Regret, blame, and division of responsibility in games*

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Abstract

Responsibility is central in the experience of regret, but at the same time divided among players in games. This paper studies how (anticipated) regret and the division of responsibility jointly shape behavior in games. I propose a model where player i's regret (for not playing a best-response) is mitigated through blame put on player j for not playing—when available—a Pareto-improving (compared to j's actual action) best-response to player i's action. I show that this model brings theoretical predictions closer to existing experimental results. Last, I provide direct experimental evidence that (i) blame mitigates regret and (ii) feelings of regret and blame elicited in certain games predict behavior in vastly different games, consistent with theoretical predictions.

Keywords: regret theory, regret intensity, blame, responsibility, division of responsibility, alignment of interests, conflict of interest

JEL classification codes: C72, C92, D81, D90, D91

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1 Introduction

Regret theory has been a prominent model in decision theory since its formulation by Loomes and Sugden (1982) and Bell (1982). When introduced in games, regret has so far been analyzed as if in a single-agent context with the other players' actions treated as the state of the world. I call this the *single-agent regret* approach. This approach has helped explain behavior in auctions (Engelbrecht-Wiggans, 1989; Engelbrecht-Wiggans and Katok, 2007, 2008, 2009; Greenleaf, 2004; Filiz-Ozbay and Ozbay, 2007, 2010; Ratan and Wen, 2016), the ultimatum game (Zeelenberg and Beattie, 1997), price competition (Renou and Schlag, 2010), the traveler's dilemma, centipede game, and asymmetric matching pennies (Halpern and Pass, 2012). I show that, if appropriately adjusted to strategic environments, regret can provide additional novel insights and bring theoretical predictions closer to experimental results.

The starting point of this paper is that responsibility is (i) central in the experience of regret, but at the same time (ii) divided among players in games. A person's regret stems from the realization that if she had acted differently, things would have gone better. However, people are often more than willing to blame others and deny responsibility. For example, in order to avoid responsibility, they delegate selfish or unethical decisions (Hamman et al., 2010; Bartling and Fischbacher, 2011; Oexl and Grossman, 2013). Also, they may blame others even if they are not responsible (Gurdal et al., 2013). Strategic interactions offer ample room for diffusion of responsibility and blaming others. Therefore, it is natural to study how regret and the division of responsibility jointly shape behavior in games. Although often negatively valenced, we will see that the division of responsibility may actually induce people to take socially desirable actions by mitigating those actions' potential to generate regret.

I propose the *strategic regret* approach, which incorporates important aspects of how individuals experience regret in multi-agent environments, where the other players' actions are not an impersonal, random state of the world but rather choices of real agents.[1] The strategic regret approach views (anticipated) regret as mediated by the division of responsibility (among players) for the outcome of a game.[2] In this perspective, blame put

[1]Indeed, in Lagnado and Channon's (2008) experiments, participants rated intentional actions as more causal and more blameworthy than physical events.

[2]Although for brevity throughout the paper I refer to regret as realized regret, *anticipated* regret is what matters. There is extensive evidence that people do in fact anticipate regret in a variety of

on another player mitigates one's own regret and self-blame.

The intuition is as follows. In a single-agent context, an outcome is *exclusively* the result of the agent's decision and "luck" (the initially unknown state of the world). Feelings of regret can then arise given the power the decision-maker has over the outcome. On the other hand, in a strategic context, the outcome is the result of the interaction of *multiple* agents.[3] In such a setting then, an agent may not experience feelings of regret in the same way or degree, as she may feel less responsible for the combined result of all players' actions.

I model this in the following way. In two-player games, when player 1 (she) has not best-responded to player 2's (he) action, the former tends to experience regret. However, in cases where player 2 has had available (but did not play) a *best-response* (to player 1's chosen action) which if chosen would have also benefited player 1, then player 1's regret is mitigated through blame put on player 2 (for not playing that best-response). While I acknowledge that blame is a complex phenomenon that cannot be fully captured by this modeling assumption, the model still manages to deliver interesting new insights.

I model strategic regret in this way for three main reasons. First, it is simple. Second, it is informed by the decision justification (Connolly and Zeelenberg, 2002) and regret regulation (Zeelenberg and Pieters, 2007) theories, which suggest that regret intensity is affected by justifications and feelings of self-blame.[4] It is then natural to expect the intensity of self-blame to decrease when someone else is to blame.[5] Last, this assumption on strategic regret is particularly weak in the following sense. Even when performing counterfactual thinking, player 1 accepts that player 2 is completely self-interested; she does not expect him to sacrifice *any* part of his payoff to benefit her. Thus, when compared to predictions under standard assumptions on preferences or under single-agent regret, theoretical results can be thought of as a conservative estimate of the effect that strategic regret can have.

The findings follow. First, I show that strategic regret gives rise to novel theoretical

settings (e.g., see Zeelenberg et al., 1996; Zeelenberg and Beattie, 1997; Zeelenberg, 1999; Zeelenberg and Pieters, 2004; Greenleaf, 2004; Filiz-Ozbay and Ozbay, 2007; Sandberg and Conner, 2008; van de Ven and Zeelenberg, 2011; Koch, 2014; Brewer et al., 2016; Imas et al., 2023).

[3]"Luck" can also be a factor but I restrict attention to games without chance moves.

[4]There has been substantive evidence in favor of these theories showing that regret intensity increases with the feeling of responsibility for having made a wrong decision (e.g., Zeelenberg et al., 1998; Inman and Zeelenberg, 2002; Pieters and Zeelenberg, 2005).

[5]Relatedly, El Zein et al. (2019) argue that regret mitigation due to diffusion of responsibility is a motive for people to make collective decisions.

predictions, which (i) differ from predictions derived under standard assumptions on preferences or single-agent regret and (ii) are closer to existing experimental evidence. The differences are most pronounced when the effect of the strategic setting on the experience of regret is asymmetric for different outcomes of a game. For instance, consider the traveler's dilemma introduced by Basu (1994) and suppose that player 1 selects a significantly lower number than player 2.[6] The regret of player 2 (for not undercutting player 1) is mitigated because what happened is partly player 1's fault. She could have best-responded by undercutting player 2's number by exactly one, causing a Pareto improvement. On the other hand, player 1 regrets not undercutting player 2 by exactly one but has nothing to blame player 2 for. Thus, blame tends to make players choose higher numbers.

Second, I provide direct experimental evidence in favor of strategic regret, as well as the mechanism behind it suggesting that subdued regret is accompanied by blame put on the other player. Interestingly, subjects' anticipated regret and blame elicited in vastly different games have predictive power over their choices in the traveler's dilemma and the stag hunt game (with hare being a safe option). Consistent with predictions of the theory, subjects who in certain games tend to more strongly blame the other player and regret less themselves (i) choose higher numbers in the traveler's dilemma and (ii) are more likely to play stag in the stag hunt game than those less prone to blame. Also, strategic regret explains Bolton et al.'s (2016) finding that people are more willing to play stag in a stag hunt game when they play against another person compared to when the other player's action is randomly chosen by the computer.

Last, I find evidence that there are limits to blame. The simple notion of blame introduced would predict that higher tendency to blame is associated with lower volunteering rates in the volunteer's dilemma, since a player in that game can blame the other players and regret less herself (only) when no player has volunteered.[7] Thus, the tendency to blame should act as a disincentive for volunteering. However, I find that the tendency to blame does not predict volunteering rates. This can be naturally explained as follows: a player i does *not* blame another player j for not taking an action that i could have

[6] In the traveler's dilemma, two players simultaneously choose an integer (i.e., amount of money) from a certain (exogenous) range. Then, each player receives the lowest of the two amounts and, if the two chosen numbers differ, the player that has announced the lower (resp. higher) number of the two receives a bonus (resp. penalty). The bonus/penalty is larger than 1. The game is studied in detail in section 4.1.

[7] Notice that volunteering is a Pareto-improving (compared to not volunteering) best-response to others not volunteering.

taken herself but did not either.[8] This explanation is consistent with Çelen et al.'s (2017) finding that in public goods games, a subject i tends to blame (i.e., punish) subject j when j's contribution is lower than i's (and not when lower than the mean contribution).

After this introduction, section 2 reviews related literature. Section 3 presents the model for two-player games. Section 4 studies the theoretical predictions in the traveler's dilemma, stag hunt game, and Kreps game under (i) standard assumption on preferences, (ii) single-agent regret, and (iii) strategic regret. Section 5 extends the model to n-player games and studies the volunteer's dilemma. Section 6 presents the experimental design and results, as well as additional (already existing) experimental evidence in favor of strategic regret. Section 7 discusses the results and deals with the robustness and generalizability of the theoretical results of sections 3, 4, and 5; these topics are studied in more detail in section A of the Appendix. Section 8 concludes. The proofs of all theoretical results are gathered in Appendix B. Appendix C presents supplementary analyses of the experimental data. Appendices D and E document the experimental procedures.

2 Related literature

A number of papers have considered regret in games. Renou and Schlag (2010) and Yang and Pu (2012) study minimax regret equilibria, while Halpern and Pass (2012) develop an alternative regret-based solution concept, iterated regret minimization. García-Pola (2020) combines regret minimization with level-k reasoning. Other papers have incorporated regret to study behavior in specific strategic settings. Linhart and Radner (1989), Engelbrecht-Wiggans (1989), Engelbrecht-Wiggans and Katok (2007, 2008, 2009), Greenleaf (2004), Filiz-Ozbay and Ozbay (2007), and Ratan and Wen (2016) incorporate regret in bilateral bargaining and auctions. Zeelenberg and Beattie (1997) find evidence of regret aversion in the ultimatum game.[9] Guo and Shmaya (2023) study a mechanism design problem where the principal minimizes her worst-case regret.

Accounting for how blame and the division of responsibility affect behavior in games by mitigating regret is the main contribution of this paper, as neither theoretical nor experimental work has previously considered this. However, there are a few more differences

[8] Section A of the Appendix formalizes this idea. It presents a generalization of strategic regret that accounts for the volunteer's dilemma findings.

[9] Namely, proposers who expected to receive feedback on the responder's minimum acceptable offer made lower offers compared to proposers who did not anticipate such feedback.

from existing theoretical work. For example, in Renou and Schlag (2010), Halpern and Pass (2012), García-Pola (2020) players' payoffs only depend on regret, while in my model players care about both baseline (e.g., material) payoffs and regret in the original spirit of Loomes and Sugden (1982). Also, Halpern and Pass' (2012) solution concept does not involve common knowledge or common belief of rationality; it rather only assumes players to know that the other players are regret minimizers. Renou and Schlag (2010) allow for inconsistent beliefs, while García-Pola (2020) studies regret under level-k reasoning. On the other hand, I theoretically study standard theoretical prediction concepts, namely, (i) a player's best-response to exogenous beliefs, (ii) rationalizability under baseline or modified payoffs, and (iii) equilibrium behavior with common knowledge of rationality and belief consistency (i.e., a Nash equilibrium). By doing so, I can juxtapose the theoretical predictions of standard solution concepts under strategic regret against predictions under standard assumptions on the payoffs or under single-agent regret. This way we will see that strategic regret *alone* (i.e., without use of alternative solution concepts) brings theoretical predictions closer to experimental evidence, which cannot be explained by single-agent regret.

My model is closer to Battigalli and Dufwenberg (2009), Battigalli et al. (2019), and Battigalli et al. (2022), who—while following the single-agent regret approach—also look at equilibrium outcomes with players caring both about baseline payoffs and regret. Particularly, they study regret in extensive form psychological games (allowing for chance moves).[10] This modeling approach is necessitated by the fact that, in an extensive form game, a player's strategy is usually not observable (by the other players) after the game has finished. Thus, the authors leverage the psychological games framework to model each player's ex-post beliefs over the other players' strategies; these beliefs are central in the player's counterfactual thinking, which determines their regret. Here I restrict attention to static games without chance moves, where strategies are ex-post observable. This removes the need to model ex-post beliefs and allows us to instead focus our attention on how blame and the division of responsibility affect regret and, in turn, behavior. Indeed, I show that equilibrium theoretical predictions in the case of single-agent regret replicate those of Battigalli et al. (2022) for static games without chance moves.[11]

[10]Psychological game theory was introduced by Geanakoplos et al. (1989) and further developed by Battigalli and Dufwenberg (2009).

[11]Yet, even in the case of single-agent regret, in section A of the Appendix, I derive additional theoretical

3 A model of two-player games with regret and blame

3.1 The environment

A (static) game is characterized by a tuple $G \coloneqq \langle N, (S_i)_{i\in N}, (u_i)_{i\in N}, (m_i)_{i\in N}\rangle$. $N \equiv \{1,\dots,n\}$ is a finite set of n players; in this section, $n = 2$. S_i is player i's finite action space and $S \coloneqq \times_{i\in N} S_i$ is the action profile space. $s \in S$ denotes an action profile and $s_{-i} \in S_{-i} \coloneqq \times_{j\in N\setminus\{i\}} S_j$ an action profile of all players except i. $u_i : S \to \mathbb{R}$ is player i's Bernoulli *baseline* payoff function, which does not account for regret.[12] This is analogous to the choiceless utility function of Loomes and Sugden (1982). $m_i : S \to \mathbb{R}$ is player i's Bernoulli *modified* utility function, which accounts for regret and is described below.

Denote a mixed action of player i by σ_i and the space of player i's mixed actions by $\Delta(S_i)$. $\sigma_i(s_i)$ is the probability with which i plays action s_i. The baseline (resp. modified) payoff of player i from a mixed action profile $\sigma \in \Delta \coloneqq \times_{i\in I}\Delta(S_i)$ is given by $u_i(\sigma_i,\sigma_{-i}) \coloneqq \sum_{s\in S} u_i(s) \prod_{j\in N} \sigma_j(s_j)$ (resp. $m_i(\sigma_i,\sigma_{-i}) \coloneqq \sum_{s\in S} m_i(s) \prod_{j\in N} \sigma_j(s_j)$).[13]

Modified payoffs. To describe the modified payoffs, it remains to define the *blame payoff* $u_i^b(s_i,s_j)$. This is the payoff that player i could have received and blames player j for not actually receiving.

Definition 1. The blame payoff for player i, $u_i^b(s_i,s_j)$, given an action profile (s_i,s_j) is the maximum baseline payoff of player i that can be achieved by changing s_j subject to the constraint that j's baseline payoff is maximized given s_i, provided that this maximum baseline payoff of player i is higher than her payoff when (s_i,s_j) is played;[14] otherwise $u_i^b(s_i,s_j)$ is equal to her payoff under (s_i,s_j). That is, $u_i^b(s_i,s_j) \coloneqq \max\left\{u_i^{ba}(s_i), u_i(s_i,s_j)\right\}$, where $u_i^{ba}(s_i) \coloneqq \max_{s_j'\in PBR_j(s_i)} u_i(s_i,s_j')$, where $PBR_j(s_i) \coloneqq \arg\max_{s_j\in S_j} u_j(s_j,\sigma_{-j})$ is player j's pure best-response correspondence (in baseline payoff terms).

results (not covered by Battigalli et al. (2022)) under more general assumptions on the functional form of regret, including results on rationalizability.

[12] In principle, payoffs given by u_i need not satisfy any standard assumptions (e.g., players being self-interested and solely interested in monetary payoffs); strategic regret considerations can be applied in addition to other behavioral phenomena that u_i accounts for. However, in the applications considered in this paper, baseline payoffs will indeed be assumed equal to monetary payoffs (with risk aversion discussed where appropriate).

[13] Abusing notation I will write both pure and mixed actions inside u_i and m_i. Also, this is an expected modified utility formulation of regret as in Loomes and Sugden (1982).

[14] This means that when player j has multiple best-responses to s_i, in the counterfactual that i considers in assigning blame to j, the latter chooses the best-response that is most beneficial to i.

$u_i^{ba}(s_i) > u_i(s_i,s_j)$ means that player j could have chosen an action s_j' that would maximize her own baseline payoff given the action s_i of player i and at the same time increase player i's baseline payoff. I postulate that in this case player i assigns part of the blame for the outcome of the game to the opponent, which mitigates the intensity of her own regret. Namely, the modified payoff is given by

$$m_i(s_i,s_j) \coloneqq u_i(s_i,s_j) - r_i\left(u_i(s_i,s_j),u_i^{br}(s_j),u_i^{b}(s_i,s_j)\right) \tag{1}$$

where r_i measures the regret of player i through the realized (baseline) payoff $u_i(s_i,s_j)$, the payoff she would achieve by best-responding, $u_i^{br}(s_j) \coloneqq \max_{s_i'\in S_i} u_i(s_i',s_j)$, and the blame payoff, $u_i^b(s_i,s_j)$.[15] Unless otherwise stated, regret is given by

$$r_i\left(u_i,u_i^{br},u_i^b\right) \coloneqq \alpha_i \max\left\{u_i^{br} - \left[\beta_i u_i^b + (1-\beta_i)u_i\right],0\right\}, \tag{2}$$

where $\alpha_i \geq 0$ measures the intensity with which player i experiences regret.[16] $\beta_i \in [0,1]$ measures the degree to which, when possible, player i assigns part of the blame to player $j \neq i$ and player i's own regret is mitigated. $\beta_i = 0$ corresponds to single-agent regret, while $\beta_i > 0$ to strategic regret. For $\beta_i = 0$, the regret function is as in Renou and Schlag (2010), Halpern and Pass (2012), García-Pola (2020), and Battigalli et al. (2022).[17] Particularly, for $\beta_i = 0$, the modified payoffs are also as defined in Battigalli et al. (2022) (for the case of static games without chance moves), where players care about both baseline payoffs and regret.

Discussion of the strategic regret assumption. Strategic regret is formulated under weak assumptions, since player i's regret is mitigated only if some of the opponent's *best-responses* would have been beneficial to player i as well. Even when performing counterfactual thinking player i accepts that player j is completely self-interested. Under alternative formulations player i could put blame on player j simply due to the availability of an action—not necessarily a best-response—to j that would have led to a Pareto

[15]Notice that this is an expected utility formulation of regret and blame. Particularly, even when players deliberately randomize, a player regrets and blames the other player with respect to their ultimately chosen pure actions. This formulation of regret is conceptually different from the one in Heydari (2023).

[16]Section A in the Appendix presents theoretical results under more general assumptions on r_i.

[17]Nonetheless, in the first three papers players only care about regret, which, loosely put, corresponds to $\alpha_i = \infty$.

improvement.

One could however argue that in some cases player 1 may not assign blame to player 2 (when he has had available a Pareto-improving best-response), as he may only unintentionally have not best-responded. Yet, regret is also generated by a player's own unintentional non-best-response; it is then natural to assume that a player attributes blame to others or oneself using common standards. Also, explicit attribution of blame is not necessary, as blame can merely be a justification that mitigates player 1's self-blame. Last, there is evidence that people blame other for unintentional behavior (Knobe and Burra, 2006) or even for outcomes that they are not responsible for (Gurdal et al., 2013).

3.2 Theoretical prediction concepts

We will study three different types of theoretical predictions: (i) a player's best-response to exogenous beliefs, (ii) rationalizability, and (iii) Nash equilibrium. In terms of equilibrium behavior, the following types of equilibria of a game G will be studied.

Definition 2. A Nash equilibrium (NE) with baseline payoffs of game G is an action profile $\sigma^* \in \Delta$ such that $\sigma_i^* \in \arg\max_{\sigma_i \in \Delta(S_i)} u_i(\sigma_i, \sigma_{-i})$ for every $i \in N$. If the cardinality $|\text{supp}(\sigma_i)| = 1$ for every player $i \in N$, then it is called a pure Nash equilibrium (PNE).

Definition 3. A regret equilibrium (RE) of game G is a Nash equilibrium with modified payoffs, that is, an action profile $\sigma^* \in \Delta$ such that $\sigma_i^* \in \arg\max_{\sigma_i \in \Delta(S_i)} m_i(\sigma_i, \sigma_{-i})$ for every player $i \in N$. If the cardinality $|\text{supp}(\sigma_i^*)| = 1$ for every $i \in N$, then it is called a pure regret equilibrium (PRE).

With attention restricted to static games without chance moves, the RE concept is the same as the one considered in Battigalli et al. (2022). I will call a NE with baseline payoffs simply a NE. Denote by $NE(G)$ and $RE(G)$ the sets of action profiles satisfying definitions 2 and 3 in a game G, respectively. The corresponding subsets of pure equilibria are $PNE(G)$ and $PRE(G)$, which Proposition 1 shows to coincide.

Proposition 1. For any game G, the set of pure NE and the set of pure RE coincide, $PNE(G) = PRE(G)$.

Thus, regret may alter or augment the set of NE by changing the set of mixed—but not pure—equilibria. This is because given belief consistency, strategic uncertainty vanishes in pure equilibria. In more detail, notice that by pure best-responding (in baseline payoff terms) a player both maximizes her baseline payoff and has no regret. Thus, each player pure best-responding (in baseline payoff terms) is a PRE. Conversely, a pure action profile not being a PNE means that a player can deviate (to a best-response) to increase her baseline payoff. But deviating to a best-response also induces no regret. Thus, the deviation also increases her modified payoff. Therefore, a pure action profile that is not a PNE is not a PRE either.

But then, can regret alter the set of mixed equilibria, and, if so, when? Proposition 2 states that under single-agent regret, it cannot; in that case, not only the pure but also the mixed NE and RE sets coincide.[18] On the other hand, with strategic regret, the mixed NE and RE can differ.

Proposition 2. The following statements hold:

(i) If $\beta_1 = \beta_2 = 0$, then $NE(G) = RE(G)$ for any game G.

(ii) However, there exist $(\beta_1,\beta_2) \neq (0,0)$ and game G such that $NE(G) \neq RE(G)$.

In fact, it is easy to see that under single-agent regret, best-response correspondences are the same as under baseline payoffs.[19] Thus, single-agent regret does not alter any theoretical predictions. As we will see in section 4, this is however not true for strategic regret.

4 A comparison of theoretical predicitons: standard assumptions on preferences versus single-agent regret versus strategic regret

Proposition 2 has shown that single-agent regret does not alter the equilibrium set derived under standard assumptions on preferences. On the other hand, strategic regret *does* change the (mixed) equilibria of some games. However, this change could in principal be in the "wrong" direction. Therefore, this section studies whether strategic regret alters

[18]This is actually true for n-player games (studied in section 5 and Appendix A), not only two-player games. Part (i) of the proposition replicates the result of Battigalli et al. (2022) for static games without chance moves.

[19]To see this, notice that with single-agent regret, player i's modified payoff becomes $m_i(s_i,s_j) = (1+\alpha_i)u_i(s_i,s_j) - \alpha_i u_i^{br}(s_j)$, and thus $\arg\max_{s_i} m_i(s_i,s_j) = \arg\max_{s_i} u_i(s_i,s_j)$, since $u_i^{br}(s_j)$ is independent of s_i.

equilibrium predictions of specific games in a way that brings them closer to experimental results. The games studied in this and the following section are the games that participants played in the experiment of section 6.

We will first study the traveler's dilemma. Existing experimental results on that game are in stark contrast to theoretical predictions under standard assumptions on preferences or under single-agent regret. We will see that indeed strategic regret brings equilibrium predictions closer to observed behavior. Similarly, we will discover that strategic regret bridges the gap between experimental findings and equilibrium predictions in the Kreps game.[20]

We conclude that strategic regret can help reconcile theoretical results with aggregate observed behavior. But can it offer insights into subject-level behavior? To answer this question, we will also derive predictions on how a player's attitudes towards regret and blame shape their behavior (i.e., best-response correspondence) in the (i) traveler's dilemma, (ii) stag hunt game, and (iii) volunteer's dilemma.[21] We will see that theory predicts that players who tend to blame more (and thus regret less) (i) choose higher numbers in the traveler's dilemma, (ii) are more willing to play stag in the stag hunt game (with hare being a safe option), and (iii) are less willing to volunteer in the volunteer's dilemma. In the experiment of section 6, participants play one-shot games, so non-equilibrium predictions are particularly relevant for the development of our hypotheses.[22]

All three games exhibit substantial heterogeneity in terms of participant behavior in existing experiments, which makes a model that explains subject-level behavior most useful. At the same time, these games cover a range of strategic environments: (i) dominance-solvable—at least under standard assumptions on preferences—games, (ii) coordination games, and (iii) public good provision. Last, a stag hunt game with a safe option (i.e., a stag hunt game where if a player chooses hare, then she receives a payoff that is independent of the other player's action) is equivalent to a two-player volunteer's dilemma with the following crucial difference: *two* volunteers (i.e., players who choose stag)—instead of one—are needed for the benefits of volunteering (i.e., playing stag) to

[20]It also provides intuitive comparative statics with respect to changes in the baseline payoffs in that game.

