

Climate extreme events and climate change are enforced by extortionate freeriders overloading those who mitigate – **An economic experiment**

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ABSTRACT

Climate extremes have become more frequent and severe due to excessive human emissions, yet it remains unclear whether the threat of costly hazards spurs collective mitigation. In a laboratory experiment, groups of six players contributed individually towards a collective target that, if unmet, triggered a simulated climate catastrophe and forfeiture of their endowment. Some groups also faced intermediate climate events, avoidable through sufficient mitigation to prevent costly losses. Although many groups suffered from losses, they reached the final target as often as the control groups without simulated climate events. Player behavior had two variants: “fair players”, who consistently contributed their share, and “extortioners”, who free-rode and forced others to compensate for their lack of contribution. Groups were randomly composed of participants, whose observed behavior revealed between 0 and 5 individuals acting as extortioners. When extortion became overwhelming, fair players failed to absorb the deficit, groups missed the target and steadfast extortioners incurred losses too. Extortioners disregarded losses and accumulated a large gain while fair players earned little. Nonetheless, fair players’ best response was to accede to extortion and cover the deficit. Extortion decreased mitigation across all conditions. Our findings may help to illustrate mechanisms also relevant in the real world where individual actions e.g., leisure travel on giant cruise ships or running power plants with coal, and much else, ultimately prevent collective success. In 2024, global CO₂ emissions and temperatures reached record highs, stressing the inability of fair players to compensate the deficit caused by freeriders. This dynamic suggests that the persistence of climate change stems from the unwavering behavior of extortioners in contexts outside of the laboratory.

Keywords:

Climate change, Mitigation, Collective risk social dilemma, Climate extreme events, Endgame, Extortion, Sanctions

Data availability

All raw data are available at Oxford University Research Archive (ORA), DOI 10.5287/oraovw148nxk.

1. Introduction

Consider a situation, in which groups of agents face threats of environmental and natural resources damages and the parties involved must work collectively to avoid impending costs. The most prominent example is climate change.

To date, efforts to tackle climate change have been slow and insufficient to put the world on a path towards Net Zero emissions (Hamburg Climate Future Outlook, 2024; Hausfather and Peters, 2020). This is in part due to strong interest groups, but also due to entrenched social dynamics (CLICCS, 2021) which appear to prevent people from reducing their environmental impact (IPCC, 2021).

Mitigating climate change is a social dilemma (Hardin, 1968). The benefits of cooperating to reduce greenhouse gas emissions are shared but the costs of doing so are individual, thus the economic incentive is for everyone to free-ride on the sacrifices of others. Furthermore, people might be less inclined to engage in pro-environmental action if they

perceive others are not acting as well (Fischbacher et al., 2001; Van Valkengoed et al., 2022a). The benefit from one's actions today for the well-being of future generations or distal populations are heavily discounted (Jacquet et al., 2013; Schelling, 1995), making them seem unworthy of effort (Jacquet et al., 2013).

However, the effects of climate change are evident. Recent IPCC reports (IPCC, 2018, 2021, 2022) are unequivocal in stating that globally, average and extreme heat are increasing (IPCC, 2021; Coumou and Rahmstorf, 2012; Fischer and Knutti, 2015; Fischer and Knutti, 2015), with tens of thousands of deaths directly attributable to climate change (Clarke et al., 2022). Progress in climate science modelling has also made clear that natural hazards and disasters such as floods, hurricanes, droughts and wildfires are growing in intensity due to increasing global temperature fueled by CO₂ emissions and methane production (IPCC, 2022; Murali et al., 2023; Otto et al., 2023; Philip et al., 2020).

How do humans respond when being confronted with severe climate events? Being exposed to extreme events could increase awareness of climate change and the perceived need to adapt to its effects (Steg, 2023; Van Valkengoed et al., 2022b; Van Valkengoed et al., 2022b; Van Valkengoed and Steg, 2019). Insights from the psychology of climate change (Steg, 2023) reveal that people's perceptions of the issue serve as general psychological antecedents that encourage engagement in a variety of adaptation activities, enhancing sentiments of moral obligation and personal responsibility (Nielsen et al., 2021; Van Lange et al., 2013; Van Valkengoed et al., 2022a; Van Valkengoed et al., 2022b).

Multiple studies have found a positive correlation between extreme weather events and pro-environmental behavior (Adger et al., 2013; Grothmann and Patt, 2005; Spence et al., 2011; Van Valkengoed et al., 2022a; Zaalberg et al., 2009). However, these studies have faced criticism (Demski et al., 2017; Howe, 2018; Howe et al., 2019) for their inability to establish causality (Rüttenauer, 2023). First, many of these studies use cross-sectional data. Large-scale individual-level data and longitudinal designs (Rüttenauer, 2023; Spence et al., 2011) are needed to elucidate the relationship between the experience of extreme weather events and behavior. Second, these studies rely on self-reported behavior and are unable to identify personal damages caused by the events. Recent studies analyzed panel data from individuals affected by floods and heatwaves in the UK, and found that exposure to these events increased beliefs in climate change, but surprisingly did not lead to a change in behavior (Lohmann and Kontoleon, 2023; Rüttenauer, 2023).

To causally link how extreme climate events impact efforts to mitigate climate change, experiments are essential. Rather than replicating real-world conditions, these experiments isolate specific mechanisms to draw causal conclusions. Laboratory settings simulate essential aspects of natural situations, employing the techniques of experimental economics pioneered by Nobel laureate Vernon Smith (e.g., Smith, 1994). Participants are assigned defined roles and receive rewards based on their performance during the experiment, mirroring real-world incentives. This controlled environment simplifies complex processes, offering insights difficult to obtain through other methods. As a result, researchers can establish cause-and-effect relationships. Conversely, while observational studies can reflect the full complexities of real-life situations, they do not necessarily allow for causal conclusions.

Our study relies on the collective-risk social dilemma design, a framework introduced by Milinski et al. (2008), which models scenarios where individuals must contribute to a collective target to avoid negative outcomes. The dilemma is especially relevant to climate change, where cooperation is needed to prevent surpassing certain global temperature thresholds and risking 'dangerous climate change' (Schneider, 2001; Schneider, 2004).

