Collective rationality in interactive decisions: Evidence for team reasoning

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Abstract

Decision theory and game theory rest on a fundamental assumption that players seek to maximize their individual utilities, but in some interactive decisions it seems intuitively reasonable to aim to maximize the utility of the group of players as a whole. Such team reasoning requires collective preferences and a distinctive mode of reasoning from preferences to decisions. Findings from two experiments provide evidence for collective preferences and team reasoning. In lifelike vignettes (Experiment 1) and abstract games (Experiment 2) with certain structural properties, most players preferred team-reasoning strategies to strategies supporting unique Nash equilibria, although individually rational players should choose equilibrium strategies. These findings suggest that team reasoning predicts strategy choices more powerfully than orthodox game theory in some games.

1. Introduction

Expected utility (EU) theory (von Neumann & Morgenstern, 1947) and subjective expected utility (SEU) theory (Savage, 1954/1972) rest on a fundamental assumption of *methodological individualism*, according to which decision makers are rational in the sense of attempting to do the best for themselves as individuals in all circumstances that arise (see also Fishburn, 1989; Rabin, 1998). Utilities are measures of the subjective desirability of outcomes or events, corresponding to individual preferences, and in games they are represented by payoffs. Underlying these expected utility theories is a narrow but clear and precise conception of *instrumental rationality* (also called *means-end rationality*), according to which individuals act to maximize their individual expected utilities relative to their knowledge and beliefs. This interpretation of rationality was summed up by Bertrand Russell (1954) as "the choice of the right means to an end that you wish to achieve" (p. 8).

In interactive decisions or games, utilities may incorporate regard for the utilities of others affected by the outcomes, but according to standard interpretations, decision makers act solely to maximize their individual utilities after incorporating such other-regarding considerations into their utility functions. Research into judgment and decision making has revealed that human agents often deviate from full rationality in practice, because they are limited by bounded rationality (Simon, 1956, 1982) that constrains them, in difficult decisions, to use rough-and-ready judgmental heuristics that are faster and more frugal (Gigerenzer & Goldstein, 1996; Gigerenzer & Selten, 2001; Gigerenzer, Todd, & the ABC

Research Group, 1999) but that sometimes generate biased judgments and decisions (Kahneman, Slovic, & Tversky, 1982; Kahneman & Tversky, 2000).

In interactive decisions or games, there is the possibility of a far more radical departure from individual rationality that violates methodological individualism itself. In certain types of games, intuition and casual observation suggest that players do not merely deviate from perfect rationality by implementing fallible heuristics; they sometimes adopt a different principle of maximization altogether. In these games, players may not even attempt to maximize their *individual* expected utilities but may prefer instead to maximize the *collective* utility of the group of players involved in the game (Gilbert, 1987, 1994; Hurley, 1989, 2005; Sugden, 2000). Decision making based on such collective preferences is usually called *team reasoning*, and it is quite distinct from individual utility maximization, even with other-regarding utilities, as we shall show. Theories of team reasoning generally assume that players are motivated to maximize either collective or individual utilities depending on circumstances (Bacharach, 1999, 2006; Gold & Sugden, in press; Sugden, 1993, 2005). Orthodox decision theory may be considered a special case in which the group happens to be a singleton. The underlying idea of team reasoning can be traced back to Regan (1980) and ultimately to Hodgson (1967).

1.1. Payoff dominance

An appealing feature of team reasoning is that it explains phenomena of interactive decision making that defy explanation within the framework of game theory, which is firmly rooted in individual utility maximization. A striking example is the powerful intuitive appeal of *payoff-dominant* Nash equilibria. In a dyadic (two-player) game, a Nash equilibrium is a pair of strategies that are *best replies* to each other in the sense that each maximizes the payoff of the player choosing it, given the strategy chosen by the co-player. Equivalently, a Nash equilibrium is an outcome from which neither player could profit by deviating unilaterally and that therefore gives neither player retrospective grounds to regret the chosen strategy. Furthermore, if a game has only one Nash equilibrium, then rational players are bound to choose it, according to game theory, because only by doing so can they both play best-reply strategies—in any other outcome, at least one player is not choosing a best reply to the co-player's strategy. If a game has multiple equilibria, and one is better for both players than any other, then it seems natural for rational players to choose the payoff-dominant equilibrium but, perhaps surprisingly, this principle cannot be derived or justified from game theory's fundamental assumptions (Harsanyi & Selten, 1988).

Fig. 1. Games exhibiting payoff dominance: Stag Hunt game (left) and Hi-Lo matching game (right).

Payoff dominance has been discussed most frequently in relation to the Stag Hunt game and the Hi-Lo matching game (see Fig. 1). In each game, Player I chooses row *L* or *R*, Player II chooses column *L* or *R*, and the pair of numbers in each cell are the payoffs to Players I and

II respectively for that outcome. In both games, (*L*, *L*) and (*R*, *R*) are Nash equilibria, and (*L*, *L*) is Pareto-dominant, because it offers both players better payoffs. The Stag Hunt game is complicated by the fact that (*R*, *R*) *risk-dominates* (*L*, *L*) in the sense that a player risks a worse possible payoff (zero) by choosing *L* than *R*;[1] but we expect rational players to choose (*L*, *L*) nonetheless, because payoff dominance is a more powerful consideration than risk dominance (Colman, 2003; Harsanyi & Selten, 1988). On the other hand, it is worth commenting that a player motivated by a competitive social value orientation would necessarily choose *R* in the Stag Hunt game, because it offers the only possibility of obtaining a higher payoff than the co-player (Van Lange, 1999). These complications are absent from the Hi-Lo game on the right of Fig. 1, where both strategies are equally risky, there is no scope for competitiveness, and the payoff-dominance phenomenon is therefore completely transparent.

The Hi-Lo game may seem jejune, but it can arise in many natural strategic interactions between human or nonhuman decision makers. In a football game, for example, suppose Player I can pass the ball either left or right for Player II to shoot for goal, and Player II can move left or right to intercept it. If the chances of scoring are better if both choose left than if both choose right, and zero otherwise, then the strategic structure is Hi-Lo (Bacharach, 2006, pp. 37, 124–127; Sugden, 2005). Similarly (from a strategic perspective), when two *Apis mellifera* honey bee scouts return to their common swarm after discovering different potential nesting sites, one objectively superior to the other, they also play the Hi-Lo game. They dance to communicate the locations and attractiveness of their sites—merely indicating the payoffs of the game, since bees cannot negotiate or discuss their intentions—and on the basis of this information, they reach agreement on the best site (with the higher payoffs) and choose it on behalf of the swarm (Seeley & Buhrman, 2001; Seeley & Visscher, 2004).