[21]The volunteer's dilemma is studied in section 5, after the model is extended to n-person games.

[22]Participants played multiple rounds of each game (with varying monetary payoffs across rounds) but were informed of their opponents' actions in the game only after they had finished playing all rounds of that game. Also, there were no practice rounds.

materialize. This connection between the two games is exploited in section 6.2.2 to help us understand the limits of blame.

4.1 The traveler's dilemma

Consider the traveler's dilemma introduced by Basu (1994). Two players simultaneously choose integers (i.e., amounts of money) in $\{11,12,\ldots,20\}$. Then each receives the lowest of the two announced amounts. On top of this, if the two announced numbers are different, the amount received by the player that has announced the lower (resp. higher) number is increased (resp. decreased) by a bonus (resp. penalty) $b > 1$.

Let baseline payoffs equal monetary amounts. The unique rationalizable outcome under baseline payoffs (and thus unique NE) is both players choosing 11. Under single-agent regret, this remains not only the unique RE (as implied by Proposition 2), but also the unique rationalizable outcome.

Claim 1. Consider the traveler's dilemma with single-agent regret, $\beta_1 = \beta_2 = 0$. The unique RE and unique rationalizable outcome under modified payoffs is (11,11).

However, experimental results show that players in fact choose higher amounts, which decrease with b (e.g., Capra et al., 1999; Goeree and Holt, 2001).[23] Table 1 presents the number of RE (including the unique NE) for different values of b and regret parameters.[24] As shown already, the only single–agent RE is (11,11). On the other hand, with strategic regret ($\beta_1 = \beta_2 > 0$) apart from the PNE (which by Proposition 1 is also the unique PRE) there are mixed RE where players choose higher amounts. Particularly, given α and β there is a threshold such that if the bonus/penalty parameter b is above that threshold, only the PNE survives. The threshold is relaxed as α and/or β increase. Strategic regret thus brings theoretical predictions closer to experimental results, which single-agent regret does not.

Similarly, Claim 2 shows that outside equilibrium analysis, a player i's best-response (in terms of modified payoff) to some fixed beliefs increases with the degree β_i to which the player tends to blame the other player. This is because the only case where i blames player j (and thus experiences reduced regret) is when j chooses a number that is lower than i's by more than 1. Thus, blame tends to make players choose higher numbers.

[23]The players' sophistication seems inadequate in explaining these results, as for example even game theory experts also choose high amounts (Becker et al., 2005).

[24]The *lrs* algorithm (Avis et al., 2010) is used for equilibrium computation. All RE are symmetric.

Table 1: Number of RE in the traveler's dilemma for various values of b and regret parameters

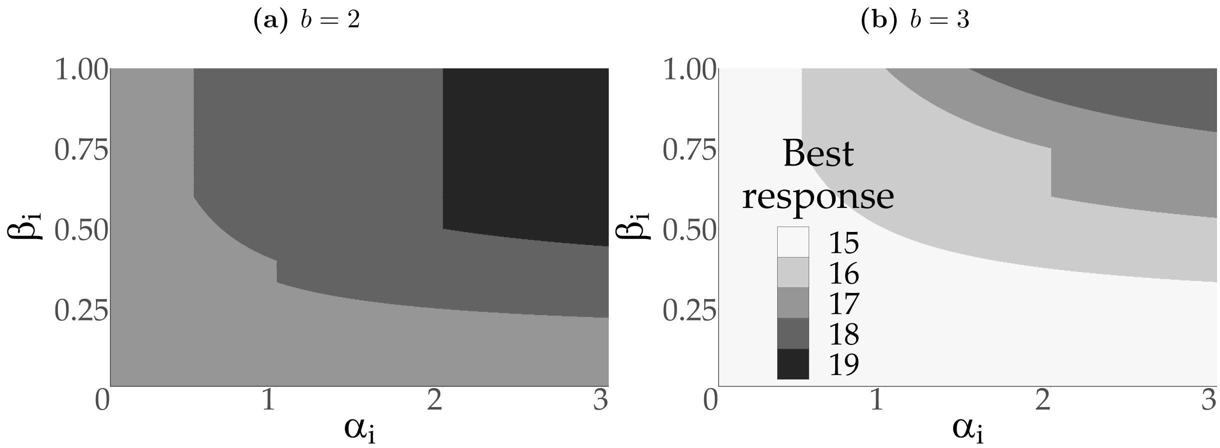
	α	β	b 1.5	2	2.5	3	3.5	4	4.5	5
# of RE	1	0.5	73	67	51	1	1	1	1	1
	0.5	0.5	374	121	1	1	1	1	1	1
	1	1	138	78	93	31	1	1	1	1
	0.5	1	441	109	1	1	1	1	1	1
	1	0	1	1	1	1	1	1	1	1
	0.5	0	1	1	1	1	1	1	1	1

Notes: in every row $\alpha_1 = \alpha_2 = \alpha$ and $\beta_1 = \beta_2 = \beta$.

Claim 2. Let regret be given by $r_i\left(u_i,u_i^{br},u_i^b\right) := \widetilde{r}_i\left(u_i^{br} - \left[\beta_i u_i^b + (1-\beta_i)u_i\right]\right)$ for some $\widetilde{r}_i : \mathbb{R}_+ \to \mathbb{R}_+$ with $\widetilde{r}_i' \geq 0$ and $\widetilde{r}_i'' \leq 0$. Then, in the traveler's dilemma, given any conjecture σ_j over player j's action, player i's best-response is non-decreasing in β_i.

Figure 1 plots the best-response of player i to uniform mixing by player j as a function of β_i and α_i under our canonical specification of regret given in (2) for various values of the parameter b. Darker colors correspond to higher best-responses. Indeed, the best-response is increasing in β_i (for α_i high enough), but also in α_i (for β_i high enough), and decreasing in b.

Figure 1: The traveler's dilemma: best-response of player i to uniform mixing by player j as a function of β_i and α_i



Notes: $r_i\left(u_i,u_i^{br},u_i^b\right)$ is given by (2). $\sigma_j(x) = 1/10$ for every $x \in \{11,12,\ldots,20\}$. In knife-edge cases where there are two best-responses, the lowest one is reported.

4.2 The stag hunt game

Figure 2 presents a stag hunt game with normalized payoffs, where $\Lambda, \lambda > 0$.

Figure 2: A normalized stag hunt game

(a) Baseline/monetary payoffs

	stag	hare
stag	1,1	$-\lambda$,$1-\Lambda$
hare	$1-\Lambda, -\lambda$	0,0

(b) row player modified payoffs

	stag	hare
stag	1	$-(\lambda + \alpha_1 \max\{\lambda - \beta_1(1+\lambda), 0\})$
hare	$1-(1+\alpha_1)\Lambda + \alpha_1\beta_1 \max\{\Lambda - 1, 0\}$	0

(stag,stag) and (hare,hare) are the PNE of the game, while there is also a NE in mixed strategies. The robustness to strategic uncertainty of stag is commonly measured by the maximum probability with which player j can play hare with stag still being a best-response for player i. This probability is called the size of the basin of attraction of stag; denote it by BAS_i.[25] Under standard preferences (i.e., baseline payoffs in Figure 2), $\text{BAS}_i = \Lambda/(\lambda + \Lambda)$, which is not player-specific. With modified payoffs BAS_i is player-specific due to α_i and β_i. Claim 3 studies BAS_i.

Claim 3. The size of the basin of attraction of stag for player i is given by

$$\text{BAS}_i = \left(1 + \frac{\lambda + \alpha_i \max\{\lambda - \beta_i(1+\lambda), 0\}}{(1+\alpha_i)\Lambda - \alpha_i\beta_i \max\{\Lambda - 1, 0\}}\right)^{-1} \in (0,1).$$

(i) BAS_i is decreasing in λ and increasing in Λ.

(ii) If $\alpha_i\beta_i = 0$, then $\text{BAS}_i = \Lambda/(\lambda + \Lambda)$.

(iii) If $\beta_i > 0$, then BAS_i is increasing in α_i.

(iv) If $\alpha_i > 0$, then (a) if $\Lambda \leq 1$, then BAS_i is increasing in β_i for $\beta_i \in [0, \lambda/(1+\lambda)]$ and constant in β_i for $\beta_i \in [\lambda/(1+\lambda)$,1], while (b) if $\Lambda > 1$, then BAS_i is increasing in β_i for $\beta_i \in [0, \lambda/(1+\lambda)]$ and decreasing in β_i for $\beta_i \in [\lambda/(1+\lambda)$,1].

[25] This probability is equal to the probability of hare in the mixed NE. For a meta-analysis of experimental work on the stag hunt game and the explanatory power of the basin of attraction of stag, see Dal Bó et al. (2021).

Part (i) shows that the comparative statics of BAS_i with respect to λ and Λ follow the same intuition under regret as they do under baseline payoffs. Part (ii) shows that under single-agent regret, BAS_i is the same as under baseline payoffs. While both hare and stag can cause regret (when the other player chooses stag and hare, respectively), part (iii) shows that the former type of regret dominates, which makes BAS_i increasing in α_i. Thus, the higher the importance of regret for a player, the more attractive stag is.

Part (iv) is our main focus. When player i chooses stag and j chooses hare, the former can blame the latter. On the other hand, for $\Lambda \leq 1$, j has nothing to blame i for in that case.[26] Thus, for $\Lambda \leq 1$, the attractiveness of stag to player i is increasing in the tendency to blame β_i. In the experiment we will look at stag hunt games where hare is a safe option (i.e., $\Lambda = 1$), so participants with higher tendency to blame are expected to play stag more frequently.

4.3 The Kreps game

Goeree and Holt (2001) study the game presented in Figure 3(a) for $\delta = 330$, a game similar to the one presented in Kreps (1989). The game possesses three NE: two pure, (T,L) and (B,R), and one where both players randomize; the column one between L and M. However, both in Kreps' (1989) informal experiments and in Goeree and Holt's (2001) incentivized lab experiments, the majority of column players choose N, an action that is not part of any NE, while M is played with very low probability.[27] Claim 4 studies the equilibria of that game.

Claim 4. Consider the Kreps game with $\delta \in [200, 330]$, $\beta_2 \leq 29/30$, and $\alpha_2 \leq 1$.

(i) There exist two PNE: (T,L) and (B,R).

(ii) If $\beta_2 = 0$, there exists a unique mixed RE; in this RE both players mix, the column one between L and M.

(iii) For $\beta_2 > 0$, if $\delta >$ (resp. $<$) δ^*, then there exists a unique mixed RE; in this RE

[26] When $\Lambda > 1$, she can blame player i. Clearly, in the PNE neither player regrets or blames.

[27] While N can be seen as a safe action, risk aversion of the column player cannot explain this finding. This is because L needs to be played with positive probability for the row player to be willing to mix. But for L to be a best-response, T needs to be played with extremely high probability for otherwise M is superior. But if T is played with extremely high probability, risk aversion (of the column player) plays a negligible role.

Figure 3: The Kreps game

(a) Baseline/monetary payoffs

	L	M	N	R
T	500,350	300,345	310,δ	320,50
B	300,50	310,200	330,δ	350,340

(b) Modified payoffs

	L	M	N	R
T	500,350	300,$345 - 5\alpha_2$	310,$\delta - (350 - \delta)\alpha_2$	320, $50 - 10\alpha_2 \cdot (30 - 29\beta_2)$
B	$300 - 10\alpha_1 \cdot (20 - 5\beta_1)$, $50 - 10\alpha_2 \cdot (29 - 30\beta_2)$	310,$200 - 140\alpha_2$	330,$\delta - (340 - \delta)\alpha_2$	350,340

Notes: the modified payoffs are given for $\beta_2 \leq 29/30$ and $\beta_1 \geq 1/6$, so that expressions are not too long.

both players mix, the column one between L and N (resp. L and M), where

$$\delta^* := 50 + 300 \cdot \frac{30(1+\alpha_2) - 59\alpha_2\beta_2}{31(1+\alpha_2) - 60\alpha_2\beta_2}$$

is decreasing in β_2.

When $\delta > \delta^*$ in the mixed RE, N is played with high probability, as seen in existing experimental results.[28] For example, for $\alpha_2 = 1$ and $\beta_2 = 9/10$, $\delta^* = 308.75$ and $\sigma_2(N) = 71/75$. Thus, strategic—unlike single-agent—regret can explain the high frequency with which N is played in experiments and the low one with which M is played. At the same time, strategic regret offers an intuitive comparative statics prediction. For δ high enough the safe option N is played in equilibrium (and M is not), while for δ low, the risky action M is played in the mixed equilibrium. Particularly, the threshold level δ^* that δ needs to surpass for N to be played in equilibrium is decreasing in β_2.[29]

[28] Namely, the probability is given by $\sigma_2(N) = [20+\alpha_1(20-5\beta_1)]/[22+\alpha_1(20-5\beta_1+\max\{2-19\beta_1, 0\})]$.

[29] Here is why this happens. Starting from $\beta_2 = 0$ (in which case M is played in the mixed RE), an increase in β_2 causes the payoff of the column player at (B,L) to increase. This increases the probability with which B has to be played to make the column player indifferent between L and M. But as the probability of B increases, N becomes more attractive compared to M. When δ passes the threshold δ^*, N is played instead of M in the mixed RE.

5 Extension to n-person games

This section presents a simple extension of the model to n-person games and studies the volunteer's dilemma (also used in the experiment of section 6) using the following definition of the blame payoff. Given an action profile s, each player i identifies the player j who by individually best-responding to s_{-j} could have increased player i's baseline payoff the most. Then, player i assigns blame to that player as in two-player games.[30]

Definition 4. The blame payoff for player i is $u_i^b(s_i,s_{-i}) \coloneqq \max\{u_i^{ba}(s_i,s_{-i}), u_i(s_i,s_{-i})\}$, where $u_i^{ba}(s_i,s_{-i}) \coloneqq \max_{j \in N \setminus \{i\}}\{\max_{s'_j \in PBR_j(s_{-j})} u_i(s'_j,s_{-j})\}$ is the payoff i would receive if a player "most to blame" had by best-responding increased i's baseline payoff.

A player is "most to blame" if by best-responding, she could have increased player i's baseline payoff the most (compared to any other player individually best-responding).[31] Modified payoffs are then given by (1) and (2).

The volunteer's dilemma. Consider the volunteer's dilemma as described in Diekmann (1985). There are n players simultaneously choosing whether to volunteer. If none of the players volunteers, then each receives baseline payoff normalized to 0. If at least one player volunteers, then (i) any volunteering player receives baseline payoff $\phi_1 > 0$ and (ii) any non-volunteering player receives baseline payoff $\phi_2 > \phi_1$, as she does not incur the cost $c \coloneqq \phi_2 - \phi_1$ of volunteering. Claim 5 characterizes a player's best-response correspondence.[32]

Claim 5. Consider the volunteer's dilemma and let ξ_i be the probability with which player i expects at least one other player to volunteer. Then, volunteering is optimal for i if and only if

$$\xi_i \leq \tau_i \coloneqq \left(1 + \frac{(1+\alpha_i)(\phi_2 - \phi_1)}{\phi_1 + \alpha_i \max\{\phi_1 - \beta_i\phi_2, 0\}}\right)^{-1} \in (0,1),$$

[30] Notice that a player blames another player for not playing a mutually beneficial best-response, which—because there are more than two players—may not be Pareto-improving (i.e., a third player could be harmed by that best-response). However, in the volunteer's dilemma, any mutually beneficial best-response is also Pareto-improving.

[31] Notice that there can be multiple players "most to blame."

[32] In the experiment of section 6, participants play one-shot games, which makes non-equilibrium predictions most relevant. For completeness, section A.4 in the appendix discusses equilibrium outcomes. See Goeree et al. (2017) for volunteer's dilemma experiments with multiple rounds, where subjects gain experience by observing the outcome of each round before proceeding to the next one.

where $\tau_i = \phi_1/\phi_2$ if $\alpha_i\beta_i = 0$. If $\alpha_i\beta_i > 0$, then τ_i is (a) decreasing in β_i for $\beta_i \in [0, \phi_1/\phi_2]$ and constant in β_i for $\beta_i \in [\phi_1/\phi_2, 1]$, and (b) decreasing in α_i.

Similar to BAS_i in the stag hunt game, τ_i can be interpreted as a measure of the robustness of volunteering to strategic uncertainty. Claim 5 shows that the more a player i tends to blame (i.e., β_i high), the less willing she is to volunteer.[33] This is because the only outcome where there is scope for blame is when no player has volunteered. In this case, a player's regret for not volunteering herself is mitigated through blame put on other(s) for not volunteering either.

6 Experimental evidence on regret and blame in games

This section experimentally tests the strategic regret assumption (i.e., that blame assigned to the other player for not playing a mutually beneficial best-response mitigates regret) and the ensuing theoretical predictions.

6.1 Experimental design and hypotheses

The sample consists of 202 participants (invited by email) from the subject pool of the Center for Experimental Social Science (CESS) at New York University.[34] Participants earned on average $21.78. The experiment was programmed in z-Tree (Fischbacher, 2007) and lasted approximately 90 minutes. The experimental procedure is documented in more detail in Appendices D and E; here I describe it briefly.

6.1.1 Description of survey-type questions

Each subject was asked to describe their thoughts and emotions after having hypothetically played a game (from those presented in Figure 4) by indicating their level of agreement to the statements presented in Table 2 using a Likert scale from 1 ("Not at all") to 7 ("Totally agree"). These questions comprise the Regret and Blame Scale (RBS), adapted to the strategic context from the Regret and disappointment scale (RDS) of Marcatto

[33] Also, the attractiveness of volunteering to player i decreases with regret intensity α_i. While both volunteering and not volunteering can generate regret (when at least one more player volunteers or no player volunteers, respectively), the former type of regret dominates, which makes τ_i decreasing in α_i (if $\beta_i > 0$). This means that a higher weight α_i on regret tends to induce player i not to volunteer, but only as long as player i has some tendency to blame others. Otherwise, α_i does not play a role.

[34] A total of 20 sessions were conducted: 3 sessions with 4 participants each, 3 with 8 participants each, 5 with 10 participants each, 7 with 12 participants each, and 2 with 16 participants each.

and Ferrante (2008), which was designed for single-agent settings. Disappointment with the turn of events beyond the subject's control in RDS is replaced by blame on the other player for her action in RBS.

Table 2: Composition of the Regret and Blame Scale (RBS)

Question item	Response variable name
1. I am sorry about what happened to me.	affective reaction
2. I wish I had made a different choice.	regret
3. I wish the other player had acted differently.	blame
4. I feel responsible for what happened to me.	internal attribution
5. The other player is the cause of what happened to me.	external attribution
6. I am satisfied about what happened to me.	control
7. Things would have gone better if (a) I had chosen differently, or (b) the other player had chosen differently.	choice between counter-factuals

In more detail, each participant was asked to answer the RBS questions in the scenario where as row player they have played (i) B and the column player has played L in SAR1, (ii) B and the column player has played L in STR1, (iii) T and the column player has played L in SAR2, and (iv) T and the column player has played L in STR2.[35] Game SAR1 (resp. STR1) is the same as STR1 (resp. STR2) except for the column player's payoffs for outcomes (B,M) and (B,R) (resp. (T,M) and (T,R)). Given the hypothesized outcomes, in games SAR1 and SAR2 the column player does not have a best-response (to the row player's action) that also increases the row player's payoff, while in STR1 and STR2 she does. Therefore, responses in the SAR items will function as a baseline and be compared to responses to STR items.[36] According to the theory, participants should (in the scenarios described above) blame more the other player and regret less themselves in the STR games than in the corresponding SAR ones.

The first item of the RBS measures the affective reaction of the subject, while item 6 is a control item. The answers to these two items should be negatively correlated. The remaining items measure how strongly a player regrets and blames herself or the other player.

One may be reluctant to accept that people can accurately predict their emotions

[35]SAR is a mnemonic for single-agent regret, while STR for strategic regret.

[36]A 3×3 game is necessary for satisfying the following feature, which cannot be satisfied by a 2×2 game. In all games of Figure 4, no action is weakly dominated. This guarantees that players are not asked to describe their feelings in an unrealistic scenario.

Figure 4: Games in reference to which subjects answer the RBS items

(a) Game SAR1

	L	M	R
T	5,5	30,10	20,15
C	0,15	10,10	50,5
B	0,20	25,15	40,10

(b) Game SAR2

	L	M	R
T	10,15	25,10	25,10
C	15,20	5,15	20,10
B	15,10	20,15	10,20

(c) Game STR1

	L	M	R
T	5,5	30,10	20,15
C	0,15	10,10	50,5
B	0,20	25,50	40,40

(d) Game STR2

	L	M	R
T	10,15	25,30	25,30
C	15,20	5,15	20,10
B	15,10	20,15	10,20

Notes: the differences between SAR1 and STR1, as well as between SAR2 and STR2 are marked in red.

in a hypothetical setting.[37] However, what matters for the theory is *anticipated regret*. Thus, it is sufficient that subjects not make any systematic errors (i.e., that depend on the game at hand) in reporting their regret anticipation.[38] Even if one is reluctant to believe that participants accurately predict emotional states, or even that they submit their true anticipated regret, it is hard to imagine why there could be systematic errors in the reporting of regret anticipation.

6.1.2 Experiment timeline

Subjects first completed the RBS survey with respect to SAR1 and SAR2. Then, they played 8 rounds of the traveler's dilemma (with the bonus/penalty parameter b taking a different value in each round) choosing integers in [80,200]. Next, depending on the treatment, they played 8 rounds (with the parameter c taking a different value in each round) of either (i) the volunteer's dilemma in groups of two or four with c being the cost of volunteering,[39] or (ii) the stag hung game with a safe option presented in Figure 5 with c being the cost of playing stag. Then, they played the Kreps games (see Figure 3) for various values of the parameter δ. Finally, they completed the survey with respect to

[37] Indeed, the literature on affective forecasting has found evidence that people often fail to forecast future emotional states (e.g., see Gilbert et al., 1998).

[38] For example, they do not over-report their anticipated regret (compared to their true regret anticipation, *not* compared to actual regret that would be realized in the hypothetical scenarios) in STR games, while under-reporting it in SAR games.

[39] The payoff if nobody volunteers was 40. The gross payoff if at least on player volunteers was 200.

STR1 and STR2.[40]

Figure 5: A stag hunt game with a safe option

	stag	hare
stag	$200-c$,$200-c$	$100-c$,100
hare	100,$100-c$	100,100

In an additional (fourth) treatment, participants first played the traveler's dilemma, then the stag hunt game, then completed the survey with respect to SAR1 and SAR2, then played the Kreps game, and finally completed the survey with respect to STR1 and STR2. This will allow us to test for order effects (e.g., whether the survey affected behavior in the incentivized games by priming subjects into thinking about regret and blame). Section C in the Appendix shows that there is no evidence of order effects. Table 3 summarizes the different treatments.

In all treatments there was random rematching without feedback between rounds. For each of the three incentivized games in each treatment, participants were rewarded points for one randomly chosen round. After they finished playing all the rounds of a game, participants saw (i) their own action in each round, (ii) the action of the participant that they were matched with in each round, (iii) which round was randomly selected for payment, and (iv) the points that they earned.[41]

Table 3: Summary of treatments

Treatment	# of participants	# of sessions
RBS SAR → TD → VD2 → KG → RBS STR	50	5
RBS SAR → TD → VD4 → KG → RBS STR	52	4
RBS SAR → TD → SH → KG → RBS STR	52	6
TD → SH → RBS SAR → KG → RBS STR	48	5

Notes: TD, SH, and KG stand for the traveler's dilemma, stag hunt game, and Kreps game, respectively. VD2 and VD4 stand for the two-player and four-player volunteer's dilemma, respectively.