In this experimental set-up, six participants are endowed with £40 and are asked to work together over 10 rounds to reach a collective target (£120) through individual contributions in each round. All group members are paid out the money left in their personal account. If they fail to meet the target, they lose all their money with a probability of 90%. Although freeriding is tempting, it increases the risk that the group will fail to meet the target.

Numerous studies have employed this basic experimental design (e.g. Andrews et al., 2018; Farjam et al., 2019; Hasson et al., 2010; Jacquet et al., 2013; Kline et al., 2018; Marotzke et al., 2020; Milinski and Marotzke, 2022; Skatova et al., 2016; Szekely et al., 2021; Wang et al., 2016; Alpizar and Gsottbauer, 2015; Hoffmann et al., 2024; Farjam et al., 2019; Goeschl et al., 2020; Hembach-Stunden et al., 2024 and others), each introducing an additional variable to reflect a real-world influence on mitigation. Taken together, they enhance our understanding of the causal factors underpinning humankind's failure to stop climate change. It is important to note that the consistency of the experimental design of all collective risk social dilemma studies ensures comparability, which is critical for gaining meaningful insights. However, while these experiments do not quantify the relative importance of each variable, they effectively demonstrate the significance of the studied factor.

We ask whether the threat of repeated climate extreme events increases mitigation efforts. To explore this, we conducted controlled laboratory experiments to investigate whether groups of volunteers are more likely to avert a final climate catastrophe when faced with avoidable intermediate climate events. Failing to address these intermediate events results in equal, known losses to all group members, and increases the risk of a final catastrophe. Unlike previous studies which focused on a single final event, our research explores experimentally the impact of repeated climate events. We seek to determine whether recurring losses, designed to represent the economic costs associated with climate hazards, compels participants to invest more in mitigation, enhancing group coordination towards mitigating climate risks.

In a 'control' treatment, players are organized randomly in groups of six and are asked to make successive voluntary contributions ~~towards~~toward a target amount that guarantees averting a simulated climate catastrophe, i.e., the avoidance of a collective loss. From an endowment of £40 each individual must allocate either 0, £2, or £4 to a climate fund in each of the 10 rounds. The group's goal is to accumulate a fixed amount of £120 in the climate fund, on average £2 per player per round. As a result, players should contribute ~~50%~~50 % of their endowment toward mitigation. Individual contribution requirements are deliberately set high relative to typical global mitigation costs estimates simulating the potential need for drastic, immediate high-stakes sacrifices to avoid end-game scenarios (Kemp et al., 2022).

Failing to meet the final target sum results in a known ~~90%~~90 % chance of losing the private endowment not invested in the climate fund. This high-risk scenario was chosen to simulate the potential for crossing certain tipping points in the climate system, which could trigger abrupt, drastic, and potentially irreversible changes (Alley et al., 2003; Lenton et al., 2008), leading to an 'end-game' scenario with catastrophic consequences (Schellnhuber, 2018). While real-world climate thresholds vary, collective social risk dilemma experiments employ a fixed target to mimic the 2°C threshold (Randalls, 2010), as this is plausibly what people may have in mind when deciding in real-world contexts.

Participants in our experiment are aware that all money accumulated in the climate fund will be used to plant trees since photosynthetic carbon capture by trees has been shown to be the best way to limit the rise of CO₂ concentrations across the globe (Griscom et al., 2017; Lewis et al., 2019; SI B) and suggested by the IPCC (De Coninck et al., 2018).

Alongside the 'control' treatment, we designed two additional treatments where groups face a climate-damage loss every second round. If the group fails to accumulate the designated proportion of the final target sum up to that round (i.e., ~~20%~~20 %, ~~40%~~40 %, ~~60%~~60 %, or ~~80%~~80 % of £120), each individual incurs a known monetary loss. This loss is intended to replicate the economic impact of being struck by an extreme weather event and is applied uniformly across all players of a group. Such losses reduce a group's wealth even if they ultimately reach the final target or, worse, it can eventually prevent the group from reaching the target altogether, resulting in the forfeiture of all remaining funds for all members. However, if the group invests exactly the amount needed to stay on track toward the final target, no losses occur. The key feature that differentiates our treatments is the loss structure.

In the 'constant fee' treatment, missing an intermediate target results in a small loss of £1 for each player. The magnitude of the loss remains constant across rounds. In total, each group member could lose up to £4 in total if all 4 intermediate targets are missed by the group. Each loss, if materialising, has a wealth reducing effect. Yet, it only lowers and does not eliminate the chance of reaching the final target as a group.

In the 'increasing fee' treatment, the magnitude of the loss rises across intermediate climate events. Each group member loses £1 in round 2, £4 in round 4, £8 in round 6, and £16 in round 8 if the group misses the respective targets. Consequently, missing all targets costs each player £29 and automatically prevents the group from reaching the final target. The 'increasing-fee' treatment therefore introduces stronger, escalating consequences for insufficient investment, testing whether progressively larger potential losses enhance coordination and effort over time.

30 independent groups of 6 people participated into each experimental condition. Each group, independently of the loss structure, must reach the final target to retain the share of the private endowment not invested in the climate fund. Players make decisions to maximize their own payoffs. In a standard threshold public-goods setting, the individually optimal strategy is to free-ride when the expected private return from contributing is below its cost. At the same time, in our context missing intermediate targets leads to climate-damage losses that reduce all players' wealth, increasing the private incentive to contribute, especially as these losses grow larger in later rounds. Thus, participants face competing motives – strategic free-riding versus loss avoidance – and we empirically examine which dominates. Since contributions required to avoid intermediate events also contribute toward reaching the final target, avoiding losses comes at no extra cost.

Our design relates to three strands of literature. First, past research on voluntary contribution mechanisms show that cooperation typically declines over time (Fischbacher and Gächter, 2010). Gallier et al. (2024) find that cooperation improves when participants make frequent, voluntary commitments. In a related study, Gallier and Sturm (2021) show that requiring steadily increasing contributions can backfire, as participants strategically reduce early contributions to avoid higher future obligations. Our design connects to this literature by introducing recurring opportunities to cooperate, where failures reduce the wealth of all group members equally, independently of whether they contributed or not, mimicking the economic consequences of insufficient climate mitigation.

