let S^g denote the set of strategies in game g, then by $B^g_{zi}=\{b^g_{zis}\}_{s\in S^g}$ we denote (i) for $z=0$ the probability distribution associated to player i's choices in game g, (ii) for $z\geq1$ the probability distribution associated to player i's beliefs of order z in game g. We assume that the probability distribution B^g_{zi} is a function of B^g_{z+1i}, i.e., $B^g_{zi}=\phi^z(B^g_{z+1i})\ \forall\ z\geq0$ where the probability to play action s in game g is given by $b^g_{zis}=(\exp(\lambda_z\pi^e_{is}(B^g_{z+1i}))/\sum_{s\in S^g}\exp(\lambda_z\pi^e_{is}(B^g_{z+1i})))$ for all $z\geq0$, λ_z is the associated precision parameter[24] and $\pi^e_{is}(B^g_{z+1i})$ denotes the expected payoff to player i from playing strategy s, as a function of B^g_{zi}. Then every probability distribution B^g_{zi} is the result of an infinite composition of logit best responses: $B^g_{zi}=\phi^z\circ\phi^{z+1}\circ\phi^{z+2}\circ\cdots\circ\phi^\infty$. As in Goeree and Holt (2004), we assume that $\lambda_{z+1}=(\lambda_z/t)$, $t\geq1$, implying that higher order beliefs are characterized by more noise.

Then let x_{ig} denote the choice of player i in game g, $x_i=\{x_{ig}\}_{g\in G}$ is the set of choices of player i in the set G of games, and $x=\{x_i\}_{i\in N}$ is the set of choices observed in a set N of players. Then the log-likelihood of the entire sample is given by

$$L(\lambda_0,t|x)=\sum_{g\in G}\sum_{i\in N}\ln b^g_{0is},\ s=x_{ig}$$

Moreover (as in Costa-Gomes and Weizsäcker, 2008) we can estimate a similar model using the stated beliefs. In the model described above we simply replace choices by stated (point) beliefs. Differently, we have that $B^g_{0i}=\{b^g_{0is}\}_{s\in S^g}$ denotes the probability distribution associated to player i's stated beliefs in game g. Again we assume a precision parameter $\lambda_{z,b}$ that evolves according the rule $\lambda_{z+1,b}=(\lambda_{z,b}/t)$, $t\geq1$.

Let y_{ig} denote the stated first order beliefs of player i in game g, $y_i=\{y_{ig}\}_{g\in G}$ is the set of stated beliefs of player i in the set G of games, and $y=\{y_i\}_{i\in N}$ is the set of stated beliefs observed in a set N of players. The log-likelihood of the entire sample is given by

$$L(\lambda_{0,b},t_b|y)=\sum_{g\in G}\sum_{i\in N}\ln b^g_{0is},\ s=y_{ig}$$

In Table 7 we present the results of the estimations for three subsets of games: (i) all games with a dominant strategy (where players are able to solve the game by one or two rounds of iterated elimination of dominated strategies), (ii) games without a dominant strategy in which players need two or three rounds of iterated elimination of dominated strategies, and (iii) games without a dominant strategy that not dominance-solvable. For the estimations, we truncated the sequence of beliefs at the 9th order, hence fixing B^g_{9i} as uniformly distributed. For each subset of games, we report the values of parameters λ_z and $\lambda_{z,b}$ with their standard errors computed using the delta method.

When discussing the results, note that a value of λ_0 ($\lambda_{0,\mathrm{b}}$) equal to zero means that strategies (stated beliefs) are chosen at random. Similarly a value of λ_z ($\lambda_{z,\mathrm{b}}$) equal to zero for $z\geq1$ means that beliefs of order z are uniformly distributed. While all estimates λ_0 ($\lambda_{0,\mathrm{b}}$) are significantly different from zero in all subsets of games, a first noticeable difference between individuals and teams arises from higher orders of beliefs λ_z ($\lambda_{z,\mathrm{b}}$), $z\geq1$. Indeed, for teams we find higher orders of beliefs that are significantly different from the uniform distribution: in the first subset of games (the D-games), teams (individuals) have

[24] Our precision parameter λ_z corresponds to the inverse of the error rate μ_z in Goeree and Holt (2004). Note that as λ_z goes to infinity, the decision with the highest expected payoff is selected with probability one, while as λ_z approaches zero , the decisions are taken according to a uniform probability distribution.