[40]The three games were placed in between the SAR and STR portions of the RBS items for two main reasons: so that participants (i) do not see the similar SAR and STR games too soon one after the other and (ii) do not consecutively answer too many survey-type questions, which could decrease their attention. Also, participants were required to spend at least 3 minutes in each game of Figure 4, reading the hypothetical scenario and filling in the survey in reference to the game.

[41]The feedback was placed at the end of all rounds of each game, so that it came as soon as possible after the participants' decisions (since delayed feedback may alleviate regret), while not allowing for learning between the rounds of the game.

6.1.3 Hypotheses

I now describe the six hypotheses to be tested. First, we will test whether indeed the availability to the column player of a Pareto-improving best-response (in STR games) makes the row player blame the column player more and regret less on average (than in SAR games).[42]

Hypothesis 1. Participants regret less and blame more (as measured by their RBS survey responses) in STR games than in SAR games.

We now develop hypotheses 2 through 4, which refer to the predictive power of RBS survey responses over behavior in incentivized games. According to the theory, participants with stronger tendency to blame the other player (and thus regret less) should choose higher numbers in the traveler's dilemma, play stag more frequently, and volunteer less frequently.[43]

The following index will be used in testing these hypotheses. For each subject i, an index of blame intensity is calculated as a single principal component from the subject's ten RBS survey responses to items 2 through 5 and 7 in the two STR games (5 items times 2 STR games):[44]

$$\text{Blame Index}_i := \text{PC}\left(\left\{\begin{matrix}\text{regret}_{iSTRj}, \text{internal attribution}_{iSTRj} \\ \text{blame}_{iSTRj}, \text{external attribution}_{iSTRj}, \\ \text{choice between counterfactuals}_{iSTRj}\end{matrix}\right\}_{j=1,2}\right).$$

[42]Namely, it will be tested whether: (i) the responses to the regret and internal attribution items are on average lower for STR1 (resp. STR2) than for SAR1 (resp. SAR2), (ii) the responses to the blame and external attribution items are on average higher for STR1 (resp. STR2) than for SAR1 (resp. SAR2), (iii) the percentage of subjects that choose (b) in the counterfactual choice question is higher for STR1 (resp. STR2) than for SAR1 (resp. SAR2), and (iv) the responses to the regret and internal attribution items are negatively correlated (at a subject level) with the responses to the blame and internal attribution items—particularly in STR games. Points (i)–(iii) are based on aggregate data, while (iv) tests whether blame mitigates regret at a subject level.

[43]This should be particularly true when the tendency to blame is measured by their responses to the STR—rather than SAR—items. Thus, in Appendix C it is also tested whether RBS responses to STR game items are a better predictor of participant behavior than RBS responses to SAR game items.

[44]choice between counterfactuals$_{iSTRj} = 1$ (resp. $= 0$) corresponds to the response "(a) I had chosen differently" (resp. "(b) the other player had chosen differently"). All the loadings in the principal components have the expected sign (see Table 11 in Appendix C). That is, the blame and external attribution items (resp. regret, internal attribution, and choice between counterfactuals) have positive (resp. negative) loadings. This serves as indirect evidence that blame indeed mitigates regret as postulated in the theory and verified by Figure 7.

A high index means that the subject blames more and regrets less. The following hypotheses will then be tested:

Hypothesis 2. Participants with higher Blame Index choose higher numbers in the traveler's dilemma (see Section 4.1).

Hypothesis 3. Participants with higher Blame Index are more likely to play stag in the stag hunt game (see Section 4.2).

Hypothesis 4. Participants with higher Blame Index are less likely to volunteer in the volunteer's dilemma (see Section 5).

Even if RBS survey responses are found to predict incentivized play consistently with predictions of the theory—which should enhance our confidence that the survey responses are meaningful, some may still be reluctant to accept survey responses as strong evidence in favor of strategic regret. Thus, hypothesis 5—which only uses data on incentivized play and not survey responses—will also be tested.[45] This hypothesis is an implication of hypotheses 2 and 3 combined.[46]

Hypothesis 5. Participants who choose higher numbers in the traveler's dilemma are more likely to play stag in the stag hunt game.

Last, hypothesis 6 will be tested.

Hypothesis 6. The frequency with which N (resp. M) is played in the Kreps game increases (resp. decreases) with δ (see Section 4.3).

6.2 Experimental results

6.2.1 Hypothesis 1: RBS survey responses

We first test hypothesis 1. Figure 6 presents the results on items 2 through 5 and 7.[47] All differences are as expected. Participants blame more and regret less in a game where according to the theory there is room for blame to mitigate regret (i.e., STR1 and STR2)

[45]Section 6.4 presents and tests an additional hypothesis that is derived from strategic regret and does not employ survey responses.

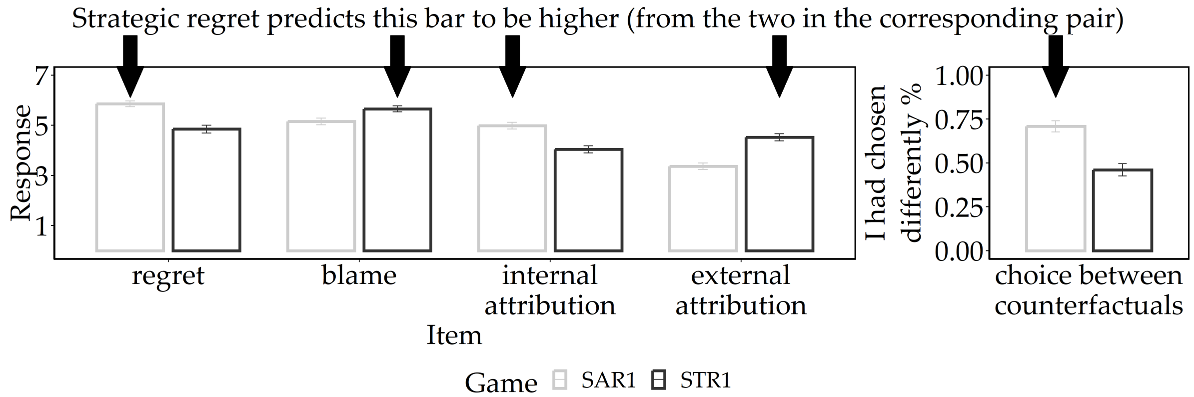
[46]Since, as we will see, hypothesis 4 is not supported by the data, it is not combined with hypothesis 2 to give a new hypothesis to be tested.

[47]Appendix C studies the affective reaction and control item responses. The two are negatively correlated, as expected.

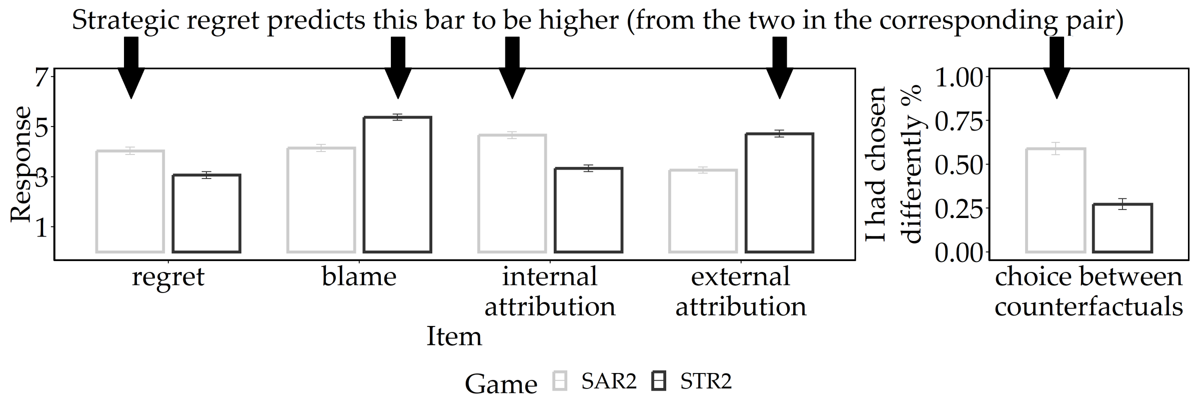
than in a game where there is no room for blame (i.e., SAR1 and SAR2, respectively). At the same time, Figure 7 shows that within each game, the responses to the blame and external attribution items are negatively correlated with the responses to the regret and internal attribution items—particularly in STR games. This suggests that indeed blame assigned to the other player is the mechanism through which regret is reduced. Overall, there is strong evidence in favor of hypotheses 1.

Figure 6: RBS results: regret and blame in SAR versus STR games

(a) SAR1 versus STR1



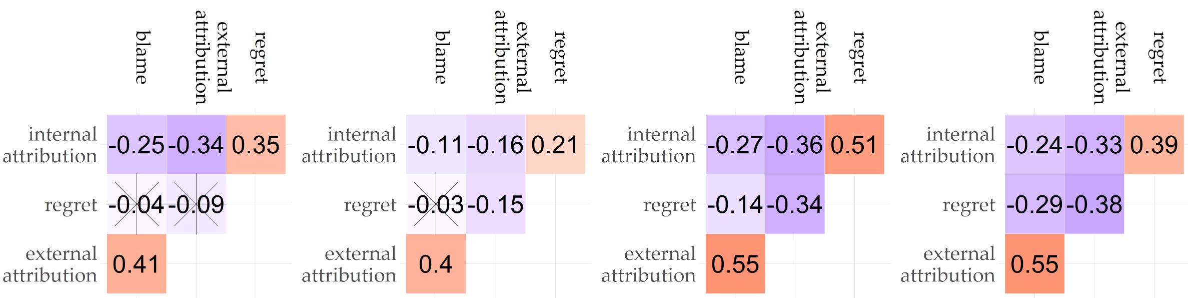
(b) SAR2 versus STR2



Notes: bars of mean responses with standard error intervals. The panels on the right show the percentage of subjects that chose (a) "I had chosen differently" in the choice between counterfactuals item. All differences are statistically significant at the 0.1% level based on (i) Wilcoxon signed-rank one-sided tests (Pratt's (1959) method of dealing with ties is used) for the items in the left panels and (ii) Fay and Lumbard (2021) one-sided tests for the right panels. The latter is a test on the sign of differences in paired responses; with binary responses, the two-sided version of the test is equivalent to McNemar's test.

Figure 7: Kendall's τ_b correlation coefficients between RBS survey responses

(a) SAR1 **(b)** SAR2 **(c)** STR1 **(d)** STR2



Notes: red (resp. blue) denotes a positive (resp. negative) correlation. Crossed-out coefficients are not significant at the 5% level based on a two-sided test under the asymptotic t approximation (with a continuity correction).

6.2.2 Hypotheses 2–4: predictive power of RBS survey responses over behavior in incentivized games

We now test hypotheses 2–4 on the predictive power of RBS survey responses over behavior in incentivized games.

RBS survey responses predict behavior in the traveler's dilemma and the stag hunt game. Figure 8(a) and Table 4 show that participants with higher than median Blame Index choose higher numbers in the traveler's dilemma (compared to participants with lower than median blame index). The differences are statistically significant across a range of values for the bonus/penalty parameter b. Particularly, as seen in Figure 8, for b not too low, participants with high Blame Index choose numbers that are on average larger by 15 compared to the numbers chosen by participants with low Blame Index.

Similarly, Figure 8(b) and Table 5 show that subjects with high Blame Index choose stag more frequently than subjects with low Blame Index.[48] This is true particularly for intermediate values of the cost c of stag.[49] For these values, the frequency with which participants with high Blame Index play stag is higher by 20 percentage points than the corresponding frequency for participants with low Blame Index.

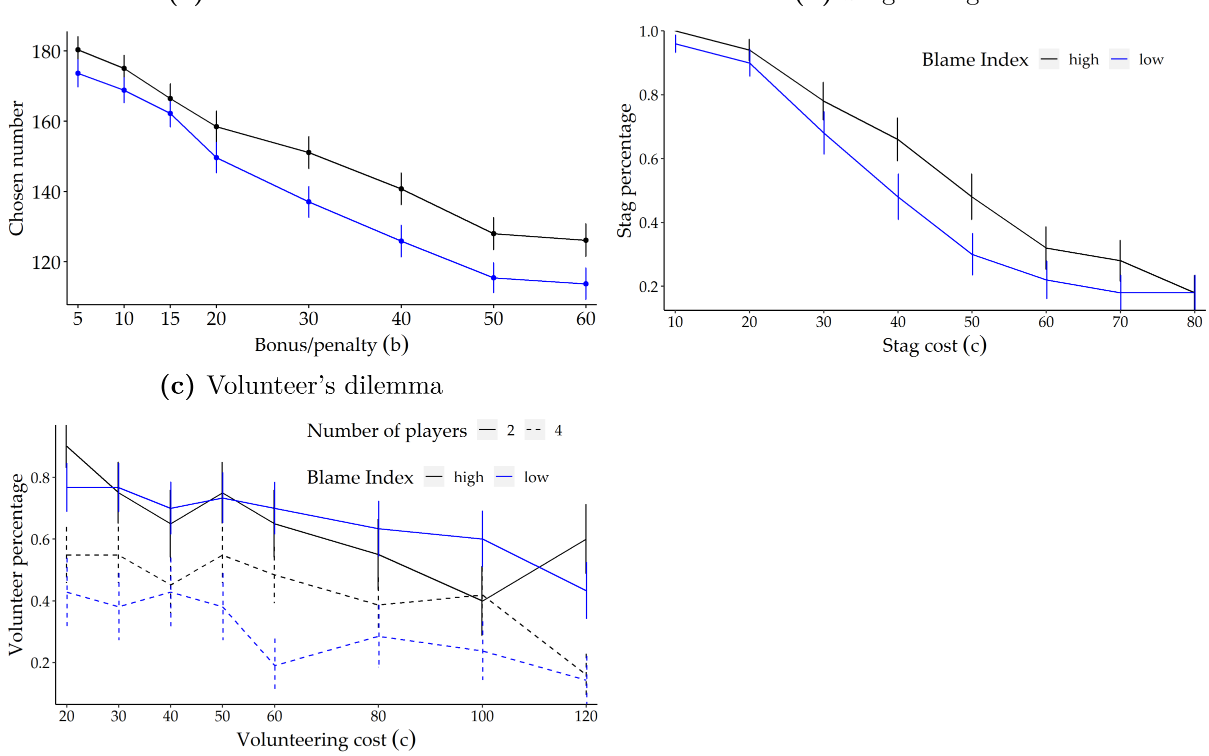
We conclude that hypotheses 2 and 3 are supported by the data. Answers in survey

[48] Boschloo's (exact) test is uniformly more powerful than Fisher's exact test and applies to cases where the sample size of each group is fixed (i.e., not random)—as are the sample sizes of the high and low Blame Index groups in our case (due to the 50%/50% split). Fisher's exact test would apply if also the number of people who play stag and (the number of people who play) hare were fixed. For completeness, Fisher's exact test p-values are reported in Appendix C.4.

[49] For extreme values of c, behavior is concentrated at the extremes.

items about anticipated emotional reactions have predictive power over the choices of subjects in incentivized play, consistent with theoretical predictions. Namely, participants that tend to blame more (and regret less) choose higher numbers in the traveler's dilemma and are more likely to play stag. This result becomes even more striking if one notices that the games used in the survey are vastly different from the traveler's dilemma and the stag hunt game.

Figure 8: Behavior of high versus low Blame Index subjects in the traveler's dilemma, volunteer's dilemma, and stag hunt game



(a) Traveler's dilemma

(b) Stag hunt game

(c) Volunteer's dilemma

Notes: the lines represent the mean action for each group of participants with standard error intervals. The group "high", in black, (resp. "low", in blue) is the subset of participants whose Blame Index is above (resp. below) the median value.

Table 4: Behavior of high versus low Blame Index subjects in the traveler's dilemma: Wilcoxon-Mann-Whitney one-sided tests

Bonus/penalty (b)	5	10	15	20	30	40	50	60
p-value	0.106	0.067	0.134	0.08	0.023	0.018	0.04	0.036

Notes: the normal approximation with a continuity correction is used.

Table 5: Behavior of high versus low Blame Index subjects in the stag hunt game: Boschloo's one-sided tests

Stag cost (c)	10	20	30	40	50	60	70	80
p-value	0.192	0.309	0.138	0.038	0.035	0.138	0.136	0.544

RBS survey responses do *not* predict behavior in the volunteer's dilemma. On the other hand, hypothesis 4 is not supported. Figure 8(c) shows no predictive power of Blame Index over choices in the volunteer's dilemma. In the four-player case, there is a significant difference for one value of the volunteering cost c and the difference is in the opposite direction than expected. In the two-player version of the game, the signs of the differences are mostly as expected, yet still mixed and insignificant.

A natural explanation is the following. The only case where a player i may blame another player j is (in theory) when nobody has volunteered. But in that case, what j could have done differently is exactly what i herself could have done. It makes sense that people do not blame others for not volunteering when they themselves have not volunteered. Put differently, when nobody volunteers, everyone bears equal responsibility for the bad outcome, and thus does not blame the others. This intuition is consistent with Çelen et al.'s (2017) finding that in public good games, a player i tends to blame (i.e., punish) another player j when j's contribution is lower than i's.

This explanation is also supported by the evidence from the other two games, where blame *does* have predictive power over incentivized play. In the traveler's dilemma, the cases where player i blames player j is when the former has chosen a number that is higher (by at least 2) compared to the number chosen by j. In that case, given i's action, j could have acted differently (i.e., best-responded by undercutting i by exactly 1, causing a Pareto improvement) in a way that i could not have, given j's action.

The stag hung game with a safe option offers even stronger evidence in favor of this explanation, thanks to its similarity to a two-player volunteer's dilemma. Notice that this stag hung game is equivalent to a two-player volunteer's dilemma with only the following difference: *two* volunteers (i.e., players who choose stag)—instead of one—are needed for the benefits of volunteering (i.e., playing stag) to materialize. Then, the only case where player i blames player j is when the former has played stag while the latter has played hare. In that case, given i's action, j could have acted differently (i.e., best-responded by playing stag, causing a Pareto improvement) in a way that i could not have, given j's action.

6.2.3 Hypothesis 5: the relationship between behavior in the traveler's dilemma and behavior in the stag hunt game

To test hypothesis 5, I estimate a logistic regression of the stag hunt action on a constant and the number chosen in the traveler's dilemma for each combination of stag cost c and bonus penalty b for a total of $8 \times 8 = 64$ regressions. That is, I estimate $Prob(stag|c) = 1/[1 + e^{-(\gamma_{c,b}+\delta_{c,b}\text{TDnum}_b)}]$, where $Prob(stag|c)$ is the probability that stag is chosen when the stag cost is c and TDnum_b is the number chosen in the traveler's dilemma when the bonus/penalty is b. This gives estimates $\widehat{\gamma}_{c,b}$ and $\widehat{\delta}_{c,b}$ for each combination of c and b.[50]

In 56 out of the 64 regressions $\widehat{\delta}_{c,b}$ is positive. In 33 (resp. 27) it is positive and significant at the 10% (resp. 5%) level. At the same time, in no regression is $\widehat{\delta}_{c,b}$ negative and significant at the 10% level. Particularly, Table 6 shows that the coefficients are negative and/or insignificant mostly for c and/or b low, which can be explained by the fact that for such parameter values behavior is concentrated on the extremes of the action space. For b and c not too low, Table 6(b) shows that an increase in the number chosen in the traveler's dilemma by 10 implies on average a 10-20% increase in the odds of stag. We thus conclude that subjects who choose higher numbers in the traveler's dilemma are more likely to choose stag, consistent with the theory of strategic regret.

6.2.4 Hypothesis 6: strategic regret predictions in the Kreps game

Table 7 shows the distribution of outcomes in the Kreps game. As predicted under strategic regret, the frequency with which N is played is increasing in δ. Namely, for δ high enough, play is concentrated on actions L and N with N played with high probability. For δ low, play is concentrated on L and M. These results are consistent with mixed strategic RE predictions, but not with predictions under single-agent regret or standard assumptions on preferences (see section 4.3).

6.3 Discussion of experimental results

The combination of survey responses with incentivized play has a number of advantages.

[50] Table 13 in Appendix C tests the hypothesis using non-parametric methods. The results are robust.

Table 6: Logistic regressions of the stag hunt action (stag = 1) on the number chosen in the traveler's dilemma

(a) p-values for $\widehat{\delta}_{c,b}$

		Stag cost (c)							
		10	20	30	40	50	60	70	80
	5	0.37	0.71	0.42	0.91	0.07	0.96	0.75	0.49
	10	0.76	0.1	0.18	0.33	0	0.26	0.45	0.16
Bonus/	15	NA	0.98	0.06	0.14	0	0.03	0.19	0.07
penalty	20	0.72	0.52	0.05	0.18	0	0.06	0.14	0.08
(b)	30	0.99	0.39	0.02	0.02	0	0.01	0.01	0.01
	40	0.72	0.41	0.02	0	0	0	0	0
	50	0.58	0.47	0.03	0.01	0	0	0	0
	60	0.62	0.98	0.28	0.01	0	0.01	0	0

(b) Odds ratios for an increase in TDnum_b by 10

		Stag cost (c)							
		10	20	30	40	50	60	70	80
	5	1.14	1.03	1.05	1.01	1.12	1	0.98	1.05
	10	1.06	1.16	1.09	1.06	1.3	1.08	1.06	1.13
Bonus/	15	NA	1	1.1	1.08	1.23	1.15	1.09	1.15
penalty	20	0.94	1.05	1.1	1.06	1.23	1.11	1.09	1.13
(b)	30	1	1.07	1.12	1.11	1.24	1.16	1.16	1.21
	40	0.95	1.07	1.14	1.16	1.25	1.2	1.19	1.21
	50	0.92	1.06	1.13	1.14	1.22	1.16	1.16	1.2
	60	0.93	1	1.05	1.12	1.2	1.13	1.15	1.18

Notes: the sample size in each regression is 100 participants. The regression for $c = 10$ and $b = 15$ is not valid because out of 100 participants, only two did not choose stag (for $c = 10$) and both of them chose 200 in the traveler's dilemma (for $b = 15$).

First, it allows us to detect the mechanism that produces incentivized behavior. For example, the observed relationship between a participant's behavior in the traveler's dilemma and her choices in the stag hunt game could also be due to other-regarding preferences or preferences for efficiency.[51] If we let modified payoffs be given by $m_i(s) =$

[51]The quantal response equilibrium (QRE), introduced by McKelvey and Palfrey (1995), has also been successful in fitting observed behavior in multiple games. For instance, Capra et al. (1999) show this to be the case for the traveler's dilemma. While strategic regret and QRE are not mutually exclusive approaches (i.e., one could study QRE by adding errors to modified payoffs that account for strategic regret), I briefly discuss some differences between them. First, the ability of QRE to remarkably fit experimental data is partly due to its great flexibility. As Haile et al. (2008) show, QRE can perfectly fit any observed behavior in a single normal-form game, unless significant a priori restrictions are imposed. This is not the case with strategic regret, which, as we have seen, delivers—for multiple games—(qualitatively) unique predictions on the deviations from behavior derived under standard assumptions. Also, as will be seen in section 7, strategic regret predictions coincide with standard predictions for games with extreme conflict of interest. Second, strategic regret provides a concrete mechanism behind observed behavior. This

Table 7: Distribution of outcomes in the Kreps game

(a) $\delta = 250$

	L	M	N	R
T	34.7%	36.6%	7.9%	3%
B	9.9%	6.9%	1%	0%

(b) $\delta = 270$

	L	M	N	R
T	24.8%	26.7%	25.7%	4%
B	5%	7.9%	5%	1%

(c) $\delta = 290$

	L	M	N	R
T	18.8%	18.8%	41.6%	3%
B	4%	1%	10.9%	2%

(d) $\delta = 310$

	L	M	N	R
T	9.9%	5%	51.5%	3%
B	5.9%	3%	20.8%	1%

(e) $\delta = 330$

	L	M	N	R
T	8.9%	0%	53.5%	3%
B	4%	2%	28.7%	0%

$u_i(s) + \gamma_i u_j(s)$ for some $\gamma_i \geq 0$, then with i's beliefs fixed, a higher γ_i will increase the attractiveness of stag and at the same time induce i to choose a higher number in the traveler's dilemma.[52] However, the survey responses suggest that the mitigating effect of blame on regret is (at least partly) the mechanism behind this relationship. Also, section 6.4 presents additional (existing) experimental results on the stag hunt game, which can be explained by strategic regret but not by other-regarding preferences.[53]

Second, the fact that survey responses indeed predict incentivized behavior as suggested by the theory increases confidence in the survey results themselves. Third, while survey responses alone support the strategic regret assumption, the connection between survey responses and incentivized play (in games very different from those used in the survey) lends direct support to the predictions of the theory.