The payoff-dominance problem arises from the surprising fact that game theory provides no justification for choosing *L* (Casajus, 2001; Colman, 2003; Cooper, DeJong, Forsythe, & Ross, 1990; Harsanyi & Selten, 1998; Hollis, 1998; Janssen, 2001; Van Huyck, Battalio, & Beil, 1990). If both players are rational individual expected utility maximizers, then Player I has a reason to choose *L* if and only if there is a reason to expect Player II to choose it; but there is no such reason, because Hi-Lo is a symmetric game and Player II faces the identical dilemma. This leads to an infinite regress of the type "I expect my co-player to expect me to expect . . ." that provides neither player with any rational justification for choosing *L*. In an empirical study, on the other hand, it is hardly surprising that almost 100 per cent of players chose *L* (Bardsley, Mehta, Starmer, & Sugden, as cited in Gold & Sugden, in press). What then accounts for the powerful intuitive appeal of the *L* strategy?

Team reasoning offers a persuasive solution to this payoff-dominance puzzle, but it requires a radical departure from orthodox game theory and decision theory, because it assumes that players do not attempt to maximize their individual utilities. Instead of asking themselves *What do I want, and what should I do to achieve it?* the players are assumed to ask *What do we want, and what should I do to help achieve it?* The answer is then obvious— we want (*L*, *L*) and I should play my part in achieving it by choosing *L*. Team-reasoning players adopt the following distinctive mode of reasoning from preferences to decisions or, in other words, of formulating reasons for decisions on the basis of their own and other players' individual preferences (Bacharach, 1999, 2006; Sugden, 1993, 2005; Gold & Sugden, in press). First, they identify a profile of strategies that maximizes the collective payoff of the group of players as a whole; then, if this profile is unique, they choose and play their component strategies of it. If the collectively rational profile is not unique, then the theory is indeterminate. Janssen's (2001) principle of individual team member rationality is a variant of this fundamental idea (see also Janssen, 2006). In Bacharach's stochastic version of the

theory, players' decisions to choose team-reasoning strategies depend partly on the subjective probability that they assign to the other player(s) doing the same.

1.2. Spurious solutions

Team reasoning is a deceptively subtle concept, easily misunderstood by anyone inured to individual rationality. There is a strong temptation to assume that the problem it is designed to solve does not exist, each player being justified in choosing *L* and assuming that the co-player will choose *L*, because this maximizes both players' payoffs. But, from a purely individualistic perspective, Player I has no reason to assume that Player II will choose *L*, because it maximizes Player II's payoff only if Player I also chooses *L*, and if Player I were to choose *R* instead of *L*, then Player II's payoff from choosing *L* would be zero. Player II's (individualistic) justification for choosing *L* depends entirely on Player I choosing *L*, but Player II has no good reason to assume that Player I will choose *L*. From Player I's (individualistic) point of view, choosing *L* is payoff-maximizing only if Player II also chooses *L*, otherwise it yields a zero payoff. Hence, according to individualistic rationality, Player I has a reason to choose *L* only if Player II has a reason to choose it, and Player II has a reason to choose it only if Player I has a reason to choose it. In other words, individualistic rationality provides neither player with any independent justification for choosing *L*.

A common fallacy is the belief that a justification for choosing *L* can be found within game theory for players with other-regarding utility functions whose arguments include their co-players' payoffs. For example, to model a player who attaches some weight to a co-player's payoffs, the player's utility may be represented by a weighted linear function of the player's own payoff and the co-player's payoff. This method of modeling other-regarding preferences was introduced by Edgeworth (1881/1967, pp. 101–102) and has been rediscovered or adapted by more recent game theorists. It results in payoff transformations that alter the strategic structure of the well-known Prisoner's Dilemma game, providing individually rational players with a reason to cooperate (Rabin, 1993), as shown below, but it leaves the structure of other games, including Hi-Lo, unchanged. Other-regarding utilities are no better than purely selfish utilities in solving the payoff-dominance puzzle in its simplest manifestations, for the following reason.

Suppose an other-regarding Player I in the Hi-Lo game shown in Fig. 1 (right) has a utility function that weights own and co-player's payoffs .60 and .40 respectively. This implies that Player I's satisfaction with any outcome depends 60% on Player I's own payoffs and 40% on Player II's payoffs. Then, in the outcome (*L*, *L*), Player I's transformed payoff is $(.60 \times 2) + (.40 \times 2) = 2$, exactly the same as before, and in every other outcome, the effect of the transformation is the same: the transformed payoffs are all identical to the original payoffs! Furthermore, this remains so for any weights whatsoever that Player I might assign to own and co-player's payoffs. Payoff transformations have *no effect whatsoever* on the Hi-Lo game, because it is a pure coordination game in which the players' payoffs are identical in every outcome, in contrast to the Prisoner's Dilemma game, in which the players' payoffs differ in some outcomes. In the standard Prisoner's Dilemma game (Fig. 2, left), each player chooses between *C* (cooperate) and *D* (defect). The only Nash equilibrium is joint defection (*D*, *D*), but in a payoff-transformed version of the game (Fig. 2, right), in which each player's payoffs are weighted averages of own payoff (.60) and co-player's payoff (.40), the unique Nash equilibrium is joint cooperation (*C*, *C*). In the outcome (*D*, *C*), for example, Player I's transformed payoff is $(.60 \times 4) + (.40 \times 1) = 2.8$, and Player II's transformed payoff is $(.60 \times 1) + (.40 \times 4) = 2.2$. Payoff transformations alter the strategic structure of the Prisoner's Dilemma game and in some cases, such as this, provide individually rational players with a reason for cooperating, but in the Hi-Lo game, they leave the structure unchanged and provide no individually rational justification for choosing *L*, despite the incorporation of

other-regarding utilities. Other-regarding utilities cannot solve the payoff-dominance problem without team reasoning.