Table 7
Noisy introspection model. Estimations using choices and stated beliefs.

	Using choices							Using stated beliefs					
	Individuals			Teams				Individuals			Teams		
	Coeff.	Std. err		Coeff.	Std. err			Coeff.	Std. err		Coeff.	Std. err	
	Games D 1R 2R												
λ_0	0.0671	0.0063	***	0.0778	0.0063	***	$\lambda_{0,b}$	0.1383	0.0090	***	0.1217	0.0073	***
λ_1^{+++}	0.0165	0.0040	***	0.0445	0.0049	***	$\lambda_{1,b}$	0.0403	0.0032	***	0.0435	0.0027	***
λ_2^{+++}	0.0041	0.0019	**	0.0255	0.0063	***	$\lambda_{2,b}$	0.0118	0.0023	***	0.0155	0.0022	***
λ_3^{++}	0.0010	0.0007		0.0146	0.0057	**	$\lambda_{3,b}$	0.0034	0.0011	***	0.0055	0.0013	***
λ_4^{+}	0.0002	0.0002		0.0084	0.0045	*	$\lambda_{4,b}$	0.0010	0.0004	**	0.0020	0.0006	***
λ_5	0.0001	0.0001		0.0048	0.0033		$\lambda_{5,b}$	0.0003	0.0002	*	0.0007	0.0003	**
λ_6	0.0000	0.0000		0.0027	0.0023		$\lambda_{6,b}$	0.0001	0.0001		0.0003	0.0001	**
λ_7	0.0000	0.0000		0.0016	0.0015		$\lambda_{7,b}$	0.0000	0.0000		0.0001	0.0001	*
λ_8	0.0000	0.0000		0.0009	0.0010		$\lambda_{8,b}$	0.0000	0.0000		0.0000	0.0000	
Log Lik.	−328.296			−307.617				−252.810			−269.388		
	Games ND 2R 3R												
λ_0^{++}	0.0531	0.0098	***	0.0843	0.0111	***	$\lambda_{0,b}$	0.1566	0.0353	***	0.1236	0.0123	***
λ_1^{+}	0.0064	0.0098		0.0288	0.0072	***	$\lambda_{1,b}^{+}$	0.0328	0.0080	***	0.0485	0.0050	***
λ_2^{+}	0.0008	0.0023		0.0099	0.0049	**	$\lambda_{2,b}^{+}$	0.0069	0.0048		0.0191	0.0048	***
λ_3	0.0001	0.0004		0.0034	0.0026		$\lambda_{3,b}^{+}$	0.0014	0.0016		0.0075	0.0031	**
λ_4	0.0000	0.0001		0.0012	0.0012		$\lambda_{4,b}$	0.0003	0.0005		0.0029	0.0017	*
λ_5	0.0000	0.0001		0.0004	0.0005		$\lambda_{5,b}$	0.0001	0.0001		0.0012	0.0009	
λ_6	0.0000	0.0000		0.0001	0.0002		$\lambda_{6,b}$	0.0000	0.0000		0.0005	0.0004	
λ_7	0.0000	0.0000		0.0000	0.0001		$\lambda_{7,b}$	0.0000	0.0000		0.0002	0.0002	
λ_8	0.0000	0.0000		0.0000	0.0000		$\lambda_{8,b}$	0.0000	0.0000		0.0001	0.0001	
Log Lik.	−156.040			−139.142				−125.974			−120.173		
	Games ND ∞R												
λ_0	0.1575	0.0183	***	0.1761	0.0193	***	$\lambda_{0,b}$	0.2066	0.0422	***	0.2405	0.0316	***
λ_1	0.0000	.		0.0000	.		$\lambda_{1,b}$	0.0497	0.0097	***	0.0627	0.0085	***
λ_2	0.0000	.		0.0000	.		$\lambda_{2,b}$	0.0120	0.0069	*	0.0163	0.0062	***
λ_3	0.0000	.		0.0000	.		$\lambda_{3,b}$	0.0029	0.0028		0.0043	0.0027	
λ_4	0.0000	.		0.0000	.		$\lambda_{4,b}$	0.0007	0.0009		0.0011	0.0010	
λ_5	0.0000	.		0.0000	.		$\lambda_{5,b}$	0.0002	0.0003		0.0003	0.0003	
λ_6	0.0000	.		0.0000	.		$\lambda_{6,b}$	0.0000	0.0001		0.0001	0.0001	
λ_7	0.0000	.		0.0000	.		$\lambda_{7,b}$	0.0000	0.0000		0.0000	0.0000	
λ_8	0.0000	.		0.0000	.		$\lambda_{8,b}$	0.0000	0.0000		0.0000	0.0000	
Log Lik.	−127.422			−118.647				−105.464			−67.527		