6.4 An alternative test based on existing experimental evidence

Our analysis suggests that the way people experience regret in games differs from how they experience it in single-agent settings. An alternative test of the theory will check exactly that: whether participant behavior in a game differs from their behavior in a

mechanism has shown to be particularly helpful in explaining heterogeneity in behavior across subjects, as well as within-subject correlation in behavior across different games.

[52] Yet, a higher γ_i will also increase the attractiveness of volunteering in the volunteer's dilemma.

[53] Also, section A of the Appendix generalizes strategic regret to account for the volunteer's dilemma findings. On the other hand, other-regarding preferences cannot account for these findings.

comparable decision-making problem, as predicted by the theory of strategic regret.[54]

Consider the following single-agent version of the stag hunt game presented in section 4.2. Player 1 chooses between stag and hare as in the standard game. However, player 2 is passive; instead of choosing an action himself, nature chooses his action for him (and this is common knowledge).[55] Denote by $\mathrm{BAS}_i^{\mathrm{STRSH}}$ the basin of attraction of stag for player i in the stag hunt game as calculated in Claim 3, and by $\mathrm{BAS}_i^{\mathrm{SASH}}$ its corresponding value in the "single-agent" version (i.e., its value for $\beta_i = 0$, since i cannot blame nature).[56] The following is an immediate corollary of Claim 3.

Claim 6. Let $\Lambda \leq 1$. Then, $\mathrm{BAS}_i^{\mathrm{STRSH}}$ is higher than (resp. equal to) $\mathrm{BAS}_i^{\mathrm{SASH}}$ if $\alpha_i\beta_i > 0$ (resp. if $\alpha_i\beta_i = 0$).

Claim 6 shows that under strategic regret people should be more willing to play stag in the stag hunt game than in its single-agent version. Particularly, $\mathrm{BAS}_i^{\mathrm{STRSH}} > \mathrm{BAS}_i^{\mathrm{SASH}}$. Indeed, Bolton et al. (2016) experimentally elicit the basin of attraction of stag in both versions of a stag hunt game with a safe option (i.e., $\Lambda = 1$; also, $\lambda = 3/2$ in their experiment) to find that $\widehat{\mathrm{BAS}}^{\mathrm{STRSH}} = 0.36$, while $\widehat{\mathrm{BAS}}^{\mathrm{SASH}} = 0.25$ on average (across subjects).[57] That is, the maximum probability with which the other player (resp. the computer) can play hare with the participant still willing to play stag is 0.36 (resp. 0.25) on average in the standard game (resp. single-agent version of the game). Overall, their finding that stag is more robust to strategic uncertainty than to uncertainty stemming from "nature" is consistent with strategic regret.[58]

To the best of my knowledge, no other model (or concrete mechanism) has been proposed that explains this finding. Bolton et al. (2016) note that the finding is consistent with the social cognition literature (e.g., see Schul et al., 2004), which suggests that games

[54] I thank Séverine Toussaert for suggesting this test of strategic regret.

[55] Namely, the computer chooses hare or stag with some exogenous probability.

[56] STRSH (resp. SASH) stands for "strategic stag hunt" (resp. "single-agent stag hunt"). Notice that $\mathrm{BAS}_i^{\mathrm{SASH}} = \Lambda/(\lambda + \Lambda)$ independent of α_i.

[57] The difference in the distributions of $\mathrm{BAS}_i^{\mathrm{STRSH}}$ and $\mathrm{BAS}_i^{\mathrm{STRSH}}$ is statistically significant. The magnitude of the difference can easily be explained by strategic regret. For example, $\alpha_i = 1$ and $\beta_i = 1/2$ give $\mathrm{BAS}_i^{\mathrm{STRSH}} = 8/15$. Also, $\mathrm{BAS}_i^{\mathrm{SASH}} = 2/5$, so $\mathrm{BAS}_i^{\mathrm{STRSH}} - \mathrm{BAS}_i^{\mathrm{SASH}} = 2/15 \approx 0.13$. Remember that these numbers are derived with baseline payoffs linear in monetary payoffs. Risk aversion can explain the lower estimates of Bolton et al. (2016) in both STRSH and SASH.

[58] Yet, strategic regret cannot explain the opposite pattern (termed "betrayal aversion") documented in the trust game (e.g., see Bohnet and Zeckhauser, 2004; Bohnet et al., 2008), where participants are less willing to trust when they play against a human compared to when they play against the computer. In that game, in the second player's decision node there is complete conflict of interest. Thus, the first player can never blame the second for not playing a Pareto-improving best-response (since such a response never exists).

with aligned interests "activate a trust mindset." Although strategic regret is about blame and division of responsibility rather than trust, it does offer a deeper explanation for the activation of a trust mindset in games with aligned interests. Indeed, the (at least partial) alignment of interests plays an important role in strategic regret, because only under such alignment can there exist (blameworthy, and thus, regret-mitigating) mutually beneficial best-responses. Conversely, as noted in section 7, in games with extreme conflict of interest, strategic regret has no bite.

7 Discussion, robustness, and extensions

Section A in the Appendix presents additional theoretical results, which I briefly discuss here.

Robustness of theoretical results. The theoretical results are robust in a number of ways. First, Proposition 1 (which states that regret does not alter the set of pure equilibria) generalizes to n-player games under weaker, non-parametric assumptions on regret. Second, (under our canonical specification of regret) all theoretical predictions are invariant to affine transformations of baseline payoffs. Third, single-agent regret has little to no impact on rationalizable outcomes when compared to baseline preferences under weaker assumptions on regret.[59] On the other hand, strategic regret can alter the set of rationalizable outcomes, as it does in the traveler's dilemma presented in section 4.

Regret, blame, and the alignment of players' interests. Yet, in weakly unilaterally competitive games—a generalization of (two-person) strictly competitive (e.g., zero-sum) games—strategic regret has no bite.[60] In this class of games, a change in a player's action that increases her own (baseline) payoff harms every other player. Thus, there is no outcome where a player can blame another for not playing a Pareto-improving best-response, since such best-response never exists. This implies that modified payoffs are independent of β_i's, so the tendency to blame plays no role in games with severe

[59]Remember that under our canonical specification of regret, best-response correspondences under single-agent regret are the same as under standard assumptions on preferences. Therefore, rationalizability always delivers the same result regardless of whether baseline or single-agent regret payoffs are used.

[60]Weakly unilaterally competitive games were introduced by Kats and Thisse (1992). For our purposes, and slightly more broadly defined than in Kats and Thisse (1992), a (normal-form, n-person) game is weakly unilaterally competitive if any unilateral change of action by a player i that results in a (weak) increase in i's baseline payoff causes a (weak) decline in the baseline payoff of every other player.

conflict of interest. For example, in the unique RE of a (one-shot) prisoner's dilemma both players defect and in the unique RE of a public goods game no player contributes. These predictions are consistent with the evidence of low rates of cooperation in the prisoner's dilemma and low contribution rates in public goods games among experienced players (e.g., see Ledyard, 1995; Andreoni and Croson, 2008; Dal Bó and Fréchette, 2018).

This theoretical result on games with extreme conflict of interest is particularly insightful when viewed against the analysis of sections 4 and 5. In the games studied there, there is (partial) alignment of interests and strategic regret *does* (at least in theory) make a difference. In the traveler's dilemma (section 4.1), if we fix player j's number, then both i and j prefer (in baseline payoff terms) that i undercut j by exactly one rather than by more than one. Similarly, in the stag hunt game (section 4.2), given that player j plays stag, both i and j prefer that i also play stag. Last, in the volunteer's dilemma (section 5), provided that every player other than i does not volunteer, every player (including i) prefers i to volunteer.

A generalization of strategic regret. However, the experimental evidence of section 6 has suggested that this alignment of interests in the volunteer's dilemma does not give rise to regret-mitigating blame. A generalized model of strategic regret reconciles the theory with this finding. This model allows for the blame assigned by player i to player j to be mitigated when i herself could have played a Pareto-improving best-response. If this blame-mitigating effect is strong enough, then no blame arises in the volunteer's dilemma, and then theoretical predictions do not depend on α_i's or β_i's. At the same time, theoretical predictions for the traveler's dilemma and the stag hunt game with $\Lambda \leq 1$ remain the same under any parametrization of the generalized model.[61]

8 Conclusion

Research on (anticipated) regret in games has so far followed the *single-agent regret* approach, modeling regret as if in a single-agent context with the other players' actions treated as the state of the world. I argue for the *strategic regret* approach, which accounts for how the division of responsibility in games mediates regret and, in turn, shapes

[61]That is because in these games, in all cases where i can blame j for not playing a Pareto-improving best-response, i does not have a Pareto-improving best-response.

behavior. Namely, I postulate that blame assigned to another player for not playing a Pareto-improving best-response mitigates one's own regret.

I find that strategic regret gives rise to theoretical predictions that are closer to existing experimental results (compared to predictions under standard assumptions on preferences or under single-agent regret) on the traveler's dilemma and the Kreps game. The theoretical analysis suggests that strategic regret can lead to a higher degree of cooperation to Pareto superior outcomes in games with (at least partially) aligned interests, including not only coordination but also dominance-solvable (under standard assumptions on preferences) games. However, consistent with existing experimental results, it makes no difference in games with extreme conflict of interest.

Experimental evidence lends direct support to both the assumptions and theoretical predictions of strategic regret. Strategic regret can explain Bolton et al.'s (2016) finding that people take more risks in a stag hunt game when they play against another person rather than when a computer chooses the other player's action. I also provide new experimental evidence in favor of strategic regret. Survey questions that elicit participants' feelings in hypothetical scenarios show that subjects' regret is indeed mitigated by blame assigned to others for not playing a Pareto-improving best-response. Notably, participants' anticipated regret and blame elicited in vastly different games have predictive power—consistent with theoretical predictions—over their choices in the traveler's dilemma and the stag hunt game. Namely, participants who (according to survey responses) tend to more strongly blame the other player (and regret less) choose higher numbers in the traveler's dilemma and are more likely to play stag in the stag hunt game.

However, there are limits to blame. Particularly, blame does not seem to play a role in participant behavior in the volunteer's dilemma. This suggests that a player i does not blame another player j for not taking a (Pareto-improving) action that i could have taken herself but did not either.

We conclude that, when modified to account for blame and the division of responsibility in games, regret offers novel insights into strategic behavior. More generally, the results emphasize that decision-theoretic models may benefit from modifications when applied in games. (Implicit) assumptions that are plausible (or even hardly qualify as assumptions) in single-agent settings (e.g., that the agent does not blame the random state of the world) should be reconsidered in strategic environments.

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Appendix

A Robustness, extensions, and some general theoretical results

This section presents additional theoretical results under weaker assumptions on regret. Assumption 1 is the weakest assumption to be used.

Assumption 1. For every player i, $r_i(u_i,u_i^{br},u_i^b)$ satisfies the following:

(i) **No rejoicing:** player i's regret is non-negative, that is, $r_i\,(x,y,z) \geq 0$ for every (x,y,z).

(ii) **Regret, realized baseline payoff, and best-response payoff:** player i's regret is non-increasing in the baseline payoff she would receive if she best-responded, non-positive if she best-responds, and non-decreasing in the own realized baseline payoff, that is, (a) $r_i\,(x',y,z) \leq r_i\,(x,y,z)$ for every (x',y,z),(x,y,z) such that $x' \geq x$, (b) $r_i\,(x,x,z) \leq 0$ for every (x,x,z), and (c) $r_i\,(x,y',z) \geq r_i\,(x,y,z)$ for every (x,y',z),(x,y,z) such that $y' \geq y$.

(iii) **Regret and blame:** player i's regret is non-increasing in the blame payoff, that is, $r_i\,(x,y,z') \leq r_i\,(x,y,z)$ for every (x,y,z'),(x,y,z) such that $z' \geq z$.

Assumptions 1(i) and 1(iib) together imply that blame put on the opponent cannot more than compensate for the regret a non-best-response (i.e., $x < y$) tends to generate. To see this, notice that $r_i\,(x,y,z') \geq r_i\,(x,x,z) = 0$ always, which means that even if $z' \gg z$, the most a high blame payoff z' can do is reduce regret down to the level it would have if i best-responded.

Assumption 1 leaves a lot of modeling freedom, since it describes the effects of realized, best-response, and blame payoffs on regret *all else constant.* For example, it can allow for $r(1,20,2) < r(1,1,1)$, which seems unreasonable. However, we will see that in the case of single-agent regret (i.e., when assumption 1(iii) holds with regret constant in u_i^b), these assumptions are sufficient for showing the inability of single-agent regret to move theoretical predictions away from predictions derived under standard assumptions on preferences. On the other hand, we will see that strategic-regret can give rise to novel predictions under the stronger assumption 2, which significantly restricts modeling freedom.

Assumption 2. There exists a function $\widetilde{r}_i : \mathbb{R} \to \mathbb{R}_+$ and $\beta_i \in [0,1]$ such that

(i) $r_i\left(u_i, u_i^{br}, u_i^b\right) = \widetilde{r}_i\left(u_i^{br} - \left(\beta_i u_i^b + (1-\beta_i)u_i\right)\right)$ for every (x,y,x),

(ii) $\widetilde{r}_i(t) = 0$ for $t \leq 0$, and

(iii) $\widetilde{r}_i(t') > \widetilde{r}_i(t)$ for every t,t' such that $t' > \max\{t,0\}$.

Assumption 2 restricts modeling freedom requiring regret to be non-decreasing in the difference between the best-response payoff and a weighted sum of the realized and the blame payoff. For instance, it requires that $r(1,20,2) = \widetilde{r}_i(19-\beta_i) > \widetilde{r}_i(0) = r(1,1,1)$. The canonical specification of regret satisfies the general assumptions above.

Lemma 1. If regret is given by (2) with $\alpha_i \geq 0$, $\beta_i \in [0,1]$, then it satisfies assumption 2. Also, if regret satisfies assumption 2, then it also satisfies assumption 1.

A.1 Standard assumptions on preferences versus single-agent regret versus strategic regret: additional comparative results

This section presents more general results on the comparison of NE, single-agent RE, and strategic RE.

A.1.1 Equilibrium outcomes

Proposition 3 shows that the result of Proposition 1 (i.e., that regret does not alter the set of pure equilibria) generalizes to n-player games with weaker assumptions on regret.

Proposition 3. Under assumption 1(i-ii) and for any game G, the set of pure NE and the set of pure RE coincide, $PNE(G) = PRE(G)$.

As we have seen, strategic regret can affect the set of mixed equilibria of multiple games. Yet, Proposition 4 shows that in weakly unilaterally competitive (normal-form) games, strategic regret has no bite.[62]

Definition 5. A game G is weakly unilaterally competitive (WUC) if for every player $i \in N$, every $s_i, s_i' \in S_i$, and every $s_{-i} \in S_{-i}$, if $u_i(s_i', s_{-i}) \geq u_i(s_i, s_{-i})$, then $u_j(s_i', s_{-i}) \leq u_j(s_i, s_{-i})$ for every player $j \neq i$.

[62]The definition provided here differs slightly from the one in Kats and Thisse (1992). As defined here, the class of weakly unilaterally competitive games is a superset of the class of weakly unilaterally competitive as originally defined by Kats and Thisse (1992).

A game is WUC if any unilateral change of action by a player i that results in a (weak) increase in i's (baseline) payoff causes a (weak) decline in the payoffs of all other players. Thus, there is no outcome where a player can blame another for not playing a mutually beneficial best-response (since such best-response never exists). Therefore, every player i's modified payoff function is independent of β_i. Particularly, modified payoffs under strategic regret coincide with those under single-agent regret, and thus, so do best-response correspondences and all theoretical predictions.[63]

Proposition 4. Let assumption 2 hold and consider a weakly unilaterally competitive game G. For any player $i \in N$ and any action profile $s \in S$, $u_i^b(s) = u_i(s)$, so $m_i(s)$ is constant in β_i.

Notice that any (two-player) strictly competitive game is WUC.[64] Also, any zero-sum game is strictly competitive.[65]

A.1.2 Rationalizable outcomes

Conventions: throughout $\subset$ ($\supset$) denotes weak subset (superset); convex (concave), means weakly convex (concave).

Before proceeding, we need to define some standard concepts. Let $\mathcal{A}$ denote the collection of all Cartesian subsets of S, that is $\mathcal{A} := \{A \subset S : \exists A_1 \subset S_1, A_2 \subset S_2 \text{ such that } A = A_1 \times A_2\}$. For $A \in \mathcal{A}$, $i \in N$, $w \in \{u,m\}$ denote by $ND_{w;i}(A) \subset A_i$ the set of actions in A_i that are not (strictly) dominated when only actions in A_i and conjectures over A_j are considered, under baseline ($w = u$) or modified ($w = m$) payoffs, respectively, and let $ND_w(A) = ND_{w;1}(A) \times ND_{w;2}(A)$. Also, define recursively $ND_w^k(A) = ND_w\left(ND_w^{k-1}(A)\right)$ with $ND_w^0(A) = A$. Similarly, define $PND_w(A) \subset A$ to be the subset of action profiles such that no action of the profile is dominated when only pure dominance is used (i.e., when a pure action is said to be dominated only if it is so by another pure action). Then, define the sets of u and m-rationalizable action profiles, as well as dominance solvable games as follows.

[63] The result will still hold if we appropriately relax assumption 2.

[64] This is true when a two-player game is said to be strictly competitive if for any pair of pure action profiles $s,s' \in S$, $\text{sgn}\{u_1(s) - u_1(s')\} = \text{sgn}\{u_2(s') - u_2(s)\}$. This also means that $u_1(s) = u_1(s')$ if and only if $u_2(s) = u_2(s')$. Strictly competitive games are usually defined as above but for pairs of (possibly) mixed action profiles $\sigma, \sigma' \in \Delta$. However, this is not necessary for our purposes.

[65] Adler et al. (2009) also show that any strictly competitive game (defined more narrowly, in terms of pairs of mixed action profiles) is an affine payoff transformation of a zero-sum game.

Definition 6. Given a two-player game $G := \langle N, (S_i)_{i\in N}, (u_i)_{i\in N}, (m_i)_{i\in N}\rangle$, for $w \in \{u, m\}$, $ND^{\infty}_w(S) := \cap_{k\geq 1} ND^k_w(S)$ is the set of w-rationalizable action profiles. Similarly, define $PND^{\infty}_w(S) := \cap_{k\geq 1} PND^k_w(S)$ to be the set of w-pure rationalizable action profiles.

Definition 7. A two-player game G is w-dominance solvable if the set $ND^{\infty}_w(S)$ is a singleton. Similarly, it is w-pure dominance solvable if $PND^{\infty}_w(S)$ is a singleton.

Given a game G, denote by $\mathbb{DR}(G) \subset \mathbb{R}^3$ the domain of r_1 and r_2 in game G, that is,

$$\mathbb{DR}(G) := \begin{Bmatrix} (x,y,z) \in \mathbb{R}^3 | \exists (s_1,s_2) \in S, i,j \in \{1,2\}, j \neq i \text{ such that} \\ \hfill x = u_i(s_i,s_j), y = u_i^{br}(s_j), z = u_i^b(s_i,s_j) \end{Bmatrix}.$$

Proposition 5 then draws connections between the set of rationalizable action profiles (and more generally k rounds of iterated deletion of strictly dominated actions) under baseline payoffs and the rationalizable action profiles when modified payoffs are used instead.

Proposition 5. Consider a two-player game $G := \langle N, (S_i)_{i\in N}, (u_i)_{i\in N}, (m_i)_{i\in N}\rangle$ and let regret satisfy assumption 1. Then, for every $k \in \mathbb{N} \cup \{\infty\}, A \in \mathcal{A}$ the following statements hold:

(i) If 1(ii) is satisfied with the regret of each player i constant in u_i^b (single-agent regret), then $PND^k_u(A) = PND^k_m(A)$.

(ii) If for some player i assumption 2 is satisfied for $\beta_i > 0$, so that 1(ii) is satisfied with regret decreasing in u_i^b (strategic regret) in a subset of the domain $\mathbb{DR}$, then it can be that $PND^k_u(A) \neq PND^k_m(A)$.

(iii) Assume that for each player i, $r_i\left(u_i, u_i^{br}, u_i^b\right)$ is concave (resp. convex) in u_i. If assumption 1(ii) is satisfied with the regret of player i constant in u_i^b (single-agent regret), then $ND^k_u(A) \supset ND^k_m(A)$ (resp. $ND^k_u(A) \subset ND^k_m(A)$).

(iv) If assumption 2 is satisfied for $\beta_i > 0$, so that 1(ii) is satisfied with regret decreasing in u_i^b (strategic regret) in a subset of the domain $\mathbb{DR}$, then the conclusions of point (iii) need not follow.

Remark: If regret is given by (2), for $\beta_i = 0$, $r_i\left(u_i, u_i^{br}, u_i^b\right)$ is linear in u_i, so $ND_u^k(A) = ND_m^k(A)$.

Single–agent regret makes little to no difference compared to baseline preferences. Parts (i) and (iii) show that in every game, the rationalizable outcomes under single-agent regret are closely connected to those under standard assumptions on preferences. Particularly, part (iii) says that under the concavity assumption, rationalizability under single–agent regret rules out all outcomes that rationalizability under baseline preferences does. Thus for dominance solvable (under baseline payoffs) games the NE and the single-agent RE coincide. Conversely, under the convexity assumption, if a game is dominance solvable under single-agent regret, then the unique RE is also the unique NE. Under our canonical specification of regret given in (2), rationalizability delivers the same result regardless of whether baseline or single-agent regret payoffs are used. Thus, the result in section 4 that the traveler's dilemma is dominance-solvable under single-agent regret—just like under baseline payoffs—is not a coincidence. Last, part (i) says that rationalizability has the same implications under single-agent regret as it does under baseline payoffs regardless of the curvature of $r_i\left(u_i, u_i^{br}, u_i^b\right)$ in u_i when only pure dominance is used.

On the other hand, strategic regret can alter the set of rationalizable outcomes. Particularly, it can lead to equilibria different from the NE even when a game is dominance solvable (in baseline payoffs terms). The traveler's dilemma presented in section 4 is an example of a dominance solvable (under baseline payoffs) game where strategic regret gives rise to new RE.

A.2 Invariance to positive affine transformations of baseline payoffs

I conclude this section examining the invariance of RE to positive affine transformations of the baseline payoffs.

Definition 8. Games $G^1 := \langle N, (S_i)_{i\in N}, (u_i^1)_{i\in N}, (m_i^1)_{i\in N}\rangle$ and $G^2 := \langle N, (S_i)_{i\in N}, (u_i^2)_{i\in N}, (m_i^2)_{i\in N}\rangle$ are u (resp. m)-strategically equivalent if for each player $i \in N$ the baseline (resp. modified) payoff function u_i^2 (resp. m_i^2) is a positive affine transformation of the baseline (resp. modified) payoff function u_i^1 (resp. m_i^1).

Proposition 6. Consider two games $G^1 := \langle N, (S_i)_{i\in N}, (u_i^1)_{i\in N}, (m_i^1)_{i\in N}\rangle$ and $G^2 := \langle N, (S_i)_{i\in N}, (u_i^2)_{i\in N}, (m_i^2)_{i\in N}\rangle$ and let each player i's regret be given by (2) (where α_i's and β_i's do not depend on the game). If G^1 and G^2 are u-strategically equivalent, then they are also m-strategically equivalent.