Fig. 2. The Prisoner's Dilemma game (left) and a payoff-transformed version (right) with own payoffs weighted .60 and co-player's payoffs weighted 0.4.

This limitation of individual rationality comes into sharp focus in a prominent integrative model of social value orientations (Van Lange, 1999) in which orientations are interpreted as maximizations of various linear functions of the variables W_1 (own payoff), W_2 (co-player's payoff), and W_3 (payoff equality, evidently equal to the negative of the absolute difference in payoffs: $-|W_1 - W_2|$). We can easily prove that no linear combination of these variables solves the payoff-dominance problem. Note first that, because $W_3 = -|W_1 - W_2|$, any linear function of W_1, W_2, and W_3 can be expressed as $aW_1 + bW_2$, where a and b are suitably chosen real numbers. Furthermore, because $W_1 = W_2$ in the Hi-Lo game, maximizing $aW_1 + bW_2$ amounts to maximizing W_1 for any values of a and b, and this is simply individual payoff maximization, which leaves neither player with any rational justification for choosing L, as we have shown. This applies even to the *cooperative* or *prosocial* social value orientation, in which each player's payoff is the sum of the payoffs to both players. Applying this transformation ($W_1 + W_2$) to the Hi-Lo game in Fig. 1 (right) merely produces another Hi-Lo game with all the payoffs doubled and no more reason to choose L than before. This approach fails because decision making remains individualistic. Team reasoning requires not only a cooperative social value orientation but also a collective mode of generating decisions from preferences.

It is also fallacious to believe that the payoff-dominance problem can be solved by modeling players' beliefs about their co-players' strategies with subjective probabilities, according to the type of game-theoretic analysis that became popular after the introduction of Bayesian game theory (Harsanyi, 1967–1968). Suppose Player I formulates the belief that the probability is $p = .75$ that Player II will choose L in the Hi-Lo game (Fig. 1, right). If any such belief were valid, then a utility-maximizing Player I would indeed have a rational justification for choosing L, because the subjective expected utility of L, $(.75 \times 2) + (.25 \times 0) = 1.50$, would then exceed that of R, $(.75 \times 0) + (.25 \times 1) = 0.25$, but the following simple *reductio ad absurdum* proof exposes the fallacy. In game theory, the properties of the game and the players' rationality are assumed to be common knowledge (Aumann, 1976; Lewis, 1969, pp. 52–68), and an implication of this, called the *transparency of reason*, is that any rational deduction about the game must also be common knowledge (Bacharach, 1987). It follows from this that if Player I's choice of L were indeed rationally justified, then Player II, assumedly also rational, would anticipate it and would choose the best reply to it, namely L, with *certainty* ($p = 1.00$). But that contradicts Player I's initial belief ($p = .75$), proving that the belief must therefore have been unjustified.

The same general refutation obviously applies to any argument based on players' subjective probabilities representing their beliefs about co-players' strategies. Arguments

based on the *principle of indifference* or of *insufficient reason* fall into this category. For example, in the Stag Hunt game (Fig. 1, left), it might be suggested that it is rational to choose R because, if we lack any reason to expect the co-player to choose one strategy or the other, we can at least observe that $(8 + 7)/2$ is better than $(9 + 0)/2$, hence it may seem rational to choose R. The hidden assumption here is that the co-player is equally likely to choose L or R, because the argument is otherwise incoherent. This is just a special case, with equal weights, of the general payoff-transformational approach already discussed. If the reasoning were indeed rationally justified, then the co-player would anticipate it by the transparency of reason and, being rational, would play a best reply to R, namely R. But this contradicts the assumption that this co-player is equally likely to choose L and R. Starting from an assumption that the co-player is equally likely to choose L or R, we have proved that the co-player is, in fact, certain to choose R, and we have a contradiction, showing the argument to be invalid.

1.3. Rationale and hypotheses

Team reasoning solves the payoff-dominance problem in theory, as we have shown.[2] But do decision makers form collective preferences in practice, and do they engage in team reasoning? Neither preferences nor modes of reasoning can be observed directly, but predictions can be made about choices that would result from collective utility maximization and team reasoning, and that behavior can be observed directly. To examine this issue empirically, we performed two experiments, using games in which collective rationality and team reasoning predict different strategy choices from individual rationality and orthodox game theory. In both experiments, we pitted predictions of team reasoning directly against predictions of game theory. To this end, we focused on the class of games with unique Nash equilibria and distinct Pareto-dominant disequilibrial outcomes—outcomes that were not Nash equilibria but offered higher payoffs to both players. Such games clearly present a stronger test of collective rationality and team reasoning than games with payoff-dominant Nash equilibria, because all Nash equilibria are rational in classical game theory, whereas in our games team reasoning entails a deliberate departure from Nash equilibria and therefore from game theory (cf. Charness & Grosskopf, 2001; Charness & Rabin, 2002).

Experiment 1 used games framed as lifelike vignettes designed to make the collectively and individually rational preferences maximally obvious and to prime team reasoning or individual rationality, and Experiment 2 used purely abstract games that enabled individual rationality and collective rationality (team reasoning) to be examined without the distracting influence of interpretive framing. In experimental games, there are advantages and disadvantages associated with meaningful interpretive frames versus purely abstract games (Loewenstein, 1999). We therefore decided to use both approaches to explore individual and collective rationality. The games in Experiment 1 were relatively complicated, having five strategy options per player, and we hypothesized that the contextual framing provided by the lifelike vignettes would encourage collective rationality in two of the games and individual rationality in two others. In Experiment 2, the games were simpler and were presented abstractly, without any interpretive framing, and each game had three strategy options per player. We hypothesized that all of the games in Experiment 2 would elicit collective rationality and team reasoning on account of their structural properties alone. In both experiments, each game had a unique Nash equilibrium and an outcome, distinct from the equilibrium, that yielded better payoffs to both players, and participants were motivated with significant financial incentives linked to the payoffs.