* The estimated parameter is significantly different from zero at the 10% level.
** The estimated parameter is significantly different from zero at the 5% level.
*** The estimated parameter is significantly different from zero at the 1% level.
$^{+++}$ The estimated parameter is significantly different between teams and individuals at the 1%, level.
$^{++}$ The estimated parameter is significantly different between teams and individuals at the 5% level.
$^{+}$ The estimated parameter is significantly different between teams and individuals at the 10% level.

λ_z significantly different from zero for $z \le 4$ ($z \le 2$); for the second subset of games (ND 2R, 3R), teams have beliefs significantly different from zero up to level three, while for individuals it's only up to level one. Only in the third subset of games (ND ∞) we do not find a significant difference between individuals and teams. When we estimate the noisy introspection model based on stated beliefs – see right hand side of Table 7 – the same qualitative results prevail, such that teams have significantly higher level of beliefs than individuals in the first two subsets of games.

Finally, we can see some differences between individuals and teams by looking at the values of the estimated parameters. Note that differences in λ_0 ($\lambda_{0,b}$) catch the difference in the ability to choose the strategy (to state the belief) with the higher expected payoff. Differences in λ_z ($\lambda_{z,b}$), with $z \ge 1$, catch the differences in the beliefs about the rationality of the opponent, the beliefs about the beliefs about the rationality of the opponents, and so on. We find that λ_0 is significantly larger for teams than for individuals in the second group of games, which is characterized by an intermediate degree of complexity. The parameter $\lambda_{0,b}$ is never significantly different between teams and individuals. Looking at the beliefs we find that λ_1, λ_2, λ_3, λ_4 are significantly larger for teams in the first subset of games and λ_1, λ_2 are significantly larger for teams in the second subset of games. These findings show that teams are more likely to state beliefs with higher expected payoffs. This general result is also confirmed when using the stated beliefs for estimations, where we find significant differences in the estimates of λ_{1b}, λ_{2b}, λ_{3b} in the second subset of games.

Result 6: Teams are characterized by higher order beliefs than individuals, by beliefs that more often are best responses to beliefs that are of one level higher order and by a higher likelihood of choosing strategies that are maximizing expected payoffs. Hence, teams differ from individuals both in rationality and in belief formation.

4. Conclusion

In this paper we have studied the strategic sophistication of individuals and teams. We have found that teams are more likely than individuals to play strategically, and to expect their opponents to be strategic and to have strategic expectations. This implies that teams consider more often the structure of the game and the incentives of their opponents when making decisions. Concerning actual choices, we have estimated the likelihood of strategic play for teams to be 62%, while it is only 40% for individuals. The modal type of team decision making is a strategic *D*1-type which applies one step of deleting strategies that are dominated by pure strategies and then plays best reply to a uniform prior over the opponent's remaining strategies. On the contrary, the modal type of individual decision making is a non-strategic *optimistic* type which picks the strategy that maximizes the maximum possible payoff, assuming that the opponent plays randomly. Combining choices and beliefs in a noisy introspection model, we have found that teams have higher higher-order beliefs than individuals, are more likely to best reply in their beliefs to a one-level higher order, and are more likely to choose strategies that have higher expected payoffs. This means that teams differ from individuals both in rationality and in beliefs. In fact, teams also expect their opponents to be more sophisticated by having higher higher-order beliefs and strategies that have higher expected payoffs.

