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Collectivist values help solve the climate dilemma

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Theories on evolution of cooperation assume that interacting individuals can change their strategies under different expected payoffs and cultural contexts. The willingness to invest resources into partners and to cooperate may therefore vary in collectivistic Eastern Asia as opposed to more individualistic Western countries partly because of cultural differences. An experiment was implemented examining the willingness of young Chinese subjects to mitigate the consequences of climate change in a country severely affected by air pollution. We set up a public goods game in which groups of six students had to reach a minimum investment threshold to be able to save funds for a reforestation project to curb climate change. Such social dilemma could not be solved in the western world. Here, instead, five out of eight Chinese groups cooperate enough to raise funds for the reforestation goal. An Individualism/Collectivism questionnaire we presented the subjects with established why we are confronted with a variance in cooperation interests across different cultures. In China, in fact, collectivistic values seem to be a key factor for allowing the emergence of this environmentally driven cooperation.

KEYWORDS

cooperation, climate change, collectivistic society, cultural effects, threshold public goods game, reinforcement learning

Introduction

In a society where air pollution casts a heavy shadow, can collectivism offer a ray of hope for tackling climate change? Our research suggests that in China, a strong sense of community may be the key to overcoming short-term self-interest and investing in a greener future.

Climate as a public good

An intense debate has fired up in recent years on how to decrease global warming and whether the scant efforts repeatedly put up by the governments will bring back tangible results. The relationship between climate as a public good and collective action is intertwined, and its solution resides at the basics of the evolution of cooperation theories. Reaching an understanding of the evolutionary mechanisms underpinning cooperation has been one of the scientific challenges in recent decades (Szathmáry and Maynard Smith, 1995) and remains so, especially vis-à-vis climate change. The transition from selfish behaviour to social behaviour, and eventually to the level of complexity apparent in consensus behaviour with multiple partners, indicates that adaptation by natural selection favours the advent of cooperative acts beneficial to all individuals in the shorter and longer-term (Ohtsuki et al., 2006). However, our scientific understanding keeps on being challenged when looking at the social dynamics for choosing cooperation or defection by groups of individuals having to preserve a public good (Brandt et al., 2006; Fehr and Gachter, 2002; Milinski et al., 2002;

Panchanathan and Boyd, 2004). The climate commons are arguably the greatest tragedy unfolding in this early-stage Anthropocene era.

Natural resources like air and water, especially, are at risk when competitive players realise their ephemeral and shifting features so that most are easily induced to freeride unless solid civic values pertaining to natural resources are instilled from a very young age. While economists have been studying the rational dynamics converted into numbers of the profitability of caring about the environment (Ito and Yamamichi, 2024), psychologists have looked at the mental obstacles to overcome for achieving long-term environmental goals (de Groot and Thøgersen, 2018; Milfont and Gouveia, 2006; Wade-Benzoni and Tost, 2009); obstacles which need to be superseded and turned into proactive engagement (Milfont et al., 2012; Shen and Zhang, 2024) in a list of "motivational interventions" (Geller, 2002) that drive problem-solving in most of our daily tasks. Hence, in this study, we do not aim at examining only if collectivistic values are beneficial to foster cooperative group behaviour, but also if they are helpful in the presence of an uncertain future (Marder et al., 2023).

Pollution and China

China is the world's biggest greenhouse gas emitter, accounting for one-fourth of the global CO2 emissions (Olhoff and Christensen, 2019). Over there, at the moment coal still provides about 70% of the country's energy, causing most CO2 emissions and particulate matter (He et al., 2020). However, as in most non-western countries, the emissions have been historically low compared to the old industrial economies. A Chinese person does not pollute nearly as much per capita as an American or a European (Tirole, 2018; Fleck, 2023). Nevertheless, the Chinese person's impact as an individual is larger than his organised collectivity. A report published in PNAS (Liu et al., 2016) found that individuals and not factories are a greater source of pollution due to the unregulated combustion of household fuels.