2. Experiment 1

2.1. Participants

The 81 participants who served as decision makers in this experiment included 36 men and 45 women, mostly undergraduate students, aged 16 to 45 ($M = 20.48$, $SD = 4.40$), recruited via an online experimental participant panel on the web pages of the University of Leicester. They volunteered to take part in what was described to them as an experiment on decision making, and each participant earned between £4.00 ($7.28) and £13.00 ($23.66), $M = £9.48$ ($17.25), $SD = 1.89$ ($3.44) according to the payoffs in a single game selected randomly from among those used in the experiment. This method of payment is a version of the random lottery incentive system, which has been found to have various desirable properties for motivating participants (Cubitt, Starmer, & Sugden, 1998).

2.2. Materials

We hypothesized that collective preferences would be primed by vignettes describing decisions in which the payoffs contribute to a respected public good, provided that the individuals play their parts in the collectively rational outcome. We call these *team-reasoning vignettes*. Accordingly, the players indicated their choices in the two lifelike team-reasoning vignettes shown in Fig. 3, both of which were specifically designed to prime collective preferences. "Fund-raising" and "GM site" are both symmetric 5 × 5 games, and each has a singular Nash equilibrium where both players choose *D* and a collectively rational outcome where both choose *C*.

Fund-raising	**GM site**
You and other students collect funds for charity. In the first hour, you and your best friend each raise some money. Here is a list of the possible options:	You are involved in a group of people who are against a proposed test site for genetically modified crops. You and another group member spend half an hour in the local town collecting money for publicity opposing the new test site. Here is a list of the possible options:

Fund-raising:

	You raise	Your friend raises
Option A	£1	£7
Option B	£3	£3
Option C	£5	£6
Option D	£6	£4
Option E	£4	£1

Which option do you prefer?
A B C D E (circle one)

What do you expect the other person to choose?
A B C D E (circle one)

GM site:

	You collect	Other person collects
Option A	£1	£7
Option B	£4	£5
Option C	£4	£6
Option D	£6	£3
Option E	£4	£0

Which option do you prefer?
A B C D E (circle one)

What do you expect the other person to choose?
A B C D E (circle one)

Fig. 3. Decision vignettes designed to prime collective preferences (team-reasoning vignettes), with Option *A* maximizing altruism, *B* equality-seeking, *C* collective rationality, *D* individual rationality, and *E* competition.

As a benchmark for comparison, we also solicited decisions from the players in two vignettes, shown in Fig. 4, designed to prime individualistic preferences, owing to the fact that payoffs provide culturally acceptable benefits to individuals rather than public goods. In these cases, we hypothesized that individualistic preferences would be primed by frames involving competitive gambling and recreational games with individual payoffs to the winners. "Prize draw" and "Poker" are both symmetric 5×5 games, each with a singular Nash equilibrium where both players choose D and a collectively rational outcome where both choose C.

Prize draw You and your next-door neighbour enter a prize draw at a school fete. Here is a list of the possible options:	**Poker** You and a classmate play a session of poker on the internet. Here is a list of the possible options:
<table><tr><td></td><td>You win</td><td>Neighbour wins</td></tr><tr><td>Option A</td><td>£3</td><td>£7</td></tr><tr><td>Option B</td><td>£4</td><td>£4</td></tr><tr><td>Option C</td><td>£5</td><td>£6</td></tr><tr><td>Option D</td><td>£6</td><td>£2</td></tr><tr><td>Option E</td><td>£5</td><td>£0</td></tr></table> Which option do you prefer? A B C D E (circle one) What do you expect the other person to choose? A B C D E (circle one)	<table><tr><td></td><td>You win</td><td>Classmate wins</td></tr><tr><td>Option A</td><td>£1</td><td>£6</td></tr><tr><td>Option B</td><td>£2</td><td>£2</td></tr><tr><td>Option C</td><td>£4</td><td>£5</td></tr><tr><td>Option D</td><td>£5</td><td>£2</td></tr><tr><td>Option E</td><td>£4</td><td>£0</td></tr></table> Which option do you prefer? A B C D E (circle one) What do you expect the other person to choose? A B C D E (circle one)

Fig. 4. Decision vignettes designed to prime individual rationality. Option *A* maximizes altruism, *B* equality-seeking, *C* collective rationality, *D* individual rationality, and *E* competition

In each vignette, players chose from a list of five options for assigning substantial monetary payoffs to self and an unidentified co-player, and they also indicated which options they expected their co-player to choose. The five options invariably represented altruism (maximizing co-player's payoff), equality-seeking (minimizing absolute difference between own and co-player's payoff), collective rationality (maximizing joint payoff), individual rationality (maximizing own payoff), and competition (maximizing own minus co-player's payoff). Four of these are standard social value orientations (Van Lange, 1999), and collective rationality, as we interpret it, is an orientation that cannot be formulated within the standard integrative model, as we have shown above.

The choice options were mutually exclusive in the sense that each maximized one and only one of the five orientations. We randomized the sequential orders in which the vignettes were presented to the players to control for order effects, and we systematically rotated the choice options within the vignettes to control for positioning and labeling effects. Players therefore responded to versions of the vignettes shown in Figs 2 and 3 in which the choice options appeared in different orders.

2.3. Procedure

Players were tested in groups of approximately 30. They were given written instructions, which the experimenters also summarized orally, explaining that they had each been "paired with another participant in this room" who would not be identified to them but was choosing from the same vignettes as themselves, and that "after each scenario you will be asked to indicate which of the outcomes you prefer. Please answer by circling the letter corresponding to your preferred outcome."

The players were told that the verbal contents of the vignettes were merely to help them understand the payoffs and that the numbers in the vignettes represented pounds sterling for self and other, and it was explained to them that each person's payoff on any particular vignette would be the sum of the self-assigned and other-assigned amounts determined by both of their choices. For example, in "Prize draw" (Fig. 4), an individual who chose *A* (£3 to self and £7 to other) while the other individual chose *B* (£4 to self and £4 to other) would receive a total of £7 (£3 + £4), and the other individual would receive a total of £11 (£4 + £7).

The vignettes were thus framed as decomposed games (Pruitt, 1967), in which individually and collectively rational strategies could be identified especially easily, the individually rational strategy invariably being the one with the greatest self-assigned payoff, and the collectively rational strategy the one with the greatest sum of self-assigned and other-assigned payoffs.