A detailed analysis of individual and team behavior has shown that teams play the Nash equilibrium significantly more often than individuals, and also expect their opponents to do so more often. Matching choices and first-order beliefs we have found that teams are more likely to play a best reply with their choices to their own first-order point beliefs. While this kind of consistency of choices and point beliefs is only found in 56% of individual decisions, it prevails in 66% of team decisions. It seems noteworthy that the relative frequency of consistency of individual decisions is very similar to the one reported by Costa-Gomes and Weizsäcker (2008).

Our paper also adds to the literature on strategic sophistication through our analysis of the determinants of textbook rationality. It is noteworthy that playing Nash and expecting the opponent to play Nash is more frequently observed with teams. Moreover, and applying to both individuals and teams, this frequency also depends on the potential monetary losses if a player deviates from Nash and on the distribution of payoffs in the Nash equilibrium, indicating that inequality aversion plays a role for textbook rationality (Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000).

Our paper also contributes to the literature on team decision making in the following ways. It offers a classification of teams according to eight different strategic and non-strategic types of decision making. The existing literature on team decision making has mainly focused on whether or not teams play equilibrium strategies more often than individuals, and our experiment can also answer this question affirmatively. Yet, we can add two novel pieces of evidence by showing the differences between individuals and teams with respect to the distribution of different types of strategic and non-strategic behavior and by examining how choices and point beliefs are related.

First, the main difference with respect to strategic types originates from teams being more likely a *D*1-type, as explained above. This is an important difference to individual decision making as it shows that the higher strategic sophistication of teams is particularly driven by teams thinking one step further than individuals, which is very important in strategic contexts such as market entry, technology races or company takeovers. Future research should definitely explore in even greater detail what makes teams more sophisticated. We conjecture that the dynamics of discussion within teams is be important for final decisions made by teams. It might well be that strategically thinking group members might gain a more than proportional influence in shaping team decisions. Alternatively, discussion within teams may let team members see the decision problem in a different perspective, and thus creating strategically sophisticated team decisions. Since we have deliberately opted for not videotaping team discussions – in order to keep conditions to the individual treatment as comparable as possible – we are not able to answer these questions in this paper.

Second, we do not only elicit actual choices, but also first- and second-order point beliefs. This has not been done in the team decision making literature before. Our approach allows checking the consistency of choices and first-order point beliefs, respectively the expected consistency of one's opponent (by relating first- and second-order point beliefs). We have found that teams are more consistent than individuals in this respect, and that they also expect their opponents to be more consistent than individuals expect their opponents to be. The latter feature of team behavior reinforces the consistency of teams, as it makes it more profitable for teams to be consistent themselves, because not playing Nash against an opponent who picks the equilibrium strategy leads to smaller payoffs than choosing the equilibrium strategy. In fact, we find that teams earn significantly more money than individuals in all games where one player has a dominant strategy (i.e., the ***D***-games). Our estimation of a noisy introspection model (Goeree and Holt, 2004) has shown that teams have higher higher-order beliefs than individuals and also are more likely to choose strategies that have higher expected payoffs. Hence, teams differ from individuals both in rationality and belief formation. One avenue for future research would be to explore whether these important differences between individuals and teams would be mediated by feedback. In our experiment, we have not given feedback in order to study strategic sophistication in the absence of learning. However, in many important real-world situations, decision makers can learn from previous experience. Since individuals and teams have been shown in different games to differ in their responsiveness to learning (Kocher and Sutter, 2005; Feri et al., 2010), it remains an open question how feedback would affect the strategic sophistication of individuals and teams.

Summing up, our paper has provided compelling evidence that teams are more sophisticated, i.e., more strategic in playing normal-form games than individuals. Given the surprisingly low level of strategic sophistication of individuals reported in previous papers – and replicated in this one – we consider the finding that team decision making increases the relative frequency of equilibrium play and the level of consistency in best responding to own point beliefs an important contribution to the literature on strategic sophistication. Additionally, our paper is the first in the team decision making literature that provides a fine-grained classification of teams into eight different strategic and non-strategic types of decision makers and that examines higher order point beliefs, thereby adding important details to the bottom-line emerging from the team decision making literature that "teams are more rational" than individuals.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.euroecorev.2013.06.003.

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