Proposition 6 asserts that under our canonical specification of regret, theoretical predictions (including best-response correspondences, rationalizable outcomes and RE) are invariant to affine transformations of baseline payoffs. Given that theoretical predictions under baseline payoffs are also invariant to affine transformations of baseline payoffs, it follows that an affine transformation of baseline payoffs will not affect the analysis of sections 4 and 5.

A.3 The limits of blame: a simple generalization of strategic regret

I now present a generalization of strategic regret to reconcile the theory with the evidence on the volunteer's dilemma. Under this generalization, the blame player i assigns to player j (for not playing a Pareto-improving best-response) can be mitigated when i herself could have played a Pareto-improving best-response. For simplicity, restrict attention to two-player games and normalize all baseline payoffs to be positive. The blame payoff for player i is given by

$$u_i^b(s_i,s_j) := u_i(s)\left(1 + \max\left\{\frac{u_i^{ba}(s_i)}{u_i(s)} - \max\left\{\gamma_i \frac{u_j^{ba}(s_j)}{u_j(s)}, 1\right\}, 0\right\}\right),$$

where for each player i, $u_i^{ba}(s_i) \equiv \max_{s'_j \in PBR_j(s_i)} u_i(s_i,s'_j)$ and $\gamma_i \in [0,1]$ measures how strongly blame (assigned by i to j) is mitigated when i herself could have played a Pareto-improving best-response.[66] For $\gamma_i = 0$, this reduces to our standard definition of the blame payoff.

Let $\gamma_i = 1$, assume that action profile s is played and that by best-responding j could have increased i's baseline payoff by percentage x. This tends to make i blame j. However, if by best-responding i could also have increased j's baseline payoff by percentage x or higher, then i does not blame j. This means that for $\gamma_i = 1$, i never blames player j in the volunteer's dilemma, so i's best-response does not depend on α_i or β_i.

At the same time, in the traveler's dilemma and the stag hunt game with $\Lambda \leq 1$, for any action profile s such that $u_i^{ba}(s_i) > u_i(s)$ it holds that $u_j^{ba}(s_j) \leq u_j(s)$. Therefore,

[66] Notice that because ratios of baseline payoffs are used in the definition of the blame payoff, linear transformations of j's baseline payoffs will not affect i's blame payoff. However, affine transformations will.

blame assigned by i to j is never mitigated regardless of the value of $\gamma_i \in [0,1]$, so the theoretical predictions of section 4 still go through.[67]

A.4 Equilibrium predictions in the volunteer's dilemma

In the volunteer's dilemma, the set of PNE (and thus PRE) consists of n asymmetric equilibria; in each of these equilibria exactly one player volunteers. Claim 5' studies additional theoretical predictions under our canonical regret specification.[68]

Claim 5'. Consider the volunteer's dilemma and let regret be given by (2).

(i) Let ξ_i be the probability with which player i expects at least one other player to volunteer. Then, volunteering is optimal for i if and only if

$$\xi_i \leq \tau_i := \left(1 + \frac{(1+\alpha_i)(\phi_2 - \phi_1)}{\phi_1 + \alpha_i \max\{\phi_1 - \beta_i\phi_2, 0\}}\right)^{-1} \in (0,1),$$

where $\tau_i = \phi_1/\phi_2$ if $\alpha_i\beta_i = 0$. If $\alpha_i\beta_i > 0$, then τ_i is (a) decreasing in β_i for $\beta_i \in [0, \phi_1/\phi_2]$ and constant in β_i for $\beta_i \in [\phi_1/\phi_2, 1]$, and (b) decreasing in α_i.

(ii) $\boldsymbol{p} \equiv (p_1, p_2, \ldots, p_n)$ is a mixed equilibrium, where p_i the probability with which player i volunteers, if and only if $\max_{i \in N} \tau_i \leq 1 - \Delta_{\boldsymbol{p}}^{1/(\nu-1)}$ and $p_i = 1 - \Delta_{\boldsymbol{p}}^{1/(\nu-1)}/(1-\tau_i)$ for every player $i \in V_{\boldsymbol{p}}$, where $V_{\boldsymbol{p}} := \{i \in N : p_i > 0\}$ the set (resp. $\nu := |V_{\boldsymbol{p}}|$ the number) of players volunteering with positive probability and $\Delta_{\boldsymbol{p}} := \prod_{j \in V_{\boldsymbol{p}}}(1 - \tau_j)$.

(iii) If $\alpha_i = \alpha$, $\beta_i = \beta$ (so that $\tau_i = \tau$) for every i, then in the unique symmetric RE, each player volunteers with probability $p_{RE} = 1 - (1-\tau)^{1/(n-1)} \leq p_{NE}$ with strong inequality if and only if $\alpha\beta > 0$, where $p_{NE} := 1 - (1 - \phi_1/\phi_2)^{\frac{1}{n-1}}$, the corresponding probability in the symmetric NE. If $\alpha\beta > 0$, p_{RE} is (i) decreasing in β for $\beta \in [0, \phi_1/\phi_2]$ and (ii) decreasing in α.

Part (iii) says that with homogeneous single-agent regret preferences, the unique symmetric RE coincides with the NE one, while when there is scope for blame ($\beta > 0$) volunteer rates are lower in RE than in NE.[69] Higher tendency to blame the others (β) or

[67] This modification of blame has no bite in the hypothetical scenario (described in the survey) for game STR1, but it does play a role in the scenario for game STR2.

[68] For completeness, we repeat part (i) from Claim 5.

[69] This is partly consistent with Goeree et al.'s (2017) experimental finding that for n small, observed volunteer rates are indeed lower than predicted by the symmetric NE but for n large, they are higher.

higher intensity of regret considerations (α) decreases the probability with which each player volunteers.

Part (i) shows an analogous result to hold in non-equilibrium analysis (i.e., with player i's beliefs exogenously fixed). While both volunteering and not volunteering can generate regret (when at least one more player volunteers or no player volunteers, respectively), the former type of regret dominates, which makes τ_i decreasing in α_i (if $\beta_i > 0$). This means that a higher weight α_i on regret tends to induce player i not to volunteer, but only as long as player i has some tendency to blame others. Otherwise, α_i does not play a role. More importantly, a higher β_i tends to induce player i not to volunteer. This is because the only outcome where there is scope for blame is when no player has volunteered. In this case, a player's regret for not volunteering is mitigated through blame put on other(s) for not volunteering either.

Finally, part (ii) says that in mixed equilibria, among players that volunteer with positive probability, those with higher α_i and/or β_i (and thus higher τ_i) volunteer with lower probability. This effect is in the opposite direction than the one suggested by non-equilibrium analysis—a common feature in mixed equilibria.[70] As is true for pure equilibria of this game, coordination to any specific mixed equilibrium seems difficult without communication. Thus, as in the stag hunt game, τ_i can be best interpreted as a measure of the robustness of volunteering to strategic uncertainty. Also, in the experiment of section 6, participants play one-shot games, which makes non-equilibrium predictions most relevant.

References

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Nonetheless, it is not clear why the symmetric equilibrium should be the main prediction, as there also is extensive multiplicity of mixed equilibria. For example, with homogeneous preferences (i.e., $\alpha_i = \alpha$, $\beta_i = \beta$ for every i, which includes the case of baseline payoffs), for any $n' \in \{2,3,\dots,n\}$ there exists an equilibrium where each of n' players mixes (so that the n' players play a symmetric equilibrium among themselves, as if there are no other players) and the remaining $n - n'$ players best-respond by not volunteering. Thus, there are $n - 1$ mixed equilibria up to relabeling of the players.

[70] Among mixing players, those with higher tendency τ_i to volunteer need to actually volunteer with lower probability in equilibrium to keep those with lower tendency to volunteer willing to do so.

B Proofs

B.1 Proofs of section 3

Proof of Proposition 1. See section B.4.

Proof of Proposition 2. Instead of part (i), I prove the more general result that if $r_i\left(u_i,u_i^{br},u_i^b\right)$ is additively separable, linear (and non-decreasing) in u_i and constant in u_i^b, then $NE(G) = RE(G)$.[71]

First step for part (i): Consider a two-player game G and take a NE $\sigma^* \in NE(G)$. By definition of a NE, we have that for every player $i \in N$ and every $s_i \in S_i$, $s_i^* \in \text{supp}(\sigma_i^*)$, $u_i(s_i^*,\sigma_j^*) \geq u_i(s_i,\sigma_j^*)$, which implies that for every $s_i \in S_i$, $s_i^* \in \text{supp}(\sigma_i^*)$

$$m_i(s_i^*,\sigma_j^*) + \prod_{s_j \in S_j} r_i\left(u_i(s_i^*,s_j),u_i^{br}(s_j),0\right)\sigma_j^*(s_j) \\ \geq m_i(s_i,\sigma_j^*) + \prod_{s_j \in S_j} r_i\left(u_i(s_i,s_j),u_i^{br}(s_j),0\right)\sigma_j^*(s_j).$$

where the terms $u_i^b(s_i^*,s_j)$ and $u_i^b(s_i,s_j)$ have been replaced with zeros, since r_i is constant in u_i^b. By additive separability, the terms of r_i depending on u_i^{br} cancel (in the LHS and RHS). Thus, by separability and linearity of r_i in u_i, the inequality above can be written as

$$m_i(s_i^*,\sigma_j^*) + \prod_{s_j \in S_j}\left[\kappa u_i(s_i^*,s_j) - \kappa u_i(s_i,s_j)\right]\sigma_j^*(s_j) \geq m_i(s_i,\sigma_j^*) \implies \\ m_i(s_i^*,\sigma_j^*) + \kappa\left(u_i(s_i^*,\sigma_j^*) - u_i(s_i,\sigma_j^*)\right) \geq m_i(s_i,\sigma_j^*)$$

for some $\kappa \leq 0$, which given that $u_i(s_i^*,\sigma_j^*) \geq u_i(s_i,\sigma_j^*)$ implies that $m_i(s_i^*,\sigma_j^*) \geq m_i(s_i,\sigma_j^*)$ for every player i and every $s_i \in S_i$, $s_i^* \in \text{supp}(\sigma_i^*)$, so $\sigma^* \in RE(G)$. Thus, $NE(G) \subset RE(G)$.

Second step for part (i): Now take an action profile $\sigma^* \notin NE(G)$. Then, there exists $i \in N, s_i \in S_i$ such that $u_i(\sigma_i^*,\sigma_j^*) < u_i(s_i,\sigma_j^*)$, which means that there exists $s_i \in S_i$, $s_i^* \in \text{supp}(\sigma_i^*)$ such that $u_i(s_i^*,\sigma_j^*) < u_i(s_i,\sigma_j^*)$, so that by the same arguments as in the first step, $m_i(s_i^*,\sigma_j^*) + \kappa\left(u_i(s_i^*,\sigma_j^*) - u_i(s_i,\sigma_j^*)\right) < m_i(s_i,\sigma_j^*)$ for some $\kappa \leq 0$,

[71]Notice that for $\beta_1 = \beta_2 = 0$, $r_i\left(u_i,u_i^{br},u_i^b\right) = \alpha_i\left(u_i^{br} - u_i\right)$, which satisfies these assumptions.

which given that $u_i(s_i^*,\sigma_j^*) < u_i(s_i,\sigma_j^*)$ implies that $m_i(s_i^*,\sigma_j^*) < m_i(s_i,\sigma_j^*)$. Therefore, $s_i^* \in \text{supp}(\sigma_i^*)$ is not a best-response to σ_j^* under modified payoffs, so $\sigma^* \notin RE(G)$. Thus, $NE(G) \supset RE(G)$.

To see why point (ii) holds look at the examples of section 4. **Q.E.D.**

B.2 Proofs of section 4

Proof of Claim 1. I prove the claim under weaker assumptions; namely, that each player's baseline payoff is strictly increasing in (and only dependent on) own monetary units and regret satisfies assumption 1, with 1(iii) satisfied with the regret of each player i constant in u_i^b (single-agent regret).

Also, for ease of notation I prove the proposition for the specific example of the traveler's dilemma described in the text but the proof works the same way for any finite set of the form $\{a,a+1,\ldots,a+m\}$, $m \in \mathbb{N}$. Denote by k_i the number chosen by player i.

Conjectures with 19 or 20 being the maximum of the support of the conjecture: consider any conjecture of i that assigns positive probability to j choosing 19 or 20. Notice that $m_i(20,k_j) = m_i(19,k_j)$ for any $k_j \in \{11,\ldots,18\}$, since (i) $u_i(20,k_j) = u_i(19,k_j)$ for such k_j by the rules of the game, (ii) $u_i^{br}(k_j)$ by definition only depends on k_j, and (iii) assumption 1(iii) holds with r_i constant in u_i^b. Also, $m_i(20,k_j) < m_i(19,k_j)$ for $k_j \in \{19,20\}$, since (i) $u_i(20,k_j) < u_i(19,k_j)$ for such k_j, (ii) $u_i^{br}(k_j)$ only depends on k_j, and (iii) assumption 1(iii) holds with r_i constant in u_i^b. Thus, 20 is not a best-response to any such conjecture, since 19 delivers a higher (modified) expected payoff given any such conjecture.

Conjectures with 17 or 18 being the maximum of the support of the conjecture: now consider any conjecture of i that assigns zero probability to j choosing 19 or 20 but positive to choosing 17 or 18. Notice that $m_i(20,k_j) = m_i(18,k_j)$ for any $k_j \in \{11,\ldots,16\}$, since (i) $u_i(20,k_j) = u_i(18,k_j)$ for such k_j by the rules of the game, (ii) $u_i^{br}(k_j)$ by definition only depends on k_j, and (iii) assumption 1(iii) holds with r_i constant in u_i^b. Also, $m_i(20,k_j) < m_i(17,k_j)$ for $k_j \in \{17,18\}$, since (i) $u_i(20,k_j) < u_i(17,k_j)$ for such k_j, (ii) $u_i^{br}(k_j)$ only depends on k_j, and (iii) assumption 1(iii) holds with r_i constant in u_i^b. Thus, 20 is not a best-response to any such conjecture, since 17 delivers a higher (modified) expected payoff given any such conjecture.

Continuing in the same fashion, we see that 20 is a never-best-response (for either player). With 20 deleted in the first iteration, 19 is a never-best-response in the second iteration (where conjectures are constrained to assign probability 0 to 20 being chosen), and so on. The only rationalizable outcome is the pure NE (11,11). **Q.E.D.**

Proof of Claim 2. I prove the claim for $i = 1$ and under weaker assumptions, namely, with $v_1(x)$ being the baseline payoff of player 1 from x monetary units where v_1 is (strictly) increasing. For $s_1,s_2 \geq 12$ we have that $m_1(s_1+1,s_2) - m_1(s_1,s_2)$ is equal to

$$= \begin{cases} \begin{array}{r} -\widetilde{r}_1\left(v_1(s_2-1+b) - (\beta_1 v_1(s_1-b) + (1-\beta_1)v_1(s_2-b))\right) \\ +\widetilde{r}_1\left(v_1(s_2-1+b) - (\beta_1 v_1(s_1-1-b) + (1-\beta_1)v_1(s_2-b))\right) \end{array} & \text{if } s_1 \geq s_2+1 \\ \\ \begin{array}{r} v_1(s_2-b) - \widetilde{r}_1\left(v_1(s_2-1+b) - v_1(s_2-b)\right) \\ -v_1(s_2) + \widetilde{r}_1\left(v_1(s_2-1+b) - v_1(s_2)\right) \end{array} & \text{if } s_1 = s_2 \\ \\ \begin{array}{r} v_1(s_2) - \widetilde{r}_1\left(v_1(s_1+b) - v_1(s_2)\right) \\ -v_1(s_1+b) + \widetilde{r}_1\left(v_1(s_1+b) - v_1(s_1+b)\right) \end{array} & \text{if } s_1 = s_2-1 \\ \\ \begin{array}{r} v_1(s_1+1+b) - \widetilde{r}_1\left(v_1(s_2-1+b) - v_1(s_1+1+b)\right) \\ -v_1(s_1+b) + \widetilde{r}_1\left(v_1(s_2-1+b) - v_1(s_1+b)\right) \end{array} & \text{if } s_1 \leq s_2-2. \end{cases}$$

The part that depends on β_1 is equal to

$$= \begin{cases} -\widetilde{r}_1\left(t_1\right) + \widetilde{r}_1\left(t_2\right) & \text{if } s_1 \geq s_2+2 \\ \\ -\widetilde{r}_1\left(t_2\right) & \text{if } s_1 = s_2+1 \\ \\ 0 & \text{if } s_1 \leq s_2. \end{cases}$$

where $t_1 \coloneqq v_1(s_2-1+b) - (\beta_1 v_1(s_1-b) + (1-\beta_1)v_1(s_2-b))$ and $t_2 \coloneqq v_1(s_2-1+b) - (\beta_1 v_1(s_1-1-b) + (1-\beta_1)v_1(s_2-b))$. Notice that $t_2 \geq t_1$. Then, the derivative of the expression in the first case (i.e., $s_1 \geq s_2+2$) with respect to β_1 is equal to

$$\begin{aligned} &\left(v_1(s_1-b) - v_1(s_2-b)\right)\widetilde{r}_1'(t_1) - \left(v_1(s_1-1-b) - v_1(s_2-b)\right)\widetilde{r}_1'(t_2) \\ &\geq \left(v_1(s_1-b) - v_1(s_2-b)\right)\left(\widetilde{r}_1'(t_1) - \widetilde{r}_1'(t_2)\right) \geq \left(v_1(s_1-b) - v_1(s_2-b)\right)\left(\widetilde{r}_1'(t_1) - \widetilde{r}_1'(t_1)\right) = 0, \end{aligned}$$

where the first equality follows from $\widetilde{r}_1' \geq 0$ and v_1 being an increasing function and the second from $\widetilde{r}_1(x)$ being a concave function for $x \geq 0$, v_1 being an increasing function,

$t_2 \geq t_1$ and $s_1 > s_2$. It is trivial that in the second case (i.e., $s_1 \geq s_2 + 1$), the expression is increasing in β_1. In the last case (i.e., $s_1 \leq s_2$), there is no room for blame (whether player 1 plays s_1 or $s_1 + 1$), and thus the expression is constant in β_1.

Last, for $s_2 = 11$, everything follows as above with the only difference that $u_1^b r(s_2) = v_1(s_2)$, instead of $u_1^b r(s_2) = v_1(s_2 - 1 + b)$. For $s_1 = 11$, $m_1(s_1 + 1{,}s_2) - m_1(s_1{,}s_2)$ is independent of, and thus constant in, β_1.

We have thus shown that $m_1(s_1 + 1{,}s_2) - m_1(s_1{,}s_2)$ is non-decreasing in β_1 for every s_2, and the claim follows. **Q.E.D.**

Note: I expect the result to hold also under the canonical $\tilde{r}_i(x) \coloneqq \alpha_i \max\{x{,}0\}$ but the fact that $\tilde{r}_i(x)$ is constant in x for $x \leq 0$ in that case creates the following complication. When $t_2 > 0 \geq t_1$, the expression in the first case (i.e., $s_1 \geq s_2 + 2$) is equal to $-\tilde{r}_1(t_1) + \tilde{r}_1(t_2) = \tilde{r}_1(t_2)$, which is—locally—decreasing in β_1 (until the increase in β_1 makes $t_2 \leq 0$). In the case $t_1 \geq 0$ we still get that $-\tilde{r}_1(t_1) + \tilde{r}_1(t_2)$ is increasing in β_1. For $t_2 \leq 0$, $-\tilde{r}_1(t_1) + \tilde{r}_1(t_2)$ is constant in β_1.

Given a conjecture σ_2, whether the best-response $PBR_1(\sigma_2)$ of player 1 moves in the same direction as β_1 depends on the sign of $m_1(PBR_1(\sigma_2) + 1{,}\sigma_2) - m_1(PBR_1(\sigma_2){,}\sigma_2)$. Thus, given that the complication arises only in small intervals of the domain of $\tilde{r}_1$ and also that $PBR_1(\sigma_2) \geq s_2 + 2$ with low probability (the probability taken over σ_2), we can expect the claim to still hold despite the complication.

Proof of Claim 3. By Proposition 1 $PNE(SH) = PRE(SH)$. Mixing is optimal for player i if and only if

$$\begin{aligned} 1 - \sigma_j^*(\text{hare}) - \sigma_j^*(\text{hare})\,(\lambda + \alpha_i \max\{\lambda - \beta_i(1+\lambda), 0\}) &= \\ \Big(1 - \sigma_j^*(\text{hare})\Big)\,[1 - (1+\alpha_i)\Lambda + \alpha_i\beta_i \max\{\Lambda - 1, 0\}]\,, \end{aligned}$$

which gives

$$\begin{aligned} \text{BAS}_i &= \frac{(1+\alpha_i)\Lambda - \alpha_i\beta_i \max\{\Lambda - 1, 0\}}{\lambda + \alpha_i \max\{\lambda - \beta_i(1+\lambda), 0\} + (1+\alpha_i)\Lambda - \alpha_i\beta_i \max\{\Lambda - 1, 0\}} \\ &= \left(1 + \frac{\lambda + \alpha_i \max\{\lambda - \beta_i(1+\lambda), 0\}}{(1+\alpha_i)\Lambda - \alpha_i\beta_i \max\{\Lambda - 1, 0\}}\right)^{-1} \in (0{,}1) \end{aligned}$$

Then, part (i) follows since given $\alpha_i \geq 0$ and $\beta_i \in [0,1]$, $\lambda + \alpha_i \max\{\lambda - \beta_i(1+\lambda), 0\}$ is increasing in λ and $(1+\alpha_i)\Lambda - \alpha_i\beta_i \max\{\Lambda - 1, 0\}$ is increasing in Λ.

For part (iii), notice that under $\Lambda > 1$ and $\beta_i \leq \lambda/(1+\lambda)$,

$$\begin{aligned}
\frac{d\left(\frac{\lambda+\alpha_i[\lambda-\beta_i(1+\lambda)]}{(1+\alpha_i)\Lambda-\alpha_i\beta_i(\Lambda-1)}\right)}{d\alpha_i} \propto & [\lambda - \beta_i(1+\lambda)]\,[(1+\alpha_i)\Lambda - \alpha_i\beta_i(\Lambda-1)] \\
& - [\Lambda - (\Lambda-1)\beta_i]\,[\lambda + \alpha_i[\lambda - \beta_i(1+\lambda)]] \\
= & [\lambda - \beta_i(1+\lambda)](1+\alpha_i)\Lambda - [\Lambda - (\Lambda-1)\beta_i]\,\lambda - \Lambda\alpha_i[\lambda - \beta_i(1+\lambda)] \\
= & [\lambda - \beta_i(1+\lambda)]\Lambda - [\Lambda - (\Lambda-1)\beta_i]\,\lambda = -\beta_i(\lambda+\Lambda) < 0,
\end{aligned}$$

so BAS_i is increasing in α_i in this case. Notice that $\Lambda > 1$ and $\beta_i \leq \lambda/(1+\lambda)$ make $[\lambda + \alpha_i[\lambda - \beta_i(1+\lambda)]]/[(1+\alpha_i)\Lambda - \alpha_i\beta_i(\Lambda-1)]$ "least" decreasing in α_i. Given that it still is decreasing under these assumptions, it is still decreasing under $\Lambda \leq 1$ and $\beta_i \leq \lambda/(1+\lambda)$, or $\Lambda > 1$ and $\beta_i > \lambda/(1+\lambda)$ or $\Lambda \leq 1$ and $\beta_i > \lambda/(1+\lambda)$.[72]

For part (iv) notice that under $\Lambda > 1$ and $\beta_i \leq \lambda/(1+\lambda)$,

$$\begin{aligned}
\frac{d\left(\frac{\lambda+\alpha_i[\lambda-\beta_i(1+\lambda)]}{(1+\alpha_i)\Lambda-\alpha_i\beta_i(\Lambda-1)}\right)}{d\beta_i} \propto & - \alpha_i(1+\lambda)\,[(1+\alpha_i)\Lambda - \alpha_i\beta_i(\Lambda-1)] \\
& + \alpha_i(\Lambda-1)\,[\lambda + \alpha_i[\lambda - \beta_i(1+\lambda)]] \\
= & - \alpha_i(1+\lambda)(1+\alpha_i)\Lambda + \alpha_i(\Lambda-1)\lambda\,(1+\alpha_i) \\
\propto & - (1+\lambda)\Lambda + (\Lambda-1)\lambda = -(\lambda+\Lambda) < 0.
\end{aligned}$$

so BAS_i is increasing in β_i in this case. Similarly, it can be checked that under $\Lambda > 1$ and $\beta_i > \lambda/(1+\lambda)$, BAS_i is decreasing in β_i. The result under $\Lambda \leq 1$ follows easily. **Q.E.D.**

Proof of Claim 4. The modified payoffs are given in the Figure 9.