Finally, players were told: "At the end of the experiment, one of the scenarios will be chosen at random by the computer, and both you and your partner will be paid according to the options that you both preferred for that scenario. So your choices will affect the amount of money that you will take away with you today." The monetary payoffs represented the actual payoffs of the games, and we assumed that these would determine the players' decisions.

The players then studied the vignettes and indicated their choices. At the bottom of each vignette, they were asked to circle *A*, *B*, *C*, *D*, or *E* in response to the following two questions: "Which option do you prefer?" and "What do you expect the other person to choose?"

2.4. Results

Full results from the team-reasoning and individual rationality vignettes are given in Table 1. In the team-reasoning "Fund-raising" vignette, the distribution of choices across the five options deviates significantly from chance: $\chi^2(4, N = 81) = 110.67, p < .001$, effect size $w = 1.17$ (large). A substantial majority of players (59.26%) chose the collectively rational option (*C*), and most of the rest (34.57%) chose the individually rational option associated with the unique Nash equilibrium (*D*). Ignoring five players who chose other options, the proportion who chose the collectively rational option was significantly greater than the proportion who chose the individually rational option: $\chi^2(1, N = 76) = 5.26, p = .02, w = 0.26$ (small). As predicted by theories of team reasoning, a large majority (77.08%) of the players who chose the collective option expected their co-players to choose it also.

Table 1
Experiment 1 results (percentages), for lifelike vignettes designed to prime collective rationality (Fund-raising and GM site) and individual rationality (Prize draw and Poker)

| Vignette | Options chosen | | | | |
	A	*B*	*C*	*D*	*E*
Fund-raising	0.00	4.94	59.26	34.57	1.23
GM site	2.47	11.11	49.36	35.80	1.23
Prize draw	1.23	16.05	23.46	54.32	4.94
Poker	1.23	6.17	22.22	59.26	11.11

Note. A = altruism, *B* = equality-seeking, *C* = collective rationality, *D* = individual rationality, *E* = competition.

In the team-reasoning "GM site" vignette, the percentages of players who chose *A*, *B*, *C*, *D*, and *E* deviated from chance: $\chi^2(4, N = 81) = 74.99$, $p < .001$, $w = 0.96$ (large). Once again, a majority (49.36%) chose the collectively rational option (*C*), and most of the rest (35.80%) chose the individually rational option associated with the unique Nash equilibrium (*D*). The proportion who chose the collectively rational option was larger than the proportion who chose the individually rational option, although not significantly so: $\chi^2(1, N = 69) = 1.75$, $p = .19$, $w = 0.16$ (small). Once again, a large majority (77.50%) of the players who chose the collective option expected their co-players to choose it.

Of the two vignettes designed to encourage individual rationality (Fig. 4), "Prize draw" elicited 54.32% individually rational and 23.46% collectively rational choices, and "Poker" 59.26% individually rational and 22.22% collectively rational choices. The majority preferences in these vignettes were individually rational, in line with the predictions of game theory. For "Prize Draw", preferences across the five options differed significantly, $\chi^2(4, N = 81) = 72.27$, $p < .001$, $w = 0.94$ (large), and comparing just the collectively and individually rational options, the difference remains highly significant: $\chi^2(1, N = 63) = 9.92$, $p = .002$, $w = 0.37$ (medium). Similarly for "Poker", preferences across the five options differed significantly, $\chi^2(4, N = 81) = 87.83$, $p < .001$, $w = 1.04$ (large), and preferences for the collectively and individually rational options also differed significantly: $\chi^2(1, N = 66) = 13.64$, $p < .001$, $w = 0.46$ (medium).

The results of this experiment suggest that the interpretive framing of the games had a moderately powerful effect on the outcome preferences and mode of reasoning adopted by the players, with predominantly collective rationality and team reasoning only in the vignettes designed to prime it, although each of the four games had a Pareto-dominant outcome—one that yielded higher payoffs to both players than the Nash equilibrium. However, it is impossible to judge how much influence interpretive framing had on collective rationality and team reasoning in the team-reasoning vignettes. Experiment 2 was therefore performed in order to seek evidence for team reasoning in abstract games without interpretive framing.

3. Experiment 2

3.1. Participants
The participants who served as decision makers in this experiment were the same 81 who served in Experiment 1: 36 men and 45 women aged 16 to 45 (*M* = 20.48, *SD* = 4.40). Experiment 2 followed immediately after Experiment 1, without any debriefing until both experiments were completed. As in Experiment 1, we randomized the sequential orders in which the games were presented to the players to control for order effects, and we rotated the strategies within the games to control for positioning and labeling effects. Once again,

participants were told that one of the games would be chosen randomly for cash payment, and each participant earned between £5.00 ($9.10) and £9.00 ($16.38), M = £6.54 ($11.90), SD = £1.18 ($2.15), according to their payoffs in the randomly selected game.