Second, a large body of work shows that punishment can foster cooperation in public-goods games (e.g., Fehr and Gächter, 2002; Gächter et al., 2008; Hauert et al., 2007; Henrich et al., 2006; Rockenbach and Milinski, 2006, 2011; Yamagishi, 1986, and others). While our design does not include agent-driven punishment, missing an intermediate target triggers an exogenous, wealth-reducing loss. Players might nonetheless perceive these losses as punitive, since they impose costs on everyone for the group's failure to act. This perceived punitive structure conceptually links our experiment to the punishment literature. We therefore examine whether missed intermediate targets are followed by higher subsequent contributions and whether groups tend to meet intermediate targets to avoid losses.

Third, our study relates to the research on strategic heterogeneity in social dilemmas. Prior studies have identified selfish or extortionate strategies, in which individuals contribute less but rely on others to secure collective success (Milinski et al., 2016; Press and Dyson, 2012). Extortion was theoretically derived by Press and Dyson (2012), who stated that “it is generally assumed that there exists no simple ultimatum strategy whereby one player can enforce a unilateral claim to an unfair share of rewards. Here, we show that such strategies unexpectedly do exist. In particular, a player X who is witting of these strategies can (i) deterministically set her opponent Y’s score, independently of his strategy or response, or (ii) enforce an extortionate linear relation between her and his scores. Against such a player, an evolutionary player’s best response is to accede to the extortion”. Beyond the verbatim presented above, the mathematical proof presented by Press and Dyson provides a precise definition of these concepts (see Press and Dyson, 2012). Milinski et al. (2016) extended this framework to threshold public-goods settings, showing that (i) the extortioners receive at least the average payoff of their co-players; (ii) the optimal response for the remaining group members is to meet the collective target; and (iii) conditions (i) and (ii) apply consistently across any game in which an extortioner participates (Milinski et al., 2016). Consequently, fair players compensate almost completely the deficit caused by the extortionate co-players. Everybody gains, however the extortionate representatives and their groups benefit the most from this behavior (Milinski et al., 2016).

In our experiment, we use this framework to evaluate groups response to the threat of losses. We classify participants *ex post* according to total contributions across the 10 rounds. Players contributing at least £20 – the fair-share amount required to reach the collective target if all contributed equally – are labeled fair players. Those contributing less than £20 are labeled extortioners.

In the control treatment, free-riding by extortioners imposes no external cost beyond lost group efficiency and is only profitable as long as other participants compensate for the under-contributions of others. ‘Fair’ players have a strong incentive to offset low contributions: by safeguarding the group’s success, they ultimately earn more than if the threshold is missed. When losses from missed targets are moderate, i. e. in the ‘constant fee’ treatment, fair players also have the incentive to compensate for extortioners to avoid group losses, allowing the extortion dynamic to take hold. In the ‘increasing-fee’ treatment, however, escalating losses erode fair players’ compensatory capacity, while extortioners persist in low contributions, ultimately leading to collective failure. We explore these dynamics further in Section 3.4.

2.2 Methods

The experiment was conducted at the University of Nottingham (CeDEX lab) in January–February 2023. It was coded in z-Tree (Fischbacher, 2007). Participants were separated from each other and the experimenter. They received the instructions, which referenced climate change rather than using neutral language to simulate real-world decision-making on climate mitigation. All decisions were made on the computer, with no communication allowed (see SI A). To ensure anonymity, each participant was randomly assigned a pseudonym (such as Ananke, Despina, Japetus, Kallisto, Metis, Telesto).

At the beginning of the experiment, each participant received an endowment of £40. In groups of six, players were asked to make successive individual voluntary anonymous contributions of £0, £2, or £4 to a ‘climate account’ during 10 rounds. The group’s objective was to accumulate a fixed amount of £120 in the ‘climate account’ to avert a simulated climate catastrophe. Participants knew that, if the group reached or surpassed this target at the end of the 10 rounds, each member would receive what they had not invested in the ‘climate account’ in cash. If the group failed to reach the collective goal, the computer ‘threw dice’, so that with probability 0.9 all group members would lose all their savings.


In two further treatments, groups were exposed in round 2, 4, 6 and 8 to a simulated climate event. In the ‘constant fee’ treatment, if the group failed to assemble the designated proportion of the final target up to that round, each player incurred a loss of £1 per event, risking up to £4 in total if all intermediate targets were missed. In the ‘increasing fee’ treatment, the magnitude of the loss rose over time: £1 in round 2, £4 in round 4, £8 in round 6, and £16 in round 8 in case the group failed to reach the respective targets. This created a potential loss of up to £29, which would imply that the group could not reach the final target and the simulated climate catastrophe would not be averted.

After every round, each group member’s decision was displayed on all computers simultaneously without any clue to a subject’s identity. However, each subject’s decision was listed in the same position after each round allowing individuals to observe and track others’ strategies. The cumulative sum of contributions was not displayed on the computer screen. Instead, participants were given pen and paper, and they were encouraged to take notes during the game. The students were assured that all money invested in the climate fund would be used to make a donation to ‘The National Forest’, UK, to plant trees that would sequester and store CO₂ (see SI B). 180 university students (30 groups of six subjects) participated in each experimental condition ($N=540$ in total).