Clearly, in any mixed RE the row player should be mixing for otherwise the column player has a unique pure best-response. For mixing by the row player to be optimal, it must be that $\sigma_2(L) > 0$, since B dominates T when the column player chooses $\sigma_2(L) = 0$. Particularly, if a totally mixed action $\sigma_1 : \{T,B\} \to \Delta^2$ of the row player makes L and at least one of M, N, or R a best-response, then a mixed RE where the row player plays σ_1 and the column player mixes between L and some of the other actions exists.

[72] This can also be checked directly.

Figure 9: The Kreps game: modified payoffs

(a) Row player payoffs

	L	M	N	R
T	500	$300 - 10\alpha_1 \cdot \max\{1-20\beta_1, 0\}$	$310 - 10\alpha_1 \cdot \max\{2-19\beta_1, 0\}$	$320 - 10\alpha_1 \cdot \max\{3-18\beta_1, 0\}$
B	$300 - 10\alpha_1 \cdot (20 - 5\beta_1)$	310	330	350

(b) Column player payoffs

	L	M	N	R
T	350	$345 - 5\alpha_2$	$\delta - (350-\delta)\alpha_2$	$50 - 10\alpha_2(30 - 29\beta_2)$
B	$50 - 10\alpha_2(29 - 30\beta_2)$	$200 - 140\alpha_2$	$\delta - (340-\delta)\alpha_2$	340

The column player is indifferent between L and M if and only if

$$0 = 5(1+\alpha_2)\sigma_1(T) + [-150 + 10\alpha_2(14 - (29 - 30\beta_2))](1 - \sigma_1(T)) \iff$$
$$\sigma_1(T) = \frac{30 - \alpha_2(28 - 2(29 - 30\beta_2))}{31 - \alpha_2(27 - 2(29 - 30\beta_2))} = \frac{1 + \alpha_2 - 2\alpha_2\beta_2}{(1+\alpha_2)31/30 - 2\alpha_2\beta_2}.$$

The column player is indifferent between L and N if and only if

$$0 = (350-\delta)(1+\alpha_2)\sigma_1(T) + [50 - \delta + \alpha_2(340 - \delta - 10(29 - 30\beta_2))](1 - \sigma_1(T)) \iff$$
$$\sigma_1(T) = \frac{\delta/10 - 5 - \alpha_2(34 - \delta/10 - (29 - 30\beta_2))}{30 + \alpha_2(1 + (29 - 30\beta_2))} = \frac{(1+\alpha_2)(\delta - 50)/300 - \alpha_2\beta_2}{1 + \alpha_2 - \alpha_2\beta_2}.$$

The column player is indifferent between L and R if and only if

$$0 = [300 + 10\alpha_2(30 - 29\beta_2)]\,\sigma_1(T) - [290 + 10\alpha_2(29 - 30\beta_2)](1 - \sigma_1(T)) \iff$$
$$\sigma_1(T) = \frac{(1+\alpha_2)29 - 30\alpha_2\beta_2}{(1 + \alpha_2 - \alpha_2\beta_2)59}.$$

Thus, L is a best-response if and only if

$$\sigma_1(T) \geq \max\left\{\frac{1 + \alpha_2 - 2\alpha_2\beta_2}{(1+\alpha_2)31/30 - 2\alpha_2\beta_2}, \frac{(1+\alpha_2)(\delta - 50)/300 - \alpha_2\beta_2}{1 + \alpha_2 - \alpha_2\beta_2}, \frac{(1+\alpha_2)29 - 30\alpha_2\beta_2}{(1 + \alpha_2 - \alpha_2\beta_2)59}\right\}.$$

First I show that R is never part of a mixed equilibrium. For this it is sufficient to show that the first term in the brackets above is higher than the last one. This is true if and only if

$$\frac{1+\alpha_2-2\alpha_2\beta_2}{(1+\alpha_2)31/30-2\alpha_2\beta_2} > \frac{(1+\alpha_2)29-30\alpha_2\beta_2}{(1+\alpha_2-\alpha_2\beta_2)59} \iff$$

$$59(1+\alpha_2-2\alpha_2\beta_2)(1+\alpha_2-\alpha_2\beta_2)-[(1+\alpha_2)31/30-2\alpha_2\beta_2][(1+\alpha_2)29-30\alpha_2\beta_2] > 0 \tag{3}$$

The partial derivative of the expression in the LHS with respect to β_2 is

$$\begin{aligned}
&59[-2\alpha_2(1+\alpha_2-\alpha_2\beta_2)-\alpha_2(1+\alpha_2-2\alpha_2\beta_2)]+2\alpha_2[(1+\alpha_2)29-30\alpha_2\beta_2] \\
&\ +30\alpha_2[(1+\alpha_2)31/30-2\alpha_2\beta_2] \\
=&59\alpha_2(-3-3\alpha_2+4\alpha_2\beta_2)+\alpha_2[(1+\alpha_2)89-120\alpha_2\beta_2] \\
=&\alpha_2\left[116\alpha_2\beta_2-(1+\alpha_2)89\right] \leq \alpha_2\left(347\alpha_2/15-89\right) \leq 0
\end{aligned}$$

where the first inequality follows from $\beta_2 \leq 29/30$ and the second from $\alpha_2 \leq 1$.

Inequality (3) indeed holds for $\beta_2 = 29/30$ and $\alpha_2 \leq 1$, and thus for every $\beta_2 \in [0{,}29/30]$.

Now it remains to see when both M and N are best-responses along with L. This is true iff

$$\begin{aligned}
\frac{1+\alpha_2-2\alpha_2\beta_2}{(1+\alpha_2)31/30-2\alpha_2\beta_2} &= \frac{(1+\alpha_2)(\delta-50)/300-\alpha_2\beta_2}{1+\alpha_2-\alpha_2\beta_2} \iff \\
\delta = 50+\frac{300}{1+\alpha_2}\frac{(1+\alpha_2-2\alpha_2\beta_2)(1+\alpha_2-\alpha_2\beta_2)+\alpha_2\beta_2\left((1+\alpha_2)31/30-2\alpha_2\beta_2\right)}{(1+\alpha_2)31/30-2\alpha_2\beta_2} &\iff \\
\delta = 50+\frac{300}{1+\alpha_2}\frac{(1+\alpha_2-2\alpha_2\beta_2)(1+\alpha_2)+\alpha_2\beta_2(1+\alpha_2)/30}{(1+\alpha_2)31/30-2\alpha_2\beta_2} &\iff \\
\delta = \delta^* := 50+300\frac{1+\alpha_2-59\alpha_2\beta_2/30}{(1+\alpha_2)31/30-2\alpha_2\beta_2}&.
\end{aligned}$$

Last, when the column player mixes between L and N, the row player is indifferent between T and B if and only if

$$\begin{aligned}
0 =&10\left(20+\alpha_1(20-5\beta_1)\right)\sigma_2(L)-10\left(2+\alpha_1\max\{2-19\beta_1,0\}\right)(1-\sigma_2(L)) \iff \\
0 =& \left(22+\alpha_1(20-5\beta_1+\max\{2-19\beta_1,0\})\right)\sigma_2(L)-\left(2+\alpha_1\max\{2-19\beta_1,0\}\right),
\end{aligned}$$

and the result follows. **Q.E.D.**

B.3 Proof of section 5

Proof of Claim 5. Claim 5 is the same as part (i) of Claim 5', which we prove later on. **Q.E.D.**

B.4 Proofs of section A

Proof of Lemma 1. It is trivial and thus omitted.

Proof of Propositions 1 and 3. Given Lemma 1, it suffices to prove Proposition 3. Assumption 1 implies that for any action profile $s \in S$ the modified payoff of a player is not higher than the baseline one: $\forall s \in S, i \in N$ $m_i(s_i, s_{-i}) \leq u_i(s_i, s_{-i})$. Also, if player i (pure) best-responds, she experiences no regret and thus the relation holds with equality: $s_i \in PBR_i(s_{-i}) \implies m_i(s_i, s_{-i}) = u_i(s_i, s_{-i})$.

First I show that $PNE(G) \subset PRE(G)$. If there is no pure Nash equilibrium, then it follows trivially that $PNE(G) \subset PRE(G)$. Now consider the case where $PNE(G) \neq \emptyset$; take an arbitrary equilibrium $s^* \in PNE(G)$. Then for every player $i \in N$, $u_i(s_i^*, s_{-i}^*) \geq u_i(s_i, s_{-i}^*)$ $\forall s_i \in S_i$, and given what we saw above

$$m_i(s_i^*, s_{-i}^*) = u_i(s_i^*, s_{-i}^*) \geq u_i(s_i, \sigma_{-i}^*) \geq m_i(s_i, \sigma_{-i}^*) \ \forall s_i \in S_i,$$

so $s^* \in RE(G)$. Thus, $PNE(G) \subset PRE(G)$.

Now, to see that also $PRE(G) \subset PNE(G)$, suppose by contradiction that $\exists s^* \in PRE(G) \setminus PNE(G)$. Since $s^* \notin PNE(G)$, there exists player $j \in N$ such that $s_j^* \notin PBR_j(\sigma_{-j}^*)$. It follows that there exists $s_j' \in S_j \setminus \{s_j^*\}$ such that $u_j(s_j', s_{-j}^*) = \max_{s_j \in S_j} u_j(s_j, s_{-j}^*) > u_j(s_j^*, s_{-j}^*)$. But given assumption 1, we have then that $m_j(s_j', s_{-j}^*) = u_j(s_j', s_{-j}^*) > u_j(s_j^*, s_{-j}^*) \geq m_j(s_j^*, s_{-j}^*)$, which contradicts $s^* \in PRE(G)$. Thus, $PNE(G) \supset PRE(G)$. **Q.E.D.**

Proof of Proposition 4. Fix an arbitrary $s \in S$ and $i \in N$. Any best-response $s_j' \in PBR_j(s_i)$ of player j to player i's action satisfies $u_j(s_i, s_j') \geq u_j(s_i, s_j)$. This combined with the fact that the game is WUC implies that $u_i(s_i, s_j') \leq u_i(s_i, s_j)$ for any $s_j' \in PBR_j(s_i)$. Thus, $u_i^{ba}(s) \leq u_i(s)$, so $u_i^b(s) = u_i(s)$. **Q.E.D.**

Proof of Proposition 5. In proving Proposition 5, we will use the following Lemma, which studies the relation between dominance under baseline and dominance under modified payoffs. Dominance relations between actions are for the most part preserved when we move from baseline to single–agent regret preferences, which is however not true with strategic regret.

Lemma 2. Consider a two-player game $G \coloneqq \langle N, (S_i)_{i\in N}, (u_i)_{i\in N}, (m_i)_{i\in N}\rangle$ and let regret satisfy assumption 1.

(i) If 1(ii) is satisfied with the regret of player i constant in u_i^b (single-agent regret), then $\forall s_i, s_i' \in S_i$ and $\forall A_j \subset S_j$

$$u_i(s_i,s_j) > u_i(s_i',s_j)\ \forall s_j \in A_j \iff m_i(s_i,s_j) > m_i(s_i',s_j)\ \forall s_j \in A_j,$$

(ii) If assumption 2 is satisfied for $\beta_i > 0$, so that 1(ii) is satisfied with regret decreasing in u_i^b (strategic regret) in a subset of the domain $\mathbb{DR}$, then the above does not follow.

(iii) Assume that $r_i\left(u_i, u_i^{br}, u_i^b\right)$ is concave (resp. convex) in u_i. If 1(ii) is satisfied with the regret of player i constant in u_i^b (single-agent regret), then $\forall(\sigma_i, s_i') \in \Delta(S_i) \times S_i$ and $\forall A_j \subset S_j$

$$u_i(\sigma_i,s_j) > u_i(s_i',s_j)\ \forall s_j \in A_j \overset{(\text{resp. } \Longleftarrow)}{\Longrightarrow} m_i(\sigma_i,s_j) > m_i(s_i',s_j)\ \forall s_j \in A_j.$$

(iv) If assumption 2 is satisfied for $\beta_i > 0$, so that 1(ii) is satisfied with regret decreasing in u_i^b (strategic regret) in a subset of the domain $\mathbb{DR}$, then the above does not follow.

Proof of Lemma 2.

(i) $\Longrightarrow$: For any $s_i, s_i' \in S_i$ and $\forall A_j \subset S_j$ we have that if $u_i(s_i,s_j) > u_i(s_i',s_j)\ \forall s_j \in A_j$, then by definition of modified utility $\forall s_j \in A_j$

$$m_i(s_i,s_j) + r_i\left(u_i(s_i,s_j), u_i^{br}(s_j), u_i^b(s_i,s_j)\right) > m_i(s_i',s_j) + r_i\left(u_i(s_i',s_j), u_i^{br}(s_j), u_i^b(s_i',s_j)\right),$$

Given (a) assumption 1(ii), (b) that regret is constant in its third argument, and (c)

$u_i(s_i,s_j) > u_i(s_i',s_j)$ $\forall s_j \in A_j$, we get that $\forall s_j \in A_j$

$$r_i\left(u_i(s_i,s_j),u_i^{br}(s_j),u_i^b(s_i,s_j)\right) \leq r_i\left(u_i(s_i',s_j),u_i^{br}(s_j),u_i^b(s_i',s_j)\right),$$

which combined with the first inequality implies that $\forall s_j \in A_j$, $m_i(s_i,s_j) > m_i(s_i',s_j)$.

$\Longleftarrow$: I prove the contrapositive. For any $s_i,s_i' \in S_i$ and $\forall A_j \subset S_j$ if $\exists s_j \in A_j$ such that $u_i(s_i,s_j) \leq u_i(s_i',s_j)$, then for such s_j

$$m_i(s_i,s_j) + r_i\left(u_i(s_i,s_j),u_i^{br}(s_j),u_i^b(s_i,s_j)\right) \leq m_i(s_i',s_j) + r_i\left(u_i(s_i',s_j),u_i^{br}(s_j),u_i^b(s_i',s_j)\right),$$

which given (a) assumption 1(ii), (b) that regret is constant in its third argument, and (c) $u_i(s_i,s_j) \leq u_i(s_i',s_j)$, implies that $m_i(s_i,s_j) \leq m_i(s_i',s_j)$ for such s_j.

(ii) Consider the game depicted in Figure 10. With baseline payoffs B dominates T, but with modified ones it does not.

Figure 10: Game with baseline payoffs (on the left) and with modified payoffs with strategic regret (on the right)

	L	M	R
T	1,1	1,1	4,2
C	4,3	4,2	-2,1
B	2,1	2,3	5,2

	L	M	R
T	1,1	1,1	3,2
C	4,3	4,1	-3,0
B	0,1	0,3	5,1

Notes: the modified payoffs are given by functions (1) and (2) for $\alpha_1 = \alpha_2 = 1$ and $\beta_1 = \beta_2 = 1$.

(iii) With $r_i\left(u_i,u_i^{br},u_i^b\right)$ concave in u_i, as in (i) we get that $\forall(\sigma_i,s_i') \in \Delta(S_i) \times S_i$ and $\forall A_j \subset S_j$, if $u_i(\sigma_i,s_j) > u_i(s_i',s_j)$ $\forall s_j \in A_j$ then

$$m_i(\sigma_i,s_j) + \prod_{s_i \in S_i} r_i\left(u_i(s_i,s_j),u_i^{br}(s_j),u_i^b(s_i,s_j)\right)\sigma_i(s_i)$$
$$> m_i(s_i',s_j) + r_i\left(u_i(s_i',s_j),u_i^{br}(s_j),u_i^b(s_i',s_j)\right) \quad \forall s_j \in A_j.$$

Then, to show that $m_i(\sigma_i,s_j) > m_i(s_i',s_j)$ $\forall s_j \in A_j$, it is sufficient to show that $\forall s_j \in A_j$

$$\prod_{s_i \in S_i} r_i\left(u_i(s_i,s_j),u_i^{br}(s_j),u_i^b(s_i,s_j)\right)\sigma_i(s_i) \leq r_i\left(u_i(s_i',s_j),u_i^{br}(s_j),u_i^b(s_i',s_j)\right).$$

By concavity of r_i in its first argument (and since r_i is constant in its third argument) and using Jensen's inequality we get that $\forall s_j \in A_j$

$$\prod_{s_i \in S_i} r_i \left(u_i(s_i,s_j), u_i^{br}(s_j), u_i^b(s_i,s_j) \right) \sigma_i(s_i) \leq r_i \left(u_i(\sigma_i,s_j), u_i^{br}(s_j), u_i^b(s_i',s_j) \right).$$

Also, by assumption 1(ii) and the fact that $u_i(\sigma_i,s_j) > u_i(s_i',s_j)$ $\forall s_j \in A_j$, it follows that $\forall s_j \in A_j$, $r_i \left(u_i(\sigma_i,s_j), u_i^{br}(s_j), u_i^b(s_i',s_j) \right) \leq r_i \left(u_i(s_i',s_j), u_i^{br}(s_j), u_i^b(s_i',s_j) \right)$, which combined with the inequality above gives the desired sufficient condition.

With $r_i \left(u_i, u_i^{br}, u_i^b \right)$ convex in u_i I show the contrapositive. Assume $u_i(\sigma_i,s_j) \leq u_i(s_i',s_j)$, $\exists s_j \in A_j$. Then, for such s_j

$$\begin{aligned} m_i(\sigma_i,s_j) + \prod_{s_i \in S_i} r_i \left(u_i(s_i,s_j), u_i^{br}(s_j), u_i^b(s_i,s_j) \right) \sigma_i(s_i) \\ \leq m_i(s_i',s_j) + r_i \left(u_i(s_i',s_j), u_i^{br}(s_j), u_i^b(s_i',s_j) \right). \end{aligned}$$

Thus, to show that $m_i(\sigma_i,s_j) \leq m_i(s_i',s_j)$, it is sufficient to show that for such s_j

$$\prod_{s_i \in S_i} r_i \left(u_i(s_i,s_j), u_i^{br}(s_j), u_i^b(s_i,s_j) \right) \sigma_i(s_i) \geq r_i \left(u_i(s_i',s_j), u_i^{br}(s_j), u_i^b(s_i',s_j) \right),$$

which follows (similarly as above) by convexity of r_i combined with Jensen's inequality, the fact that r_i is constant in its third argument, and assumption 1(ii) combined with the fact that $u_i(\sigma_i,s_j) \leq u_i(s_i',s_j)$.

(iv) For a counterexample see point (ii) above, where it can be checked that the regret of the row player is constant (and thus linear) in her realized payoff over $\mathbb{DR}$.

Q.E.D.

(i) Given point (i) from Lemma 2 the exact same procedure of iterated deletion of strictly dominated strategies is used under baseline and modified payoffs.

(ii) Consider the game depicted in Figure 10. With baseline payoffs B dominates T, then M dominates R, then C dominates B, and finally L dominates M. However, with modified payoffs no action is dominated.

(iii) If $r_i \left(u_i, u_i^{br}, u_i^b \right)$ is concave (resp. convex) in u_i, then by point (iii) of Lemma 2 the exact same procedure of iterated deletion of strictly dominated strategies that is used under baseline (resp. modified) payoffs can be used under modified (resp. baseline) payoffs—and after the procedure is finished, additional actions may be deleted, thus the inclusion relation.

(iv) For counterexamples see point (ii) above. **Q.E.D.**

Proof of Proposition 6. For any action profile $s \in S$ the best-responses and the actions that give the blame payoffs are the same in the two u-strategically equivalent games. Then, for modified payoffs $\forall s \in S, i \in N$ (suppressing functional notation) we have:

$$\begin{aligned}
m_i^2(s_i,s_j) &= u_i^2 - \alpha_i \max\left\{u_i^{2;pbr} - \left[\beta_i u_i^{2;of} + (1-\beta_i)u_i^2\right], 0\right\} \\
&= \kappa_i u_i^1 + \lambda_i - \alpha_i \max\left\{\begin{aligned} &\kappa_i u_i^{1;pbr} + \lambda_i - \Big[\beta_i\left(\kappa_i u_i^{1;of} + \lambda_i\right) \\ &\qquad + (1-\beta_i)\left(\kappa_i u_i^1 + \lambda_i\right)\Big], 0\end{aligned}\right\} \\
&= \kappa_i u_i^1 + \lambda_i - \alpha_i \kappa_i \max\left\{u_i^{1;pbr} - \left[\beta_i u_i^{1;of} + (1-\beta_i)u_i^1\right], 0\right\} \\
&= \kappa_i \left(u_i^1 - \alpha_i \max\left\{u_i^{1;pbr} - \left[\beta_i u_i^{1;of} + (1-\beta_i)u_i^1\right], 0\right\}\right) + \lambda_i \\
&= \kappa_i m_i^1(s_i,s_j) + \lambda_i
\end{aligned}$$

so an affine transformation of baseline payoffs implies an affine transformation (the same one) of modified payoffs. **Q.E.D.**

Proof of Claim 5'. (i) Volunteering is optimal for i if and only if

$$\phi_1(1-\xi_i) + \left[\phi_1 - \alpha_i(\phi_2 - \phi_1)\right]\xi_i \geq \phi_2 \xi_i + \left[0 - \alpha_i \max\{\phi_1 - \beta_i\phi_2, 0\}\right](1-\xi_i) \iff$$
$$\xi_i \leq \tau_i := \frac{\phi_1 + \alpha_i \max\{\phi_1 - \beta_i\phi_2, 0\}}{(1+\alpha_i)(\phi_2-\phi_1) + \phi_1 + \alpha_i \max\{\phi_1 - \beta_i\phi_2, 0\}}.$$

(ii) Clearly, the only equilibria where (at least) one player volunteers with probability 1 are the asymmetric pure equilibria where exactly one player volunteers. Thus, in identifying mixed equilibria, we can restrict attention to equilibria where each player i volunteers with probability $p_i \in [0,1)$.