3.2. Materials

The players made one-off decisions in five symmetric 3 × 3 games presented abstractly, without interpretive framing. Fig. 5 shows all five game matrices. Each of these games has a unique Nash equilibrium and a distinct, collectively rational, Pareto-dominant outcome. We hypothesized that this class of games would be likely to elicit team reasoning in spite of having unique game-theoretic solutions that differed from the team-reasoning outcomes.
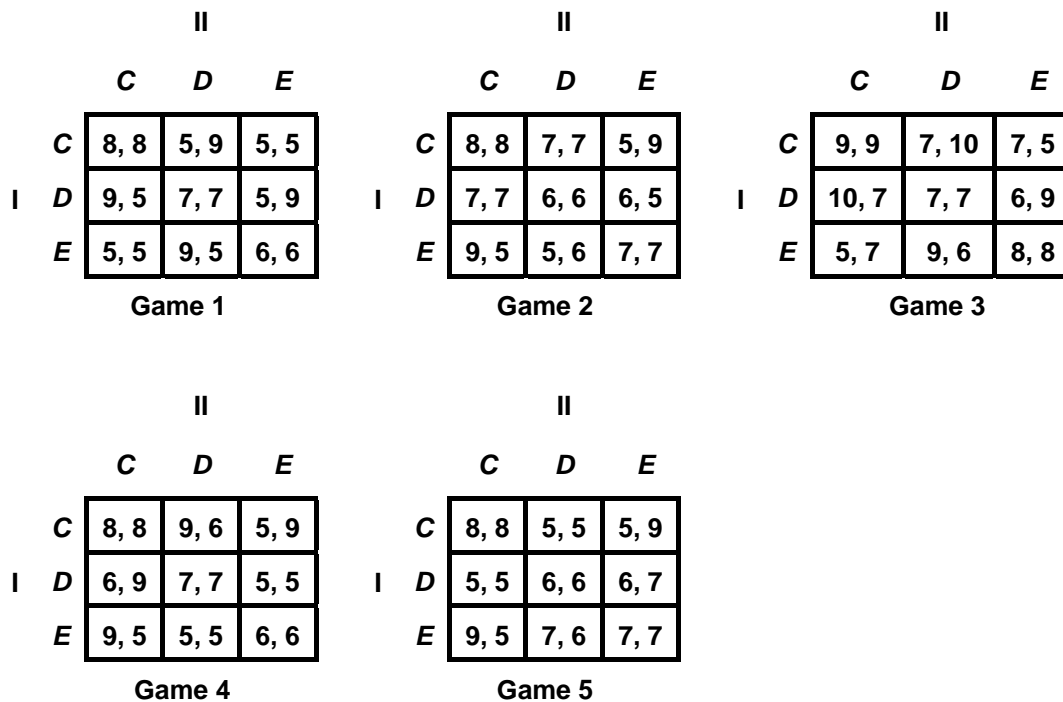
		II					II					II	
	C	*D*	*E*			*C*	*D*	*E*			*C*	*D*	*E*
C	8, 8	5, 9	5, 5		*C*	8, 8	7, 7	5, 9		*C*	9, 9	7, 10	7, 5
I *D*	9, 5	7, 7	5, 9	I	*D*	7, 7	6, 6	6, 5	I	*D*	10, 7	7, 7	6, 9
E	5, 5	9, 5	6, 6		*E*	9, 5	5, 6	7, 7		*E*	5, 7	9, 6	8, 8
Game 1					**Game 2**					**Game 3**			

		II					II		
	C	*D*	*E*			*C*	*D*	*E*
C	8, 8	9, 6	5, 9		*C*	8, 8	5, 5	5, 9
I *D*	6, 9	7, 7	5, 5	I	*D*	5, 5	6, 6	6, 7
E	9, 5	5, 5	6, 6		*E*	9, 5	7, 6	7, 7
Game 4					**Game 5**			

Fig. 5. The five games used in Experiment 2, in normal (strategic) form, with singular Nash equilibria at (*E*, *E*), collectively rational outcomes at (*C*, *C*), and payoffs in pounds sterling.

To see why the (*C*, *C*) outcome in each of the games in Fig. 5 is collectively rational, note that this outcome is Pareto optimal in the sense that no outcome yields higher payoffs to both players—in any outcome in which one player does better, the co-player does worse. A consequence of this is that the (*C*, *C*) outcome maximizes the joint payoff (sum of payoffs) of the pair of players. But (*C*, *C*) is not individually rational in any of these games, because it is not a Nash equilibrium. In Game 1, for example, *C* is not a best reply to *C*, because if Player I chooses *C*, then Player II receives a higher payoff by choosing *D* than by choosing *C*—Player II's payoff is 9 following a *D* choice and 8 following a *C* choice. For this reason, (*C*, *C*) is not a Nash equilibrium, and the *C* strategy is not a rational choice for either player, because players are not choosing best replies to each other's strategies and are therefore not maximizing their individual utilities. The only Nash equilibria in the games in Fig. 5 are at (*E*, *E*). In Game 1, for example, if Player I chooses *E*, then Player II's best reply is *E*, and conversely if Player II chooses *E*, then Player I's best reply is *E*. Each of these games has a unique Nash equilibrium at (*E*, *E*) that is the rational outcome according to orthodox game theory, but this uniquely rational solution is Pareto-dominated by the outcome at (*C*, *C*), where both players receive higher payoffs.[3]

The games were presented to the players verbally rather than in matrix form. For Game 1, for example, the description was: "You choose *C* or *D* or *E*. The other person chooses *C* or *D* or *E*. Here are the possible outcomes: You choose *C*; the other person chooses *C*. You get £8, other gets £8. You choose *C*; the other person chooses *D*. You get £5, other gets £9. . . .", and so on. The singular Nash equilibrium of every game in Fig. 5 is (*E*, *E*) and the collectively rational outcome is (*C*, *C*). Payoffs represent pounds sterling.

3.3. Procedure

The participants were presented with the five abstract games, on separate pages, preceded by the following written instructions, which were summarized orally by the experimenters:

> You are now going to make [several] decisions, from which you can earn more money. There are no scenarios with these—they are purely cash decisions. You and the other person will be presented with the identical problems. To work out the likely consequences of any decision, you will have to take into account what the other person is likely to choose. Once again, one of these problems will chosen at random by computer, and you and the other person will receive the amounts shown, in cash, depending on both your choices for that problem.

The players indicated their choices by circling *A*, *B*, or *C* on their answer sheets. For each game, they also responded to the following question: "What do you expect the other person to choose: Circle A or B or C."

3.4. Results

Results from the abstract 3×3 games are shown in Table 2. The percentages of players who chose collectively and individually rational strategies are displayed graphically in Fig. 6. In every game in which team reasoning was pitted directly against individual rationality, an absolute majority of players chose the team-reasoning strategy, and a smaller proportion chose the individually rational (Nash equilibrium) strategy. Restricting attention to the collectively rational and individually rational strategies, in Games 1, 3, and 4, these differences are significant by chi-square tests: Game 1, $\chi^2(1, N = 55) = 17.47$, $p < .001$, effect size $w = 0.56$ (large); Game 3, $\chi^2(1, N = 49) = 34.31$, $p < .001$, $w = 0.84$ (large); Game 4, $\chi^2(1, N = 76) = 53.90$, $p < .001$, $w = 0.84$ (large). These findings provide strong evidence that team reasoning can influence decision making in games of this type. In Game 2 the difference is marginally significant: $\chi^2(1, N = 78) = 2.51$, $p = .14$, $w = 0.18$ (small); and in Game 5, it is nonsignificant: $\chi^2(1, N = 81) = 0.61$, $p = .51$, $w = 0.09$.