3.3 Results

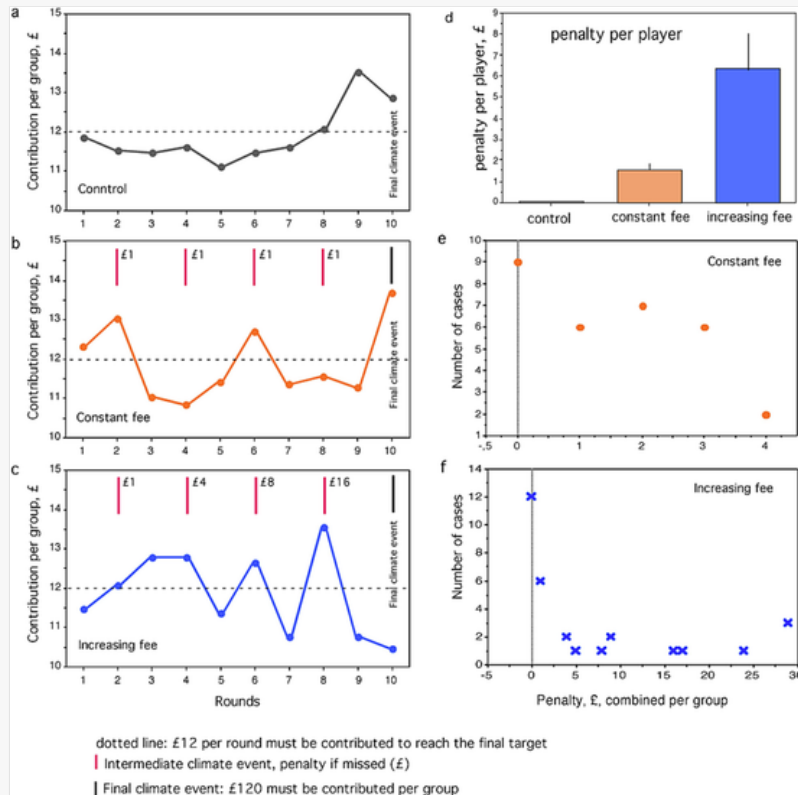
3.3.1 Group contribution to the climate fund over rounds

As shown in Fig. 1a, in ‘control’ groups contributions remain systematically below the fair share contribution of £12 until round 8. In the ‘constant fee’ treatment (Fig. 1b), contributions exceed £12 only in rounds 2 and 6 before anticipated climate events, after which they immediately declined. In the ‘increasing fee’ (Fig. 1c) treatment, contributions increased above £12 in rounds 3, 4, 6 and 8, decreasing thereafter. In rounds between climate events players safely conserved money by contributing less. Thus, in both treatments, intermediate climate events increase contributions and help avoiding further losses, albeit only temporarily.

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[Fig. 1](#)



Contributions to the climate fund and losses for missing intermediate targets.

Contributions to the climate fund per group in each of the 10 rounds (a) in the control, (b) the ‘constant fee’ (c) and the ‘increasing fee’ treatment. (d) Loss per player (average + s.e.m.) incurred in the ‘control’, the ‘constant fee’ and the ‘increasing fee’ treatments. Compared with the ‘control’ with zero losses, losses are significantly different from the zero expectation in ‘constant fee’ ($P=0.0001$, $Z=-4.657$), and in the ‘increasing fee’ treatment, ($P=0.0001$, $Z=-4.929$, $N_1=30$, $N_2=30$, Mann-Whitney U -test). (e) Frequency of incurred losses in the ‘constant fee’ treatment. (f) Frequency of incurred losses in the ‘increasing fee’ treatment. Note that each group member, irrespective of their individual contribution, was exposed to losses if the group failed to meet the intermediate target. Intermediate losses were scheduled to occur in rounds 2, 4, 6 and 8 as per red vertical lines in panel (b) and (c). [\(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.\)](#)

Fig. 1c shows that average contributions decline sharply in round 9 and 10. This could indicate that fair players cease compensating once the group can no longer reach the threshold. However, reduced contributions might also reflect diminished balances after paying for sanctions. Indeed, there were groups in the ‘increasing fee’ treatment which contributed only £94 or £96 by round 8. In these instances, meeting the final threshold in the last 2 rounds was unattainable. There were no compensating players in these groups, which would explain why they missed the final threshold by such an extent. However, due to this we cannot formally test a ‘give-up’ effect whereby players stop compensating when the threshold is no longer within reach.

3.2.3.2 Missing intermediate targets


Empirically, we find that many groups missed multiple intermediate targets and incurred losses although it would have been a profitable strategy to invest up front the amount needed to reach the final target.

In the 'constant fee' treatment, 7 groups out of 30 missed one intermediate target, 6 groups missed 2 targets, 6 groups missed 3 targets while 2 groups missed all 4 targets incurring into the corresponding losses. Only 9 groups (30%30 %) met all 4 intermediate targets (Fig. 1e). In the 'increasing fee' treatment, 18 of the 30 groups missed some intermediate targets. 6 groups incurred into a loss of £1, 2 groups paid £4, 1 group paid £1+4, 1 group paid £8, 2 groups £1+8, 1 group £16, 1 group £1+16, 1 group £8+16, 3 groups incurred all four losses and paid £1+4+8+16 (Fig. 1f). Those 4 groups who were exposed to combined losses of £8+16 and £1+4+8+16 failed to meet the final target and lost all their funds. Only 12 groups (40%40 %) met all intermediate targets and avoided any loss (Fig. 1f).

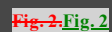
Missing intermediate targets carries costs yielding no benefits and should, therefore, be avoided. However, most groups were unable to avoid intermediate events resulting in substantial reductions in individuals' private endowments, especially in the 'increasing fee' treatment (Fig. 1d). As a result, some groups were forced to stop contributing.

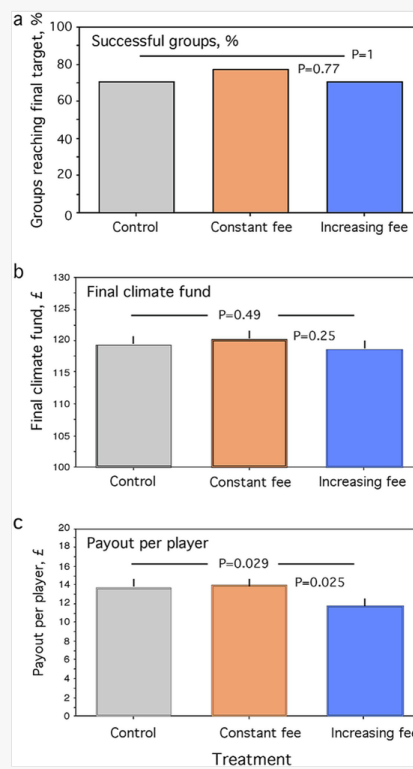
3.3.3 Reaching the final target is not affected by intermediate events – puzzle

Although numerous groups, particularly in the 'increasing fee' treatment (Fig. 1d), faced substantial losses affecting their ability to reach the final target, the proportion of groups successfully reaching the final target remains comparable across the 'control', 'increasing fee', and 'constant fee' treatments (Fig. 2a). This outcome appears to be clearly puzzling. The climate fund's cumulative amount seems to be slightly lower in the 'increasing fee' treatment (Fig. 2b), which results in a noticeably smaller payout for each player (Fig. 2c). This is most likely because some groups depleted their available resources due to the accumulated costs from missed intermediate targets.