With uncorrelated strategies, $\xi_i = 1 - \prod_{j \neq i}(1-p_j)$. Let $V_{\boldsymbol{p}} := \{i \in N : p_i > 0\}$ and

$NV_{\boldsymbol{p}} \coloneqq N \setminus V_{\boldsymbol{p}} = \{i \in N : p_i = 0\}$. Then, a player $i \in V_{\boldsymbol{p}}$ is best-responding if and only if

$$1 - \tau_i = \prod_{j \neq i}(1 - p_j), \tag{4}$$

which implies that for every pair of players $i,k \in V_{\boldsymbol{p}}$

$$\frac{1-\tau_i}{1-\tau_k} = \frac{\prod_{j\neq i}(1-p_j)}{\prod_{j\neq k}(1-p_j)} \implies \frac{1-\tau_i}{1-\tau_k} = \frac{1-p_k}{1-p_i}.$$

Substituting this back in (4), we get that

$$1 - \tau_i = \prod_{j \in V_{\boldsymbol{p}}\setminus\{i\}} \left[(1-p_i)\frac{1-\tau_i}{1-\tau_j}\right] \implies p_i = 1 - \frac{\Delta_{\boldsymbol{p}}^{1/(\nu-1)}}{1-\tau_i}, \tag{5}$$

where $\Delta_{\boldsymbol{p}} \coloneqq \prod_{j\in V_{\boldsymbol{p}}}(1-\tau_j)$ and $\nu \coloneqq |V_{\boldsymbol{p}}|$ the number of players volunteering with positive probability (notice that in any mixed equilibrium it must be that $\nu \geq 2$). $p_i \in (0,1)$ for every $i \in V_{\boldsymbol{p}}$ if and only if

$$\max_{i \in V_{\boldsymbol{p}}} \tau_i < 1 - \Delta_{\boldsymbol{p}}^{1/(\nu-1)}.$$

Provided that this holds, with p_i's given by (5), players in $V_{\boldsymbol{p}}$ are playing a RE among themselves. Thus, it remains to make sure that the remaining players also best-respond. This is true if and only if

$$1 - \prod_{j\neq i}(1-p_j) \geq \max_{i \in NV_{\boldsymbol{p}}} \tau_i \iff 1 - \prod_{j\in V_{\boldsymbol{p}}}\left(\frac{\Delta_{\boldsymbol{p}}^{1/(\nu-1)}}{1-\tau_j}\right) \geq \max_{i\in NV_{\boldsymbol{p}}} \tau_i \iff$$
$$1 - \frac{\Delta_{\boldsymbol{p}}^{\nu/(\nu-1)}}{\prod_{j\in V_{\boldsymbol{p}}}(1-\tau_j)} \geq \max_{i\in NV_{\boldsymbol{p}}} \tau_i \iff 1 - \Delta_{\boldsymbol{p}}^{1/(\nu-1)} \geq \max_{i\in NV_{\boldsymbol{p}}} \tau_i.$$

We conclude that $\boldsymbol{p}$ is a mixed equilibrium if and only if $\max_{i\in N}\tau_i \leq 1 - \Delta_{\boldsymbol{p}}^{1/(\nu-1)}$ and

$$p_i = 1 - \frac{\Delta_{\boldsymbol{p}}^{1/(\nu-1)}}{1-\tau_i} \quad \text{for every player } i \in V_{\boldsymbol{p}}.$$

(iii) For $\alpha_i = \alpha$, $\beta_i = \beta$, in a symmetric equilibrium

$$p_i = 1 - \frac{\Delta_{\boldsymbol{p}}^{1/(n-1)}}{1-\tau_i} = 1 - \frac{(1-\tau)^{n/(n-1)}}{1-\tau} = 1 - (1-\tau)^{1/(n-1)}.$$

Q.E.D.

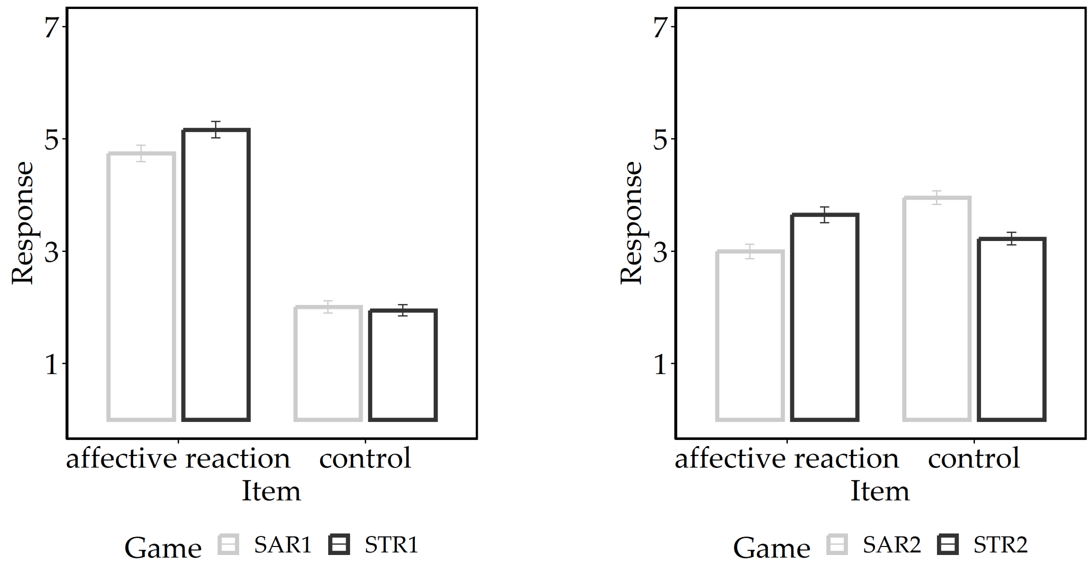
C Additional analyses of experimental data

C.1 Affective reaction and control item responses

Figure 11 presents the mean responses to the affective reaction and control item of the RBS. These suggest that in all games there is on average a significant (anticipated) emotional reaction to the outcome of the game.

Figure 11: RBS results: affective reaction and control items

(a) SAR1 and STR1 **(b)** SAR2 and STR2



Notes: bars of mean responses with standard error intervals.

We also verify that responses to the affective reaction item are negatively correlated with those to the control item, as seen in Table 8.

Table 8: RBS results: correlation between affective reaction and control item responses

Correlation coefficient	Game SAR 1	SAR2	STR1	STR2
Pearson	-0.26	-0.39	-0.22	-0.24
Kendall's τ_b	-0.25	-0.28	-0.29	-0.18

Notes: all coefficients are significant at the 1% level based on two-sided tests under the asymptotic t approximation (with a continuity correction).

C.2 Predictive power over incentivized play of RBS survey responses to STR versus SAR items

We run regressions to compare the predictive power of RBS survey responses to STR versus SAR items over incentivized play. Since STR—but not SAR—games allow for blame as described in the theory, responses to STR items should be a better predictor than responses to SAR items. For each game type (SAR and STR) and each subject i, an index of blame intensity is calculated as a single principal component from the subject's 10 responses to items 2 through 5 and 7 in that game type (5 items times 2 games per game type):

$$\text{BISAR}_i \coloneqq \text{PC}\left(\left\{\begin{matrix} \text{regret}_{iSARj}, \text{blame}_{iSARj}, \text{internal attribution}_{iSARj}, \\ \text{external attribution}_{iSARj}, \text{choice between counterfactuals}_{iSARj} \end{matrix}\right\}_{j=1,2}\right),$$

$$\text{BISTR}_i \coloneqq \text{PC}\left(\left\{\begin{matrix} \text{regret}_{iSTRj}, \text{blame}_{iSTRj}, \text{internal attribution}_{iSTRj}, \\ \text{external attribution}_{iSTRj}, \text{choice between counterfactuals}_{iSTRj} \end{matrix}\right\}_{j=1,2}\right).$$

BISTR is the blame index also used in the main part of the analysis in section 6, while BISAR the corresponding index when SAR games are used instead of STR ones. BISAR (resp. BISTR) stands for *blame index SAR* (resp. *blame index STR*). After each principal component is calculated, it is normalized between 0 and 1 to produce the corresponding blame index.

Indeed, Table 9 shows that subjects with higher BISTR—but not BISAR—choose on average higher numbers in the traveler's dilemma.[73] The coefficient on BISTR shows that the participant with the highest index is expected to choose a number higher by 20-35 (depending on the bonus/penalty parameter) than the the number chosen by the participant with the lowest index. Similarly, Table 10 shows BISTR to be a better predictor of behavior in the stag hunt game than SAR, consistent with what we have seen in Figure 8.

C.3 Principal component analysis loadings

Table 11 presents the loadings in the principal component analysis that produced the indices BISAR and BISTR.

[73]The estimated coefficients of BISAR are smaller and not statistically significant.

Table 9: Linear regressions of number chosen in the traveler's dilemma on blame indices

b	5	10	15	20	30	40	50	60
BISAR	14.22	12.89	6.52	13.41	14.20	29.68	10.89	22.99
	(11.34)	(10.88)	(12.53)	(13.25)	(13.86)	(15.63)	(16.17)	(17.04)
BISTR	21.84	21.74	18.18	28.08	34.39	32.88	29.80	29.21
	(9.93)	(9.25)	(10.57)	(11.69)	(12.04)	(12.91)	(12.77)	(13.65)
Intercept	158.77	154.37	151.58	132.82	119.07	102.11	100.70	93.78
	(7.93)	(7.17)	(7.94)	(8.67)	(8.87)	(8.88)	(8.88)	(9.25)
N	202	202	202	202	202	202	202	202

Notes: coefficients with heteroscedasticity-consistent standard errors (HC3) clustered at the subject level in parentheses.

Table 10: Logistic regressions of the stag hunt action (stag = 1) on blame indices

Stag cost (c)	10	20	30	40	50	60	70	80
BISAR	−3.79	−2.16	−0.73	−0.74	−0.98	−1.57	−1.98	−2.27
	(4.43)	(1.90)	(1.16)	(1.03)	(1.02)	(1.09)	(1.16)	(1.26)
BISTR	5.94	0.73	1.60	1.86	2.15	1.70	1.78	1.38
	(4.52)	(1.66)	(0.97)	(0.87)	(0.88)	(0.92)	(0.96)	(1.01)
Intercept	3.14	3.10	0.47	−0.40	−1.23	−1.28	−1.38	−1.35
	(1.74)	(1.14)	(0.64)	(0.60)	(0.65)	(0.70)	(0.74)	(0.79)
N	100	100	100	100	100	100	100	100

Notes: coefficients with heteroscedasticity-consistent standard errors (HC3) clustered at the subject level in parentheses.

Table 11: PCA loadings in BISAR and BISTR

Index	Game	RBS item: regret	blame	internal attribution	external attribution	choice between counterfactuals
BISAR	SAR 1	-0.21	0.35	-0.37	0.41	-0.4
	SAR 2	-0.19	0.29	-0.23	0.35	-0.26
BISTR	STR 1	-0.29	0.31	-0.28	0.38	-0.37
	STR 2	-0.26	0.29	-0.3	0.36	-0.3

Notes: before the principal component analysis was performed, responses to each of the 20 items were centered and scaled to have zero mean and unit variance.

C.4 Additional test on the predictive power of RBS survey responses over behavior in the stag hunt game

Using Fisher's exact test, Table 12 verifies the result of Table 5 that subjects with high Blame Index choose stag more frequently than subjects with low Blame Index.

Table 12: Behavior of high versus low Blame Index subjects in the stag hunt game: Fisher's exact one-sided tests

Stag cost (c)	10	20	30	40	50	60	70	80
p-value	0.247	0.357	0.184	0.053	0.05	0.184	0.171	0.602

C.5 Additional tests on the relationship between behavior in the traveler's dilemma and behavior in the stag hunt game

Table 13 shows that the results of Table 6 are robust when we instead use a non-parametric test. Namely, for b and c not too low, participants that played stag in the stag hunt game chose higher numbers in the traveler's dilemma. Table 13(a) shows that the difference is large: the median number chosen by the former is larger by about 30 to 100 (compared to the median number chosen by the latter) depending on the parameters of the games.

C.6 Order effects

Table 14 shows that the null hypothesis that no order/priming effects exist for the traveler's dilemma cannot be rejected at the 10% level for any value of b. Similarly, Table 15 and Figure 12 shows that the null hypothesis that no order/priming effects exist for the stag hunt game cannot be rejected for any value of c. Filling in the RBS questionnaire before playing the traveler's dilemma and stag hunt game does not seem to affect behavior.

Table 13: Number chosen in the traveler's dilemma: participants who played stag in the stag hunt game versus participants that played hare

(a) Difference in median number chosen (i.e., median number chosen by those that played stag minus the median number chosen by those that played hare)

		Stag cost (c)							
		10	20	30	40	50	60	70	80
	5	48	0.5	4	0	4	0	0	0.5
	10	27.5	26.5	19	19	35	11	1	10.5
Bonus/	15	-25	-2	33	29	40	26	25	28
penalty	20	-1	28	48	38	42	29	28	26.5
(b)	30	5	45	49	49	70	51	55	55
	40	-20.5	34.5	60	62	72	68	61	71.5
	50	-47.5	17.5	33	50	69	69	69	87
	60	-50.5	-10.5	20	54	60	60	89	102.5

(b) Wilcoxon-Mann-Whitney one-sided p-values

		Stag cost (c)							
		10	20	30	40	50	60	70	80
	5	0.39	0.56	0.25	0.49	0.08	0.57	0.67	0.38
	10	0.51	0.1	0.06	0.26	0	0.1	0.23	0.1
Bonus/	15	0.97	0.68	0.06	0.14	0	0.02	0.07	0.03
penalty	20	0.71	0.24	0.03	0.12	0	0.04	0.07	0.03
(b)	30	0.54	0.2	0.01	0.01	0	0	0.01	0
	40	0.74	0.23	0.01	0	0	0	0	0
	50	0.67	0.19	0.01	0	0	0	0	0
	60	0.66	0.43	0.12	0	0	0	0	0

Notes: the sample size for each cell in each table is 100 participants. In the Wilcoxon-Mann-Whitney test, the alternative hypothesis is that if we randomly select a participant that played stag and one that played hare, the probability that the former chose a higher number in the traveler's dilemma (than the latter) is higher than the probability that the latter chose a higher number in the traveler's dilemma (than the former).

D Participant instructions (for stag hunt treatment)

This section presents the participant instructions. After the instructions were read, the ability of participants to read two-player game matrices was tested before they completed any survey or played any game. Before playing the traveler's dilemma, volunteer's dilemma, and stag hunt game, participants answered comprehension questions on how the game works.[74] The instructions follow:

[74] In all comprehension tests, only after they answered correctly were the subjects allowed to proceed.

Table 14: Order effects in the traveler's dilemma: Kolmogorov-Smirnov test p-values

				b			
5	10	15	20	30	40	50	60
0.168	0.187	0.287	0.305	0.995	0.108	0.314	0.354

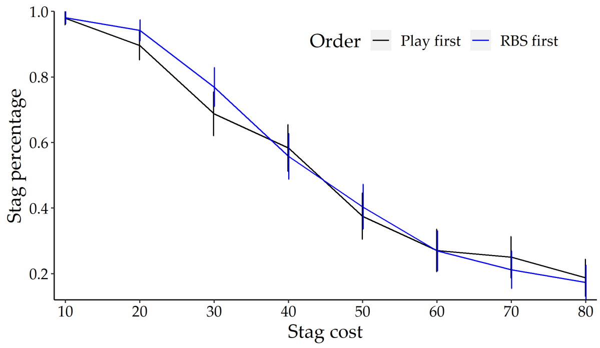
Notes: for each value of b, the null hypothesis is that the numbers chosen in the traveler's dilemma in the treatment where participants answered the SAR portion of the RBS first are drawn from the same distribution as the numbers chosen in the treatment where participants first played the traveler's dilemma and stag hunt game, and then completed the SAR portion of the RBS. Since the distributions are discrete, simulated (two-sided) p-values are reported with 10,000 replicates used in the Monte Carlo simulation.

Table 15: Order effects in the stag hunt game: exact test two-sided p-values

				c				
	10	20	30	40	50	60	70	80
Fisher's exact test	1	0.475	0.377	0.842	0.839	1	0.812	1
Boschloo's test	1	0.416	0.334	0.832	0.824	1	0.775	1

Notes: for each value of c, the null hypothesis is that the percentage of participants that play stag in the treatment where participants answered the SAR portion of the RBS first is equal to the corresponding percentage in the treatment where participants first played the traveler's dilemma and stag hunt game, and then completed the SAR portion of the RBS.

Figure 12: Order effects in the stag hunt game



Notes: the percentage of subjects that chose stag with standard error intervals is reported.

"Welcome to our experiment!

D.1 General guidelines

During this experiment you and other participants will be asked to answer questions and make decisions in various different settings. In the end of the experiment you will receive a sum of money that will depend both on your decisions and the other participants' decisions during the experiment. Therefore, it is important that you read these instructions carefully, so that you can make informed decisions during the experiment.

The experiment will last approximately 90 minutes; even if a participant finishes earlier, they will have to wait until the experiment has concluded to receive their payment. Thus, it is best to spend your time considering carefully the different scenarios presented in the experiment.

No communication with the other participants is allowed during the experiment. Any participant who fails to follow this rule will be excluded from the experiment and will receive no payment. Should you have any questions, please raise your hand.

During the experiment, the currency that is used will not be dollars but points. Your earnings will therefore initially be calculated in points. The total number of points that you accumulate during the experiment will be paid to you in dollars (you will get a receipt which you will then bring to the Office of the Bursar to receive money) at a rate of:

$$1 \text{ point} = 0.04 \text{ dollars } (25 \text{ points} = 1 \text{ dollar}).$$

D.2 What is a game?

A game is a situation where each of multiple (2 or more) participants makes decisions (independently and privately) and the number of points that each participant earns depends (based on well-defined rules) on the actions of that participant and the actions of the other participants in the game.

When there are two participants that take part in a game, it is sometimes (but not always) useful to present that game in a table. For example, a game with two players where each player has 3 actions to choose from can be represented as follows.

	L	M	R
T	a_1,a_2	b_1,b_2	c_1,c_2
C	d_1,d_2	e_1,e_2	f_1,f_2
B	g_1,g_2	h_1,h_2	i_1,i_2

where a_1,a_2,b_1,b_2, . . . ,i_1,i_2 are some numbers that differ from game to game (in a specific game you will see what these numbers are).

In this game, the *row player* has three actions to choose from:, T, C, and B. The *column player* also has three actions to choose from, L, M, and R. Thus, there are $3 \times 3 = 9$ possible outcomes in this game (e.g., a possible outcome is that the row player chooses C and the column player chooses R).

Each of the nine cells inside the table then gives the amount of points each player will earn in each possible outcome of the game. The first number in the cell is the amount of points earned by the row player and the second number in the cell is the amount of points earned by the column player. For example, if the row player chooses action C and the column player chooses action R, then the row player earns f_1 points and the column player earns f_2 points from this game.

D.3 Types of settings and questions that you will face during the experiment

There are two types of items in this experiment. You will first complete some items of the first type, then some of the second, and finally again some of the first type. Before completing items you will sometimes be asked to answer questions that will test your understanding of the item. Only after you have answered correctly will you be allowed to complete the items.

In the first item type, a hypothetical scenario is described to you and you are asked to describe your thoughts, feelings and emotions in that scenario. You will do so by denoting your level of agreement with various statements. For this type of item, you will be required to spend at least 3 minutes on a scenario before you can proceed to the next scenario (but you are free to spend more than 3 minutes). The button "Continue" will only appear on your screen after said amount of time has passed.

In the second item type, you are randomly matched with another participant and a game is described to both of you. Each of you then is asked to individually and privately choose an action in the game. You will play 3 different games and you will play each game multiple times. For each of the three games, one of these multiple rounds will be randomly selected by the computer to be the pay round. You will be rewarded points only for that pay round (and not for the other times that you played the specific game). Thus, the total number of points that you accumulate in this experiment will be the sum of three numbers (one number for each of the 3 games).

Each time that you play a game you are randomly matched with a participant. Thus, in most cases the participant that you play a game with will not be the same as the participant(s) that you played that game with before (unless by chance you are again matched with the same participant(s), which happens with low probability). After you have finished playing all the rounds of a game, you will see what the participant you were matched with in each round chose and which round has randomly been chosen to be the pay round.

D.4 Games that you will play (second item type)

D.4.1 Game 1 (8 rounds)

You will be repeatedly and randomly matched with another participant to play the following game. Each of you will privately choose a number (integer) between 80 and 200; that is, any of the following numbers: 80, 81, 82, . . . , 198, 199, 200.

- If you both choose the same number, then each of you earns points equal to that number.
- If you choose different numbers, then each of you earns points equal to the lowest of the two numbers plus a bonus or minus a penalty, which is determined as follows:
  - if you have chosen the lowest number of the two, then you receive a bonus of additional b points, and the other participant's points are reduced by a penalty of b points (the value of b will change from round to round and will be shown on everyone's screen).
  - if you have chosen the higher number of the two, then your points are reduced by a penalty of b points, and the other participant receives a bonus of additional b points.

For example, if you choose the number 135, the other participant chooses the number 145, and $b = 5$, then you receive $135 + 5 = 140$ points, while the other participant receives $135 - 5 = 130$ points.

D.4.2 Game 2 (8 rounds)

You will be repeatedly and randomly matched with 1 other participant (so that you are a group of 2 people in total) to play the following game.

Both you and the other person in your group will (individually and privately) decide whether to incur a cost to undertake an action (i.e., invest) that can benefit all the people in the group. The full benefit from this action is available to all the people in the group if both people in the group undertake the costly action.

The cost c of taking the action will be the same for all people in each group. In the game each player in the group decides whether to invest by incurring a cost of c points (the value of c will change from round to round and will be shown on everyone's screen). If a player does not invest, then that player incurs no cost.

If both people in your group decide to invest, both people in the group will receive 200 points. Thus, if both people (in a specific group) invest, then each person (in that specific group) earns $200 - c$ points.

If in a specific group none or only one person invests, then each person in that group earns 100 points (minus investment costs, when applicable).

For example, if $c = 20$ and you invest and the other person in your group does not invest, then you earn $100 - 20 = 80$ points and the other person (who does not incur the cost) earns 100 points.

The game can be presented in a table as follows:

	invest	not invest
invest	$200 - c$,$200 - c$	$100 - c$,100
not invest	100,$100 - c$	100,100

D.4.3 Game 3 (5 rounds)

You will be repeatedly and randomly matched with other participants to play the following game under various values of the parameter x (the value x will change from round to round and will be shown on everyone's screen).

	L	M	N	R
T	500,350	300,345	310,x	320,50
B	300,50	310,200	330,x	350,340

One of you will randomly be assigned the role of the row player and the other the role of the column player. All the times that you will play the game you will have the same role, either row or column player, as determined before the first time that you play the game."

Note: The instructions were modified accordingly in the other treatments. For example, in the four-player volunteer's dilemma treatment, Game 2 was described as follows:

"You will be repeatedly and randomly matched with 3 other participants (so that you are a group of 4 people in total) to play the following game.

Both you and each of the other 3 people in your group will (individually and privately) decide whether to incur a cost to undertake an action (i.e., invest) that can benefit all the people in the group.

The full benefit from this action is available to all the people in the group if at least one person from the group undertakes the costly action, and no additional benefit is accrued if more than one person incurs this cost.

The cost c of taking the action will be the same for all people in each group.

In the game each player in the group decides whether to invest by incurring a cost of c points (the value of c will change from round to round and will be shown on everyone's screen). If a player does not invest, then that player incurs no cost.

If at least one person in your group decides to invest, all people in the group will receive 200 points whether or not they invested themselves.

Thus, if at least one person (in a specific group) invests, then any person (in that specific group) who invests earns $200 - c$ points, and any person (in that specific group) who does not invest earns 200 points.

If in a specific group nobody invests, then each person in that group earns 40 points.

For example, if $c = 20$ and you invest and one more person in your group invests, then each of the two of you earns $200 - 20 = 180$ points and each of the two other people in your group (who do not incur the cost) earns 200 points."

E Screenshots from experiment interface

In comprehension tests, when a participant had given a wrong answer to one or more questions and clicked *Continue*, she received the following message: "You have answered some question(s) incorrectly. Please, read the instructions carefully and try again."