Table 2
Experiment 2 results (percentages) for abstract 3×3 games, displayed with C = collectively rational strategy and E = individually rational strategy (Strategy D is neither collectively nor individually rational)

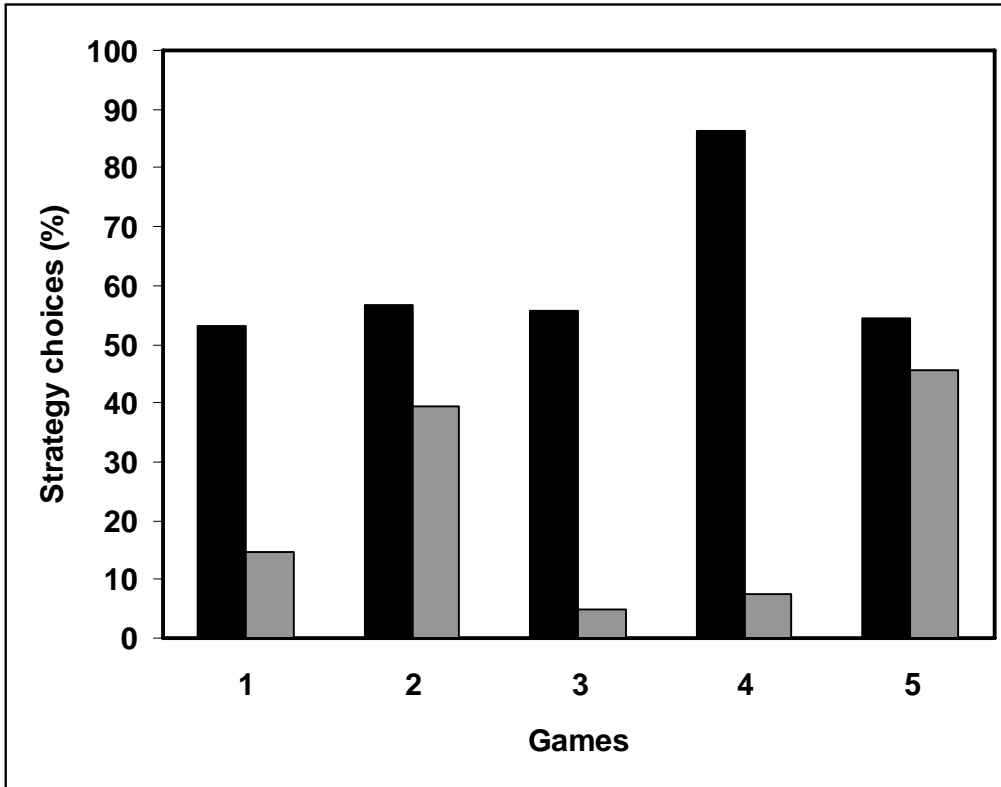| Game | Strategy chosen | | | $\chi^2(2, N = 81)$ | p |
	C	*D*	*E*		
1	53.09	32.10	14.81	17.85	< .001
2	56.79	3.70	39.51	35.63	< .001
3	55.55	39.51	4.94	32.52	< .001
4	86.42	6.17	7.41	102.74	< .001
5	54.32	0.00	45.68	41.41	< .001

Fig. 6. Collective versus individual rationality: Percentages of collectively rational (dark bars) and individually rational (light bars) strategy choices in five abstract 3 × 3 games.

Players who chose team-reasoning strategies in the abstract 3 × 3 games generally predicted that their co-players would choose them also. Expectations of team-reasoning co-player choices by team-reasoning players in Games 1–5 were 88.37%, 78.26%, 75.56%, 81.16%, and 79.55% respectively. This, and the similar finding in Experiment 1, is consistent with the theoretical prediction (Bacharach, 1999, 2006; Sugden, 1993, 1995, 2005) that players who engage in team reasoning need to be confident that their co-players will do the same.

4. Discussion

In both experiments, we presented players with games in each of which a collectively rational strategy was available in addition to an individually rational strategy yielding smaller payoffs, and in both experiments, substantial majorities of players chose the collectively rational strategies. These findings are consistent with the hypothesis that team reasoning tends to influence decision making in strategic interactions of certain types.

In Experiment 1, four symmetric 5 × 5 games were decomposed and framed as lifelike vignettes to make the collectively and individually rational strategies obvious to the players. Two of the vignettes, the team-reasoning vignettes designed to prime collective rationality, described decisions in which individuals who played their parts in the collectively rational outcome contributed to a respected public good, although the actual payoffs were in cash and were paid to individual players, who never discovered who their co-players were. Each of these games had a unique Nash equilibrium, corresponding to the individually rational options, and a disequilibrial but collectively rational outcome that Pareto-dominated it. In these two vignettes, most of the players preferred the collectively rational to the individually rational options, and in two vignettes designed to prime individual rationality, they preferred

the individually rational options. These results suggest that team reasoning can occur in games of this type, at least when interpretive priming encourages it.

In Experiment 2, we examined strategy choices in five symmetric 3 × 3 games, each with a unique Nash equilibrium once again strictly Pareto-dominated by a disequilibrial outcome. These games were presented abstractly, without any interpretive framing, but they were simpler than the games used in Experiment 1, and we hypothesized that the structural property that they shared in common would be sufficient to cause players to choose the collectively rational strategies. In all five games, a majority of players did indeed choose the Pareto-dominant, collectively rational strategies in preference to the individually rational strategies mandated by Nash equilibria. These results show clearly that team reasoning predicted strategy choices more powerfully than game theory.

The collective rationality effect was large and significant in Games 1, 3, and 4, and relatively smaller and nonsignificant in Games 2 and 5, and these differences are not difficult to understand with the benefit of hindsight. In Games 1 and 4, the effect was probably strengthened by the fact that the collective payoff was greater by a margin of £4 in the collectively rational outcome (*C*, *C*) than in the Nash equilibrium (*E*, *E*), whereas in the other games it was greater by a margin of only £2. In Game 3, the effect may have been strengthened by the risk-dominance of the collectively rational outcome over the Nash equilibrium—only the individually rational *C* strategy carried the risk of the lowest possible payoff (£5). In Games 2 and 5, on the other hand, Nash equilibria risk-dominated collectively rational outcomes, and that may have inhibited the choice of collectively rational strategies in those games. Previous research (Cooper, DeJong, Forsythe, & Ross, 1990; Van Huyck, Battalio, & Beil, 1990) has shown that risk dominance has some influence on strategy choices in experimental coordination games with multiple Nash equilibria, and our findings extend this to games with unique Nash equilibria.