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 Fig. 2, Fig. 2



Groups reaching the final target and total contribution.

(a) Percentage of successful groups reaching the final target. P -value after Fisher's exact test (2-tailed). (b) Average (mean + s.e.m.) total contribution to the climate fund in round 10. P -values from Mann Whitney U -tests, $N_1=30$ groups, $N_2=30$ group, 2-tailed. (c) Average (mean + s.e.m.) pay out per player. P -values from Mann Whitney U -tests, $N_1=180$ players, $N_2=180$ players, 2-tailed.

3.4.3.4 Solving the puzzle: understanding the lack of impact of intermediate targets

There are strong differences in contribution among the 6 participants in each group in all treatments. Fair players make a minimum contribution of £20, i.e., the fair share, while free riders make smaller contributions. These differences appear to be driven by pre-existing behavioral tendencies: we find that players' contributions are consistent over rounds. In all three treatments, the decision made in the first round is strongly correlated with a player's total contribution, (in 'control', Spearman corr. Coef. $Rho=0.612$, $P=0.0001$, $Z=6.909$; in 'constant fee', Spearman corr. Coef. $Rho=0.531$, $P=0.0001$, $Z=5.654$; in 'increasing fee', Spearman corr. Coef. $Rho=0.561$, $Z=5.851$, $P=0.0001$).

We observe that some individuals behave in an extortionist manner, adopting steadfast strategies and enforcing cooperation from fair players. These players maintain low contribution over time, even as the threat of disaster escalates or others increase their contributions. To reach the final target and avoid losing their funds, fair players are left with no choice but to compensate the deficit caused by their extortionate co-players (Becks and Milinski, 2019; Hilbe et al., 2016; Milinski et al., 2016; Press and Dyson, 2012; Stewart and Plotkin, 2012, 2013; Wang et al., 2016).

3.5.3.5 Extortion drives cooperation in the climate game

It is possible to test whether, for each group, the cumulative deficit brought about by extortionists is offset by increased contributions from fair players, ensuring that the final target is met. Are all fair players willing to compensate? Not all

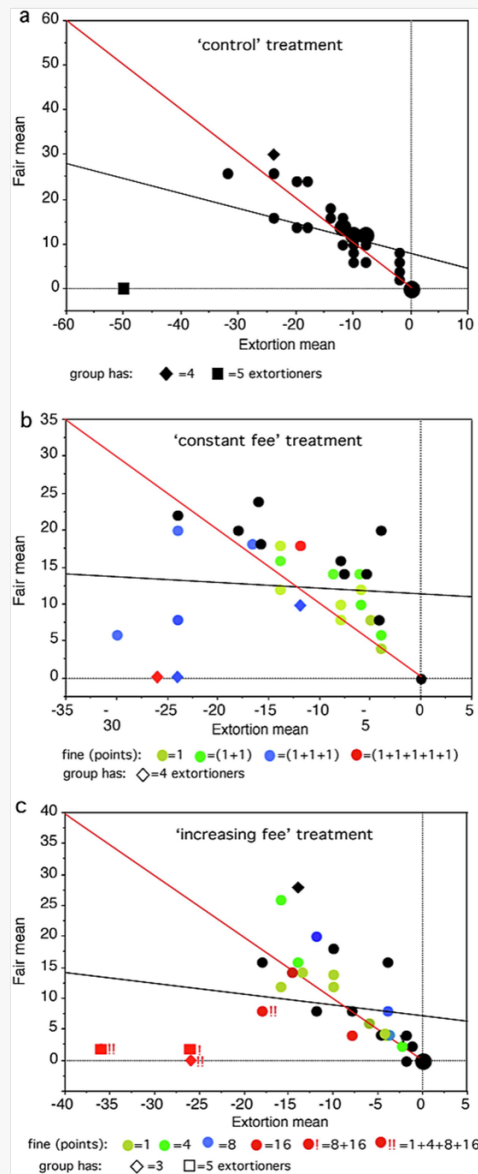
'fair' players compensate for deficit generated by extortioners. In the 'increasing fee' treatment, 46%46 % of the fair players contributed exactly £20, indicating that they were not willing to cover any shortfall, whereas the 54%54 % of the fair players in the 'increasing fee' treatment contributed more than £20, helping offset extortion. Similarly, in the 'constant fee' treatment, 42.4 % of fair players contributed only £20, while 57.6 % went beyond £20 to compensate for the deficit created by extortioners.

In the 'control' treatment (Fig. 3a), there are 9 dots below the red line, indicating that the surplus generated by fair players did not offset the extortion mean – i.e. the deficit created by freeriders. This observation is descriptive rather than inferential. The overall correlation between the fair mean and the extortion mean is, however, significant ($P=0.0001$, Kendall corr. Coef., $Z=-5.226$, $N=30$ groups). This outcome implies that extortion was successful in this case.

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Fig. 3



Fair players' compensation – the fair mean – of their selfish co-players' deficit – the extortion mean.

(a) for each group in the 'control' treatment. Each dot represents a group; larger dots show overlaid results from several groups. The black line depicts a simple regression; the red line depicts all combinations of hypothetical contributions in which all fair players exactly compensate for the deficit caused by all selfish players of that group. Thus, dots on or above the red line correspond to groups that reach the final target sum, dots below the red line depict groups that miss the final target. Diamonds show groups containing 4 extortioners, squares show groups with 5 extortioners; all other groups have between 0 and 3 extortioners. (b) For each group in the constant fee treatment; losses are depicted by colored points; Diamonds depict groups with 4 extortioners, squares depict groups with 5 extortioners, other groups have 0 to 3 extortioners; see panel (a) for other details. (c) For each group in the 'increasing fee' treatment. Diamonds show groups containing 3 extortioners, squares groups with 5 extortioners; all other groups have between 0 and 3 extortioners; see panel (a) for additional details. [\(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.\)](#)

Most fair players give in to extortion and prevent simulated dangerous climate change in the majority of groups. Furthermore, most groups achieved the final target in both the 'constant fee' and 'increasing fee' treatments (note dots on and above red lines in Fig. 3b, c). These groups experienced fewer extortioners per group, which resulted in smaller losses from missing intermediate targets.