Figure 13: Game matrix comprehension screenshot

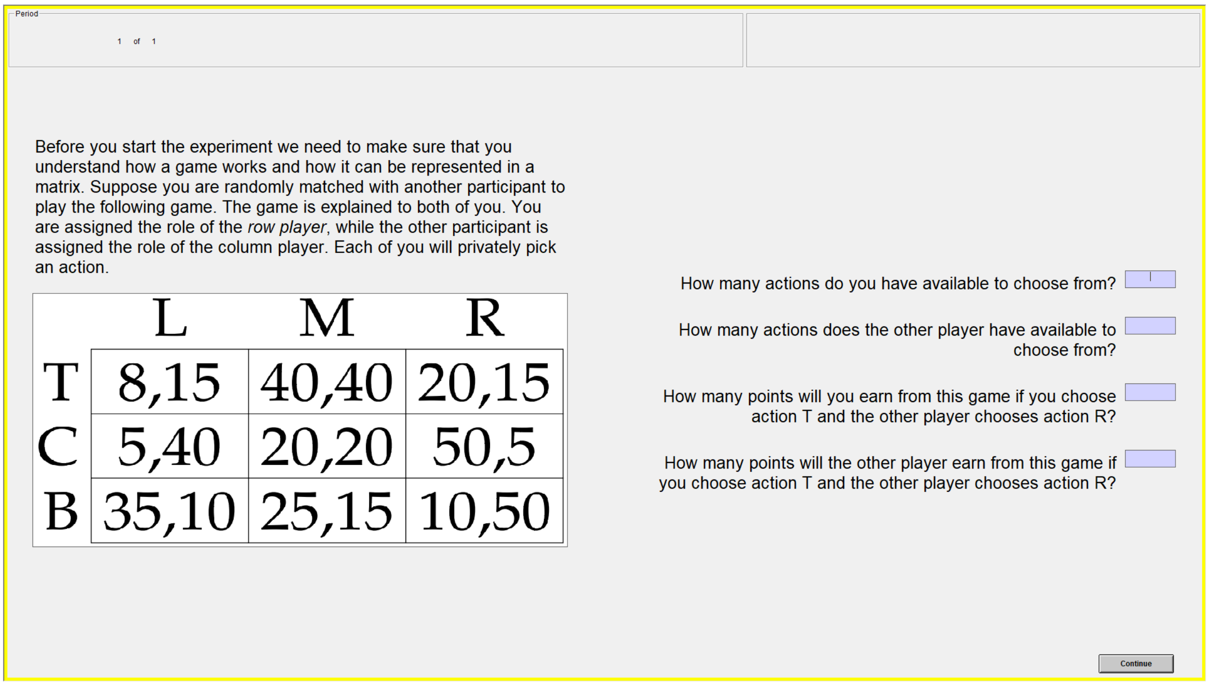
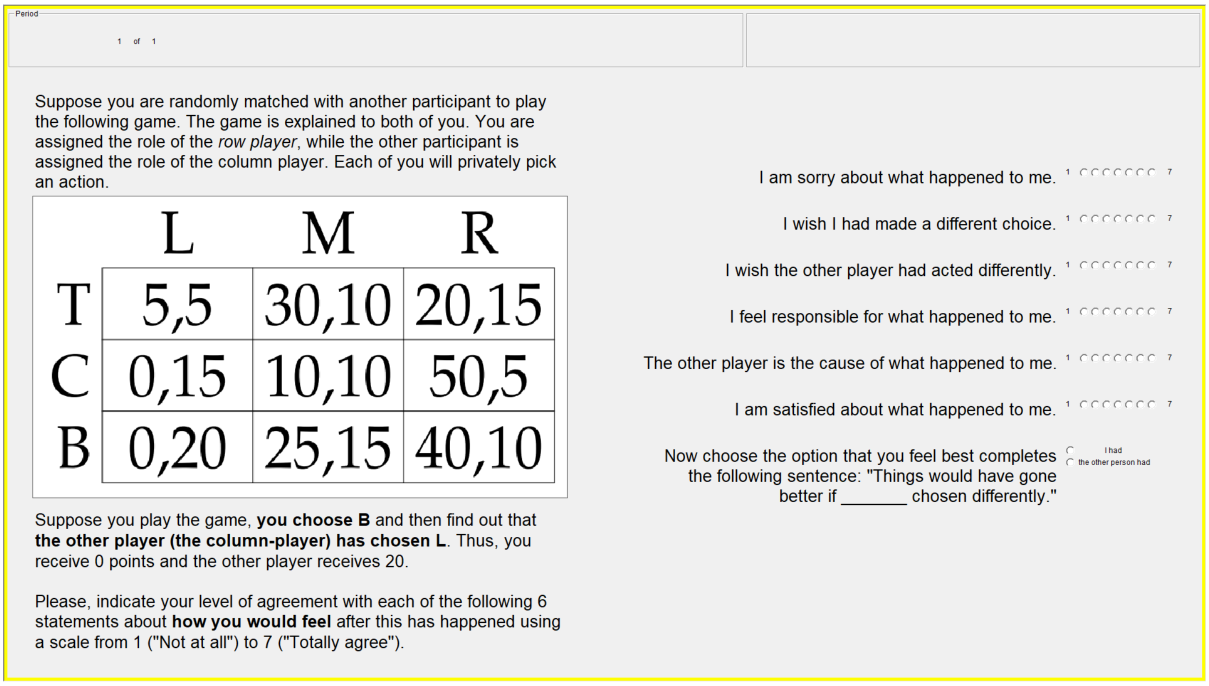
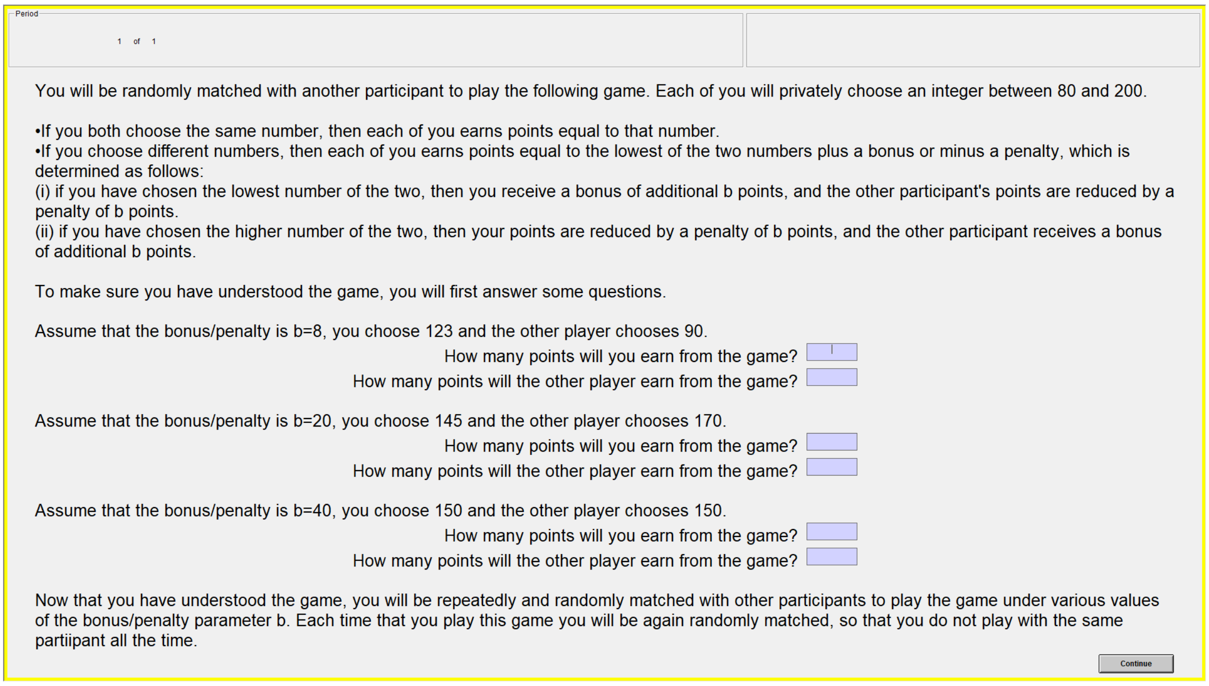


Figure 14: RBS survey for game SAR1 screenshot



Notes: the button *Continue* appeared in the bottom-right corner of the screen after 3 minutes had passed.

Figure 15: Traveler's dilemma comprehension test screenshot



Period

1 of 1

You will be randomly matched with another participant to play the following game. Each of you will privately choose an integer between 80 and 200.

•If you both choose the same number, then each of you earns points equal to that number.
•If you choose different numbers, then each of you earns points equal to the lowest of the two numbers plus a bonus or minus a penalty, which is determined as follows:
(i) if you have chosen the lowest number of the two, then you receive a bonus of additional b points, and the other participant's points are reduced by a penalty of b points.
(ii) if you have chosen the higher number of the two, then your points are reduced by a penalty of b points, and the other participant receives a bonus of additional b points.

To make sure you have understood the game, you will first answer some questions.

Assume that the bonus/penalty is b=8, you choose 123 and the other player chooses 90.
How many points will you earn from the game?
How many points will the other player earn from the game?

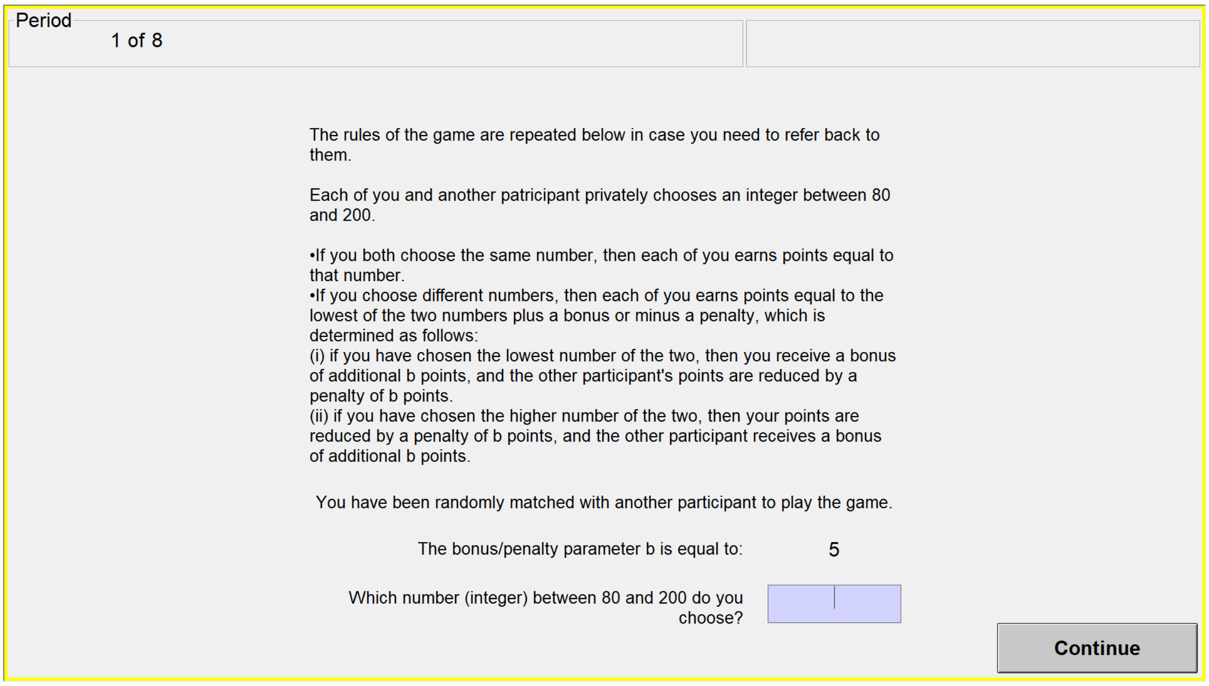
Assume that the bonus/penalty is b=20, you choose 145 and the other player chooses 170.
How many points will you earn from the game?
How many points will the other player earn from the game?

Assume that the bonus/penalty is b=40, you choose 150 and the other player chooses 150.
How many points will you earn from the game?
How many points will the other player earn from the game?

Now that you have understood the game, you will be repeatedly and randomly matched with other participants to play the game under various values of the bonus/penalty parameter b. Each time that you play this game you will be again randomly matched, so that you do not play with the same partiipant all the time.

Continue

Figure 16: Traveler's dilemma choice screenshot



Period

1 of 8

The rules of the game are repeated below in case you need to refer back to them.

Each of you and another patricipant privately chooses an integer between 80 and 200.

•If you both choose the same number, then each of you earns points equal to that number.
•If you choose different numbers, then each of you earns points equal to the lowest of the two numbers plus a bonus or minus a penalty, which is determined as follows:
(i) if you have chosen the lowest number of the two, then you receive a bonus of additional b points, and the other participant's points are reduced by a penalty of b points.
(ii) if you have chosen the higher number of the two, then your points are reduced by a penalty of b points, and the other participant receives a bonus of additional b points.

You have been randomly matched with another participant to play the game.

The bonus/penalty parameter b is equal to: 5

Which number (integer) between 80 and 200 do you choose?

Continue

Figure 17: Stag hunt game comprehension test screenshot

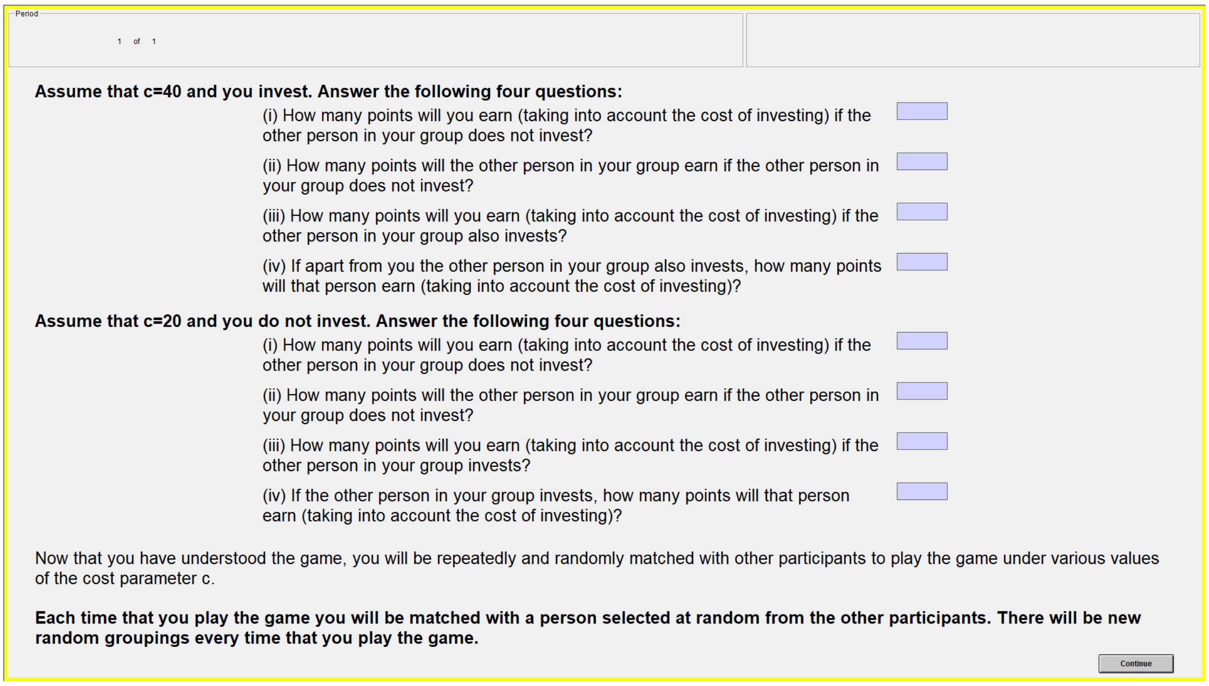


Figure 18: Stag hunt game choice screenshot

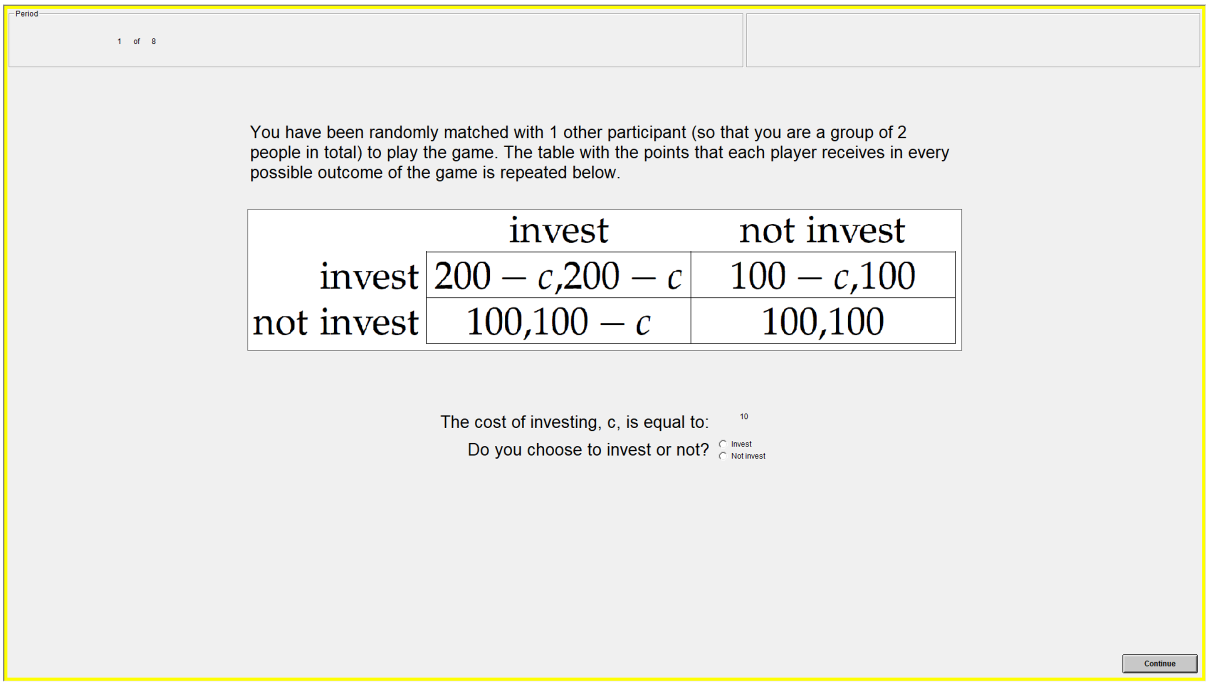
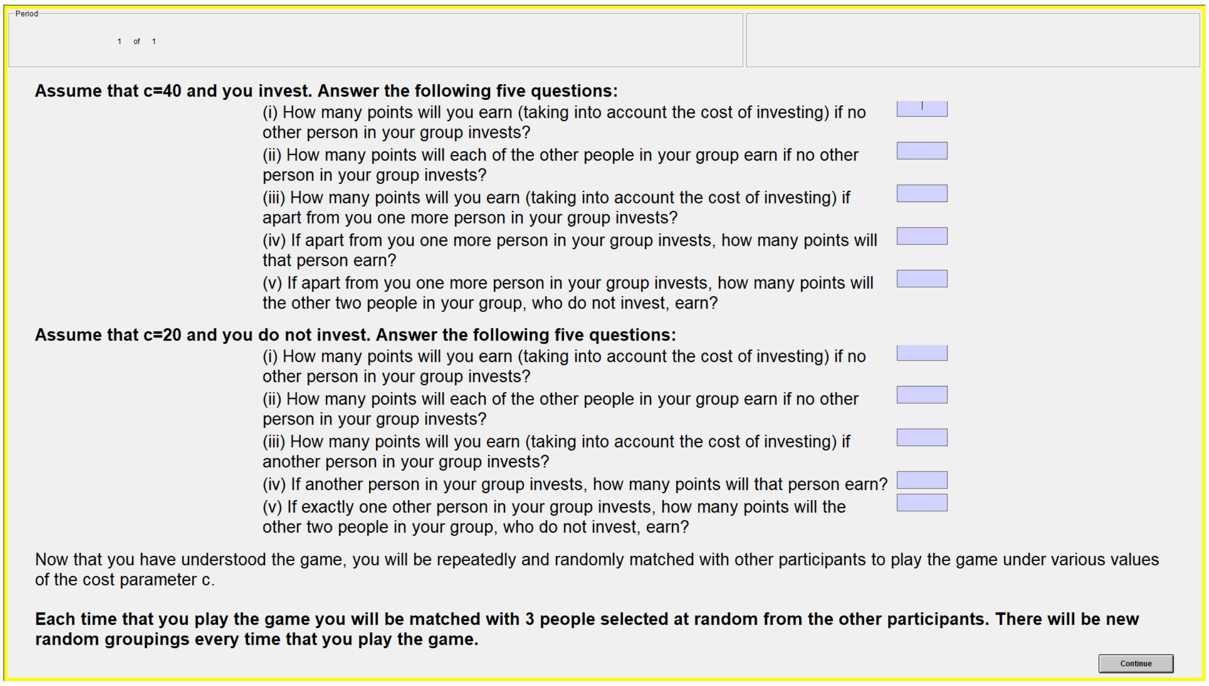


Figure 19: Four-player volunteer's dilemma comprehension test screenshot


Period

1 of 1

Assume that c=40 and you invest. Answer the following five questions:

(i) How many points will you earn (taking into account the cost of investing) if no other person in your group invests?

(ii) How many points will each of the other people in your group earn if no other person in your group invests?

(iii) How many points will you earn (taking into account the cost of investing) if apart from you one more person in your group invests?

(iv) If apart from you one more person in your group invests, how many points will that person earn?

(v) If apart from you one more person in your group invests, how many points will the other two people in your group, who do not invest, earn?

Assume that c=20 and you do not invest. Answer the following five questions:

(i) How many points will you earn (taking into account the cost of investing) if no other person in your group invests?

(ii) How many points will each of the other people in your group earn if no other person in your group invests?

(iii) How many points will you earn (taking into account the cost of investing) if another person in your group invests?

(iv) If another person in your group invests, how many points will that person earn?

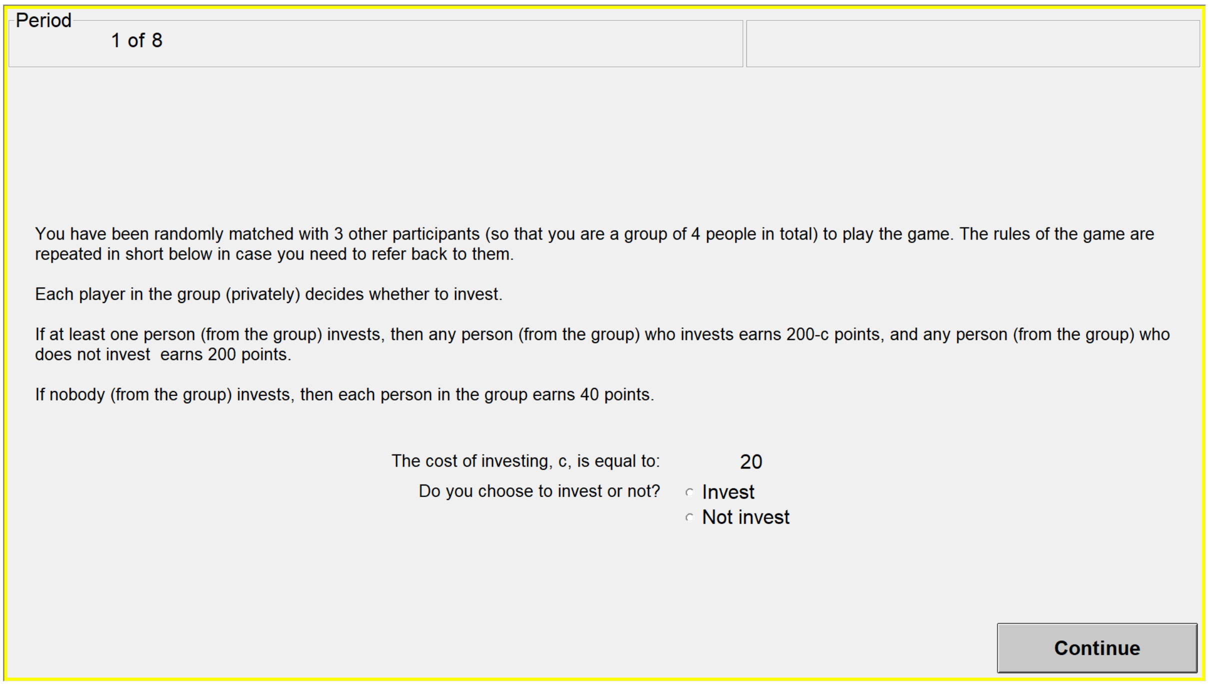
(v) If exactly one other person in your group invests, how many points will the other two people in your group, who do not invest, earn?

Now that you have understood the game, you will be repeatedly and randomly matched with other participants to play the game under various values of the cost parameter c.

Each time that you play the game you will be matched with 3 people selected at random from the other participants. There will be new random groupings every time that you play the game.

Continue

Figure 20: Four-player volunteer's dilemma choice screenshot


Period

1 of 8

You have been randomly matched with 3 other participants (so that you are a group of 4 people in total) to play the game. The rules of the game are repeated in short below in case you need to refer back to them.

Each player in the group (privately) decides whether to invest.

If at least one person (from the group) invests, then any person (from the group) who invests earns 200-c points, and any person (from the group) who does not invest earns 200 points.

If nobody (from the group) invests, then each person in the group earns 40 points.

The cost of investing, c, is equal to: 20

Do you choose to invest or not?

- Invest
- Not invest

Continue

Figure 21: Kreps game choice screenshot