Players who chose collectively rational strategies generally predicted that their co-players would choose them also. In the lifelike vignettes of Experiment 1, almost 80 per cent of the players who chose collective options expected their co-players to choose them also, and in the abstract 3 × 3 games of Experiment 2, the corresponding expectations were over 75 per cent in all games. These findings are consistent with the theoretical assumption (Bacharach, 1999, 2006; Sugden, 1993, 1995, 2005) that team reasoning tends to be associated with confidence that co-players will do the same.

We doubt that there was any significant carry-over of collective rationality from Experiment 1 to Experiment 2, partly because the tasks were so very different from the participants' point of view, and also because two of the four vignettes in Experiment 1 were specifically (and successfully) designed to encourage individualistic rationality. However, irrespective of any carry-over effects, the departures from Nash equilibrium in Experiment 2 are particularly striking, because they do not rely on any interpretive priming, and they are sharply at odds with orthodox game theory.

In all of the games that we studied, pairs of players who chose team-reasoning strategies received higher payoffs than pairs who chose Nash equilibria, but this does not imply that they were motivated by individual payoff maximization, because collectively rational choices were out of equilibrium in all of our lifelike and abstract games. This means that, in all cases, a player motivated by strictly individualistic payoff maximization could have obtained a higher payoff by choosing differently. In Fig. 5, for example, pairs of players who both chose *C* were not making best replies to each others' strategies. To maximize individual playoffs against a player who chooses *C*, a player should choose *D* in Game 1, *E* in Game 2, *D* in Game 3, *E* in Game 4, and *E* in Game 5. Bearing in mind the finding that the vast majority of players who chose *C* expected their co-players to choose *C*, these players, at least, must have deliberately rejected individual payoff maximization in favor of something else. That

"something else" appears, in the light of our findings, to have been collective payoff maximization, in other words, team reasoning.

Although social psychologists have up to now largely ignored team reasoning, there is a considerable body of psychological research that is potentially relevant to it. Social psychology's mysterious blind spot for game theory is exemplified by the omission of any direct mention of team reasoning from Brewer and Chen's (2007) otherwise comprehensive recent review of the conceptual issues underlying individualism and collectivism. Game theory and social psychology, although they are evidently not on speaking terms at present, clearly have shared interests in issues related to team reasoning. For example, research based on public goods games and other types of social dilemmas has shown that mutually beneficial cooperation and "we-thinking" can be dramatically enhanced by raising players' sense of group identity (Brewer & Kramer, 1986; Dawes, van de Kragt, & Orbell, 1988); and De Cremer and Van Vugt (1999) have reported evidence from three experiments suggesting that such social identity effects may be due not to any increase in interpersonal trust but to an increase in the value of collective goods. Findings such as these may help to explain how players come to switch from individual to collective payoff maximization and team reasoning.

Each of our games had a single Nash equilibrium and a collectively rational outcome that was out of equilibrium and was therefore strictly irrational according to orthodox (individualistic) game theory. The same applies to social dilemmas, including the well-known Prisoner's Dilemma game (Fig. 2, left), in which the unique Nash equilibrium mandates joint defection, but both players are better off if both cooperate. Rampant cooperation typically occurs in experimental Prisoner's Dilemma games (Colman 1995, chap. 7; Sally, 1992) and in multi-player social dilemmas, which also have unique Nash equilibria and distinct outcomes that are collectively rational (Colman 1995, chap. 9; Dawes, van de Kragt, & Orbell, 1988; Ledyard, 1995), and team reasoning provides a plausible explanation for these findings. Our findings suggest that team reasoning has implications that go far beyond social dilemmas and coordination games. Coordination games are games with two (or more) Nash equilibria in which the problem confronting the payers is one of coordinating their strategy choices on the same equilibrium. In these games, orthodox game theory is indeterminate, regarding any equilibrium as a rational outcome and providing no criterion for choosing between them. In social dilemmas, and in the games used in our experiments, team reasoning inclines players to choose outcomes that are not Nash equilibria and are therefore not regarded as rational solutions in orthodox game theory.

The results of our experiments show that collective rationality motivates decision making in strategic interactions with certain specifiable structural properties, and we hope that these findings, close as they are to areas of psychological research, will help to break the ice in the standoff between game theory and its close neighbor, social psychology. A proper understanding of social behavior needs to take account of collective rationality and team reasoning, and team reasoning needs to be incorporated into any game theory that purports to explain naturally occurring interactive decisions, although such a radical reorientation would launch game theory into largely uncharted waters. This may be necessary, because everyday experience suggests that it is not uncommon for people to set aside their individual self-interests and to make decisions in what they judge to be best interests of their families, or the companies that employ them, or their departments or universities, or the religious, ethnic, or national groups with which they identify themselves, sometimes fervently, and a comprehensive understanding of strategic interaction needs to recognize and understand this mode of decision making.

Footnotes

[1] This intuitive simplification suffices for the present discussion, but Harsanyi and Selten's (1988) formal definition is more complicated. If (L, L) and (R, R) are both Nash equilibria, and we use the symbol a to label the payoff for choosing L against a co-player's choice of L, b for the payoff for L against R, c for the payoff for R against L, and d for the payoff for R against R, then (L, L) risk-dominates (R, R) iff $(a - c)^2 > (d - b)^2$, and (R, R) risk-dominates (L, L) if the reverse inequality holds.

[2] The only other solutions that do not involve changing the rules of the game, as far as we are aware, are individual team member rationality (Janssen, 2001), which is very close to team reasoning, and Stackelberg reasoning (Colman & Bacharach, 1997; Colman & Stirk, 1998). Stackelberg reasoning assumes that players use *evidential reasoning*, maximizing *conditional* expected utility rather than pure expected utility as in classical decision theory.

[3] An anonymous referee commented that although the E strategies form Nash equilibria, they seem "woefully lacking in common sense". We interpret this as empirical evidence of collective rationality and team reasoning on the part of the referee, additional to our experimental data.

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