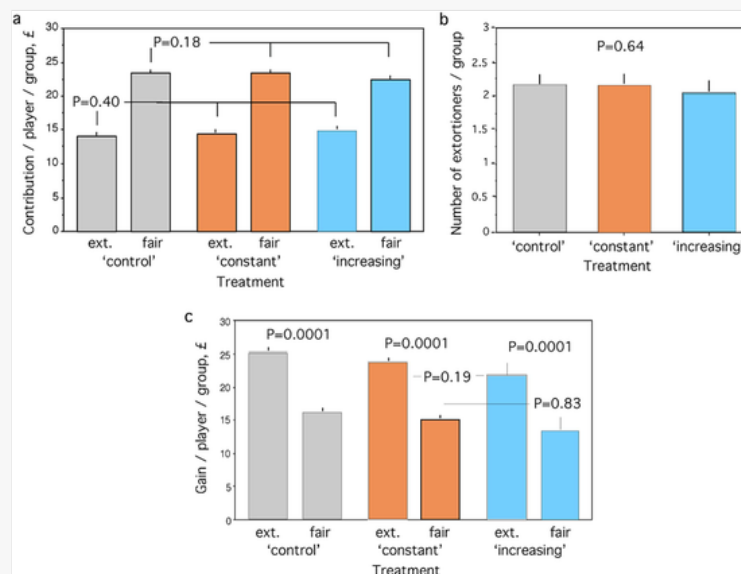
3.6.3.6 The random occurrence of extortioners and their invariant contribution in each treatment

We find that, on average, contributions from fair players as well as those of extortioners are not statistically different across treatments (Fig. 4a). We also find that the average number of extortioners in a group does not differ across treatment conditions (Fig. 4b), indicating that the presence of extortioners in groups is exogenous to treatment assignment.

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Fig. 4, Fig. 4



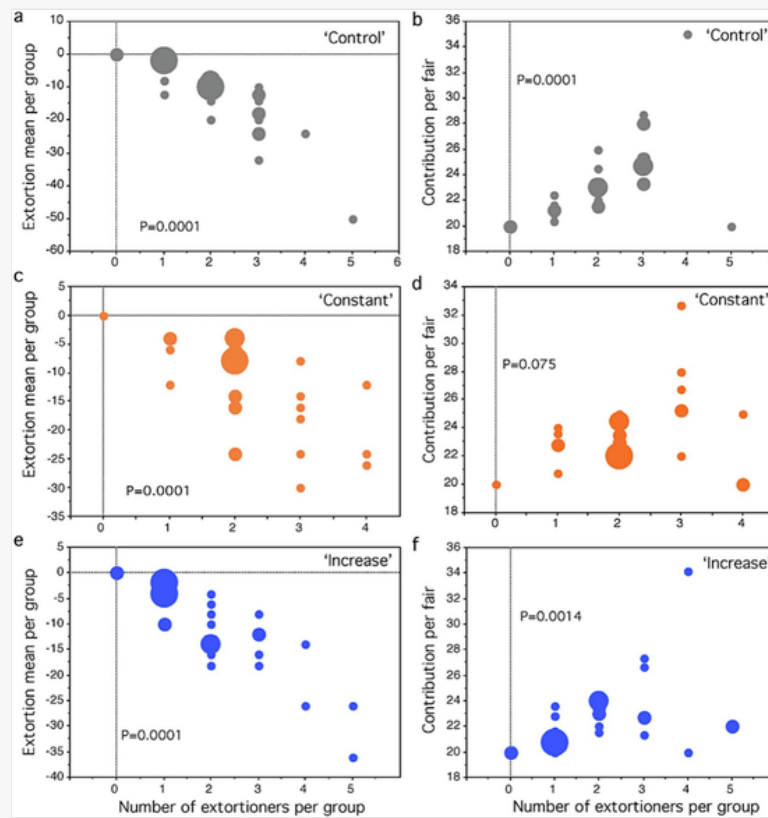
Contribution per player and number of extortioners per group.

(a) Contribution per extortioner per group (mean + s.e.m.) and per fair player per group in each treatment. Contribution per extortioner: $P=0.40$ across 3 treatments, $H=1.741$, Kruskal-Wallis test, $N=65$ players in 'control', $N=65$ players in 'constant', $N=60$ players in 'increasing'; contribution per fair player: $P=0.18$ across 3 treatments, $H=3.34$, Kruskal-Wallis test, $N=115$ players in 'control', $N=115$ players in 'constant', $N=120$ players in 'increasing'. (b) Number of extortioners per group (mean + s.e.m.) in 'control', 'constant' and 'increasing' fee treatment. $P=0.64$ among 3 treatments, $H=0.887$, Kruskal-Wallis test, $N=90$ groups.

Figs. 5 a, c, and e demonstrate that the combined deficit caused by extortioners increases with their number in a group. Furthermore, Figs. 5 b, d, and f show that the contributions made by fair player increase as the number of extortioners in a group grows, supporting the hypothesis that fair players are forced to compensate the extortion mean. However, when 4 or 5 extortioners are present in a group of 6, full compensation becomes unattainable (Fig. 5 b, d, f).

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Number of extortioners, extortion mean and enforced contribution.