Experimental research

Consider the conundrum arising when people are asked to invest money or resources into mitigating global warming, like the need to overcome short-term personal benefits to achieve long-term collective payoffs for future generations. A proper way to model such effort in laboratory conditions is to implement a threshold Public Goods game with delayed payoffs (Rapoport and Suleiman, 1993; Wang et al., 2020; Alberti and Cartwright, 2016; Brekke et al., 2017). Among other means (Lange, 2023), this paradigm is particularly suitable for testing cooperation behaviour tendencies toward avoiding climate change (Jacquet et al., 2013; Milinski et al., 2006; Milinski et al., 2008; Tavoni et al., 2011; Feige et al., 2018; Kline et al., 2018) because there are critical greenhouse-gas concentrations above which ice sheets will melt, corals dissolve, and tipping points will be overtaken making life on earth unsustainable to our species (Rockström et al., 2013). Through such a paradigm, it is not up to one individual only, but to a group of individuals to collectively agree to invest the necessary minimum amounts of resources to curb climate change plausibly. In their elegant experiment, Jacquet and co-authors (Jacquet et al., 2013) showed that although German students manage to invest in public goods to reach short-term monetary benefits, they eventually fail to invest when asked to raise funds for the much longer-term benefit of planting trees to clean the air from pollutants. Testing in-between investment levels in an intermediate treatment, the authors conclude that the further away in time the benefits of an investment are gained, the less willing individuals are to cooperate. Regarding climate change actions, this implies that as long as individuals, groups or countries focus mainly on benefitting from selfish short-term investments, they are unlikely to invest in the future wellbeing of the next generation. In a previous experiment, Milinski et al. (2006) explored contextual and motivational factors influencing cooperative behaviour in the climate change context in Germany. They found that both priming the subjects with information about climate research, as well as giving them the opportunity to gain social reputation, increased investments in the public good.

Cooperative behaviour and collectivistic values

While previous studies have explored cooperation in climate change contexts, few have examined it specifically within collectivistic cultures. This research investigates whether Chinese citizens, known for their strong emphasis on group wellbeing, are more likely to engage in pro-environmental cooperation compared to individuals from individualistic societies. As it is often the case, a limitation to the state of the art is posed by the fact that it has been conducted mainly in Western, so-called WEIRD countries (Henrich et al., 2010), except for at least four studies (known to us) run in China (Wang et al., 2020; Kline et al., 2018; Wang et al., 2023; Dong et al., 2021). When it comes to understanding the worldwide willingness to cooperate in global issues like climate change, it is necessary to examine the replication of findings in Eastern countries, especially those that have been harshly impacted by environmental issues in recent years due to a delayed industrial revolution. Although there is some preliminary evidence that collectivism can lead to increased short-term cooperative behaviour in groups (Talhelm et al., 2014; Nisbett, 2003), it is less clear whether this also holds true for long-term cooperative goals. The Chinese society, still permeated with original and traditional values, including collectivism, offers a natural setting for this experiment.

The theory of future economic discounting asserts that people should fare aversion at getting less today compared to getting relatively more tomorrow (Schelling, 1995). Present earnings are more valuable than future ones because the future is uncertain. When individuals need to interact to earn resources, competition among them may cause exploitation of available resources due to the high rate of discounting, and if the cooperation game deals with rewards that have a potential positive consequence on the livelihood of subsequent generations, this psychological aversion is even greater (Jacquet et al., 2013; Sumaila and Walters, 2005; Cartwright, 2018).

The current research

A key aim of the current research is to examine the effect of time-delayed payoffs in a collectivistic context. Specifically, we explore whether framing the PGG under an ecological perspective impacts prosocial behaviour in Chinese subjects to check whether a long-term discounting theory applies in Asia too.

Our design conceptually replicates the experiment run by Jacquet et al. (2013) in Germany. We split the treatments testing either strategic economic decision-making for short-term benefits (Sumaila and Walters, 2005) or for longer-term environmental issues (Beckerman and Hepburn, 2007). Basing our assumptions on cross-cultural research, we expected a higher proportion of prosocials among the collectivist Chinese, as they should seek to maintain interpersonal and group harmony and restrain immediate personal gains in an effort to address the needs and interests of the society.

Methods

Sample

The experiment was performed with university students still novel to game theory after having assessed the needed number of groups to obtain likely statistical significance (power analysis reported in Supplementary material). The experiment took place during four different sessions in May and June 2015. While sitting in a computer lab, a total of 144 students were briefed on a whiteboard and via PowerPoint in neutral terms regarding the rules (not the outcome) of the threshold Public Goods Game (for instructions, see Supplementary material). No talking or discussion was allowed between the anonymous participants coming from different classes and mixed during the sessions. The experiments lasted about 45 min. Participants were informed about the general procedure and signed an informed consent form, while the university ethics committee approved the experiment.