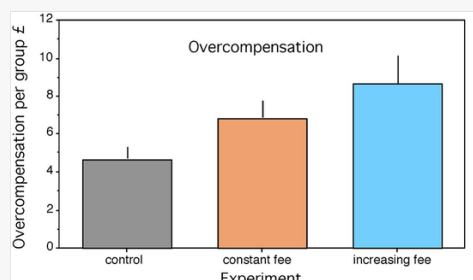
The number of extortioners in a group matter, (a, c, e) determines the extortion mean that needs to be compensated by fair players, (b, d, f) extortioners enforce the contribution of fair players in each treatment by their sheer number. Larger dots show overlaid results from several groups. P-values are based on Kendall's Correlation Coefficient: (a) $Z_{\tau} = -5.883$, $N_{\tau} = 30$ groups, (b) $Z_{\tau} = -5.026$, $N_{\tau} = 30$ groups, (c) $Z_{\tau} = -4.309$, $N_{\tau} = 30$ groups, (d) $Z_{\tau} = 1.78$, $N_{\tau} = 30$ groups, (e) $Z_{\tau} = -5.646$, $N_{\tau} = 30$ groups, (f) $Z_{\tau} = 3.185$, $N_{\tau} = 30$ groups.

Those groups that fail to reach the final target happened to include higher numbers of extortioners, or more precisely, suffer from higher extortion means (i.e., the combined effect of extortion per group). In these instances, the corresponding low number of fair players often struggle to compensate the deficit generated by extortioners. As a result, some of these groups eventually miss the final target after initially failing to avert the costly intermediate climate events. Since the monetary costs for missing intermediate targets are low, though wealth reducing, in the 'constant fee' treatment and non-existent in 'control', it is evident that extortion is the main reason why the final target is missed by nearly the same number of groups in all experimental conditions (Fig. 2a). The impact of intermediate climate events is merely an incidental consequence of extortion.

Fig. 6 confirms that the probability of missing the final target increases with number of extortioners per group. There exists, however, an exception, i.e. a group with 4 extortioners who underwent no losses thanks to the benevolence of 2 fair players who contributed £40 and £28, respectively, enabling the group to meet the final target (black diamond in Fig. 3a).

i Images may appear blurred during proofing as they have been optimized for fast web viewing. A high quality version will be used in the final publication. Click on the image to view the original version.

alt-text: Fig. 6



Groups missing the final target and number of extortio[Instruction: ART: Replace Figs. 6 and 7]ners per group.

Percentage of groups missing the final target as a function of the number of extortioners per group (mean + s.e.m.) across all treatments combined. $P < 0.02$ from Fisher combination test based on 3 Kendall's Correlation Coefficients (for a breakdown by treatment, see Table S1 in SI C) of (Adger et al., 2013) 'control' $P = 0.1876$, $Z = 1.291$, $N = 5$ percentages, (Alley et al., 2003) 'constant' $P = 0.0415$, $Z = 2.038$, $N = 4$ percentages, (Alpizar and Gsottbauer, 2015) 'increasing' $P = 0.05$, $Z = 1.96$, $N = 5$ percentages.


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3.7.3.7 Overcompensation: a positive but wasteful effect of intermediate targets

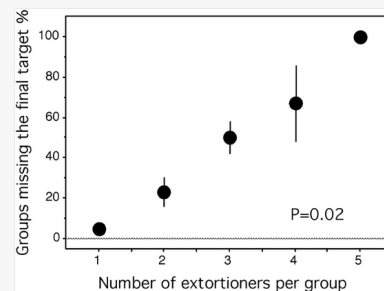
In the 'control' treatment (Fig. 3a) all the dots above the red line are in close proximity to it, suggesting that fair players tried to invest just enough to reach the final target. However, in both the 'constant fee' and the 'increasing fee' treatment (Fig. 3b, c), the points above the red lines are widely dispersed suggesting that the fair players consciously and willingly tried to compensate any yet unknown low investment of their co-players.

As shown in Fig. 7, the average level of overcompensation differs across treatment conditions. In both treatments with intermediate targets, net investments are much higher than necessary. This suggests that fair players anticipated substantial freeriding from extortionate co-players when facing the possibility of intermediate climate events.

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Fig.7, Fig.7



Overcompensation per group that reached the final target across treatments.

Net contribution of groups (mean + s.e.m.) that are by at least £2 above the red line in Fig. 3. The net increase in 'constant fee' treatment was £6.769 + 0.893 (s.e.m.), in 'increasing fee' treatment was £8.571 + 1.429 (s.e.m.), in 'control', however, was only £4.600 + 0.306 (s.e.m.). This net increase is significantly higher both in the 'constant fee' treatment ($P = 0.0209$, $Z = 2.333$, $N_1 = 10$, $N_2 = 13$, Mann-Whitney U-test) and in the 'increasing fee' treatment ($P = 0.0196$, $Z = 2.333$, $N_1 = 10$, $N_2 = 7$, Mann-Whitney U-test) compared to the 'control' treatment. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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4.4 Discussion

In a laboratory climate game, groups of six participants made repeated contribution decisions toward a collective target designed to avert a simulated climate-related loss. We examine whether recurring monetary losses – representing the economic costs associate with climate hazards – encourage participants to invest more in collective action and thereby enhance cooperation.

The study introduces two treatments that differ in the structure of these losses. In the 'constant-fee' treatment, missing an intermediate target triggered small, uniform losses across rounds. In the 'increasing-fee' treatment, losses escalated over time, imposing larger costs in later rounds.

The novelty of this design lies in examining how the temporal pattern of recurring losses shapes cooperative dynamics in a threshold public-goods setting. Whereas earlier climate games typically feature a single end-of-game catastrophe, our design tests whether the anticipation of smaller, uniform losses ('constant-fee' treatment) or larger, escalating losses ('increasing-fee' treatment) produces distinct behavioral trajectories over time.

Our results show that many groups failed to meet several intermediate targets and incurred the associated losses. Although such losses could be perceived as punitive and in principle, encourage cooperation by raising the cost of collective failures (e.g., Fehr and Gächter, 2002; Gächter et al., 2008; Hauert et al., 2007; Henrich et al., 2006;

Rockenbach and Milinski, 2006, 2011; Yamagishi, 1986), the proportion of groups successfully reaching the final target was almost the same as in the control where intermediate targets and losses were absent. This is a puzzle and the economic damages triggered by the intermediate climate events in our experiment had, obviously, no effect on cooperation – unlike the frequent, voluntary commitment mechanisms in Gallier et al. (2024), where repeated decisions allowed participants to signal reliability and build trust. This contrast suggests that simply increasing the frequency of decision opportunities is insufficient to sustain cooperative behavior when losses are exogenous rather than negotiated commitments that facilitate reciprocal trust-building.

A solution of the puzzle lies in the stark differences in contribution among group members across treatments. Previous studies have found that selfish acts occur in collective risk social dilemma games (Milinski et al., 2016). Some individuals behave in an extortionist manner (Press and Dyson, 2012), adopting steadfast freeriding, thus enforcing cooperation from fair players (Becks and Milinski, 2019; Hilbe et al., 2016; Milinski, 2022; Press and Dyson, 2012; Stewart and Plotkin, 2012, 2013; Wang et al., 2016). To reach the final target, fair players can only try to compensate the deficit caused by their extortionate co-players by acceding to extortion (Becks and Milinski, 2019; Hilbe et al., 2016; Milinski, 2022; Press and Dyson, 2012; Stewart and Plotkin, 2012, 2013; Wang et al., 2016).

In our setting, we find that players exhibit time-consistent behavior, with their initial choices remaining stable and predictive of their future contributions throughout the game. The decision made in the first round is strongly correlated with the total contribution of a player, in all three treatments. Thus, freeriding proved steadfast. Extortioners behave consistently from the outset, choosing low contributions in round 1 and maintaining them, rather than adapting the generosity of fair players or the ~~behaviour~~ behavior of other extortioners.

Furthermore, we find that the average number of extortioners in a group did not differ across treatments indicating that their presence is exogenous to treatment assignment, with their numbers varying randomly between 0 and 5. The combined deficit caused by extortioners increased with their number in a group. Thus, they did not become less extortionate when joined by other extortioners. The contributions made by fair players, however, increased with number of extortioners in a group. In combination, this means that the fair players' compensation increases with the magnitude of exploitation. Despite their sense of fairness (Brosnan and De Waal, 2014), fair players gave in to extortion, almost fully covering the extortionate deficit at their own expenses. This allowed groups to often avoid the final catastrophe and helped extortioners to obtain substantial individual gains.

Missing intermediate targets was just a by-product of extortion on the way to eventually reach the final target. However, when the number of extortioners per group exceeded the fair players' capacity to compensate, the probability of missing the final target increased significantly.

In sum, our puzzling finding that reaching the final target is not affected by the threat of losses associated with climate events can be explained by the role of extortion. Since extortion occurred randomly, and decreased mitigation efforts irrespective of experimental condition, its impact remains consistent. Extortioners were unresponsive to the losses associated with climate events, showing no behavioral adjustment to these losses. Thus, intermediate targets are often missed by default.

5.5 Conclusions

Our findings that extortion hinders cooperation in the climate game may help to understand mechanisms also relevant to real-world coordination problems. Despite the frequent headlines about climate extreme events, people continue engaging in high emission activities such as flying to holiday destinations. This behavior is also evident on a large scale. Global CO₂ emissions alongside global temperatures reached record levels in 2024. Countries had agreed to 'pursue efforts' to limit global temperature rises to 1.5°C (IPCC, 2018) under the 2015 Paris agreement adopted at COP21. This threshold was exceeded in both 2023 (Berkeley Earth, 2024) and 2024 (Berkeley Earth, 2025; Cannon, 2025), and is projected to be breached repeatedly over the next 20 years (Bevacqu et al., 2025; Marotzke et al., 2022). January 2025 marked the warmest month on record globally (Copernicus, 2025; Cesaretti, 2025; Copernicus, 2025).

Extortioners contribute minimally to mitigation efforts while forcing others to compensate for their shortfall. This behavior accelerates emissions and may lead to climate extremes. Those attempting to cover the deficit often fail due to being overburdened.

Consequently, our experimental results suggest that climate change is effectively being 'enforced' by extortionist behavior. Experiments, cited in Milinski (2022) found potential extortioners at a frequency of about ~~40%~~ 40%, similar as in the present study, implying that many people might be potential extortioners, which, as we found here, do not change their behavior. Overall, fair players appear to have been unable to compensate the global extortionate deficit.

In this context, governments, institutions and policy could play a crucial role in curbing detrimental behaviors by promoting systemic policies that encourage cooperation and link individual efforts to collective actions, such as implementing a global carbon tax. However, incorporating the role of these entities would require adding another layer of variation to the game — beyond the existing cost structure of climate events—which could have introduced

confounding factors in our experimental design. As highlighted by the [Hamburg Climate Future Outlook, 2024](#) “corporate responses, consumption trends, and the lack of effective fossil-fuel divestment inhibit deep de-carbonization, significantly reducing the likelihood of achieving net-zero CO₂ emissions by 2050”.

Authors contribution

SI initiated the study, MM conceived and designed the study with input from SI, MM analyzed the data and drafted the manuscript. SI and MM revised the manuscript.

Ethics declarations

We obtained informed consent in written form from all participants involved in the study. This experiment has been approved by the University of Oxford ethics committee, CUREC (SOGE C1A-22-251).

CRedit authorship contribution statement

Manfred Milinski: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Stefania Innocenti:** Writing – review & editing, Project administration, Conceptualization.

Informed consent

Informed consent was obtained from all participants after the nature and possible consequences of the studies were explained.

Funding

⁰⁴ ["Max Planck Society for the Advancement of Science"](#) (MM) and the ["John Fell Fund of the University of Oxford"](#) (SI).

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~~Cesaretti et al., 2025~~

~~Fischer and Knutti, 2015~~

~~Van Valkengoed and Steg, 2019~~

Declaration of competing interest

All authors declare they have no competing interests.


~~Acknowledgments:~~ Acknowledgments

We thank the students from the university of Nottingham for their participation and CeDEX Nottingham for performing the experiment. We thank A. Ferris for the z-tree program and for organizing the supplementary information.

~~Appendix A:~~ Appendix A Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ecolecon.2025.108866> "Game instructions, Certificate National Forest, Groups meeting climate disaster"

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 The corrections made in this section will be reviewed and approved by a journal production editor. The newly added/removed references and its citations will be reordered and rearranged by the production team.

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~~Appendix A~~ Appendix A Supplementary data

 [Multimedia Component 1](#)

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alt-text: Image 1

Queries and Answers

Q1

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Q7

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Answer: this is appropriate