Demography

The students' age spanned from 18 to 22, primarily from within the province of Yunnan and a few subjects had varying geographical provenance across other parts of China. The median age of the participants was 20 years, with an even proportion of males and females. The great majority were of Han ethnicity, with 9 Yi, 4 Hui, 3 Tujia, 3 Bai, 2 Miao, 1 Hani, 1 Lagu, and 1 Jin. They agreed on joining the experiment on a voluntary basis, although the great majority of those we asked agreed in doing so. Even if the subjects could not see each other while in the computer lab, we shuffled the students depending on their taught subjects and classes.

Procedure

Threshold public goods games require a minimal investment into the common pool for the public good to be obtained. By requiring some minimum amount of cooperation to avert the risk of severe climate change, they attempt to capture the seriousness of environmental problems and the idea that if the 1.5°C temperature is surpassed, the damage to the environment will be such that humans and other species will suffer greatly. In the experiment, the participants know in advance about the minimum target amount, which the group must raise to achieve the target so that the hypothetical dangerous climate change is averted. In our set-up, therefore, groups of 6 participants had a collective-risk decision to make today with consequences in the future.

For the game to function, each subject received some points as an operating fund and, at each of 10 rounds, could choose one of just five possible options: to invest 0, 1, 2, 3, or 4 points. Points here equal to Chinese Renminbi on a 1:1 ratio. If at the end of 10 rounds the group of six reached the target of 120 points (on average 20 per participant), they successfully averted "dangerous climate change" and each participant received an additional 45 points bonus. If the group failed to reach the 120 target, the situation of "dangerous climate change with significant economic losses" was simulated, and the additional bonus of 45 was lost with a 90% probability (as in 27). At the end of each round the subjects were told the total contribution of others in the round and they were reminded of the current total.

The experiment consisted of three treatments as between-subject factors looking at intra-and intergenerational discounting (Jacquet et al., 2013; Schelling, 1995; Sumaila and Walters, 2005). After informed consent, the participants were randomly assigned to one of three treatments and given 85 points endowment to play. Funds not invested into the PG were paid out directly following the experiment. The reward of cooperation into the PG was going to be dispensed only if the players were able to meet a 120-point threshold target, similar to the necessary effort to avert dangerous environmental damages by at least keeping a temperature level below a certain level or, as in our case, to reach a minimum budget for purchasing environmental positive goods, namely, in all treatments for printing posters with ecological messages to be displayed at the university, and in T3 for purchasing medicinal and fruit trees to be planted in the country for depolluting the air and the soil in the framework of a reforestation project based in the Yunnan and Heibei provinces (S. I. Liming and Quinlong planting progress reports). If the cooperation game was successful in going beyond the 120-point threshold, the bonus was rewarded to the players across three different time horizons: in T1, paid the next day, in T2 after 2 months, and in T3 it was not given to the participants, but with the higher investment effort of planting trees, reserved especially for the benefit of the years to come and for future generations (hence to check the intra-and intergenerational discounting effect).

Individualism/collectivism questionnaire

To obtain information related to collectivism and individualism (Triandis, 2001), we requested each student to fill out a questionnaire (Triandis et al., 1998), supplying us with this indispensable data before the start of the experiments randomly. This questionnaire could have ascertained the causation arising on why a specific student chooses a particular answer, that is, whether our results simply followed the German model or whether the cultural differences exposed by the subjects influenced the outcome.

In general, collectivism can be defined as the propensity of individuals to identify themselves as part of a group rather than as single entities (Nisbett et al., 2001; Triandis, 1995). A collectivist society is one able to sacrifice the needs of its individuals in order to prioritise the needs of the group. Often, the group is intended as a family unit or a circle of close friends, but in these emergencies, it extends to the urban or national community. When the Westerners aim at ensuring that their freedoms of thought, speech and action are

respected by the community in which they live, the Orientals are more concerned with maintaining their social relationships stable, even at the expense of personal rights. The high density of individuals living in a finite space, therefore, leads to the establishment of a culture that favours the good of the group, made up of individuals who must relate with each other leading to a state of harmony.

The answers to the questionnaire show that there is a variation across individuals from the same culture concerning collectivism. Assessing the answers, we can position the subjects within a polygon of 4 edges in which individualism vs. collectivism stands on the two intersecting axes and a vertical vs. horizontal dominance-related dimension (Supplementary Figure S3). We can therefore profile the respondents to either one of the four dimensions: Horizontal Individualism (HI), Horizontal Collectivism (HC), Vertical Individualism (VI), and Vertical Collectivism (VC). For instance, horizontal collectivists are part of their social niche without feeling subordinate to others. Vertical collectivists, on the other hand, submit to the norms of their in-groups. The horizontals do not employ much hierarchy.

Ascribing to different cultures different social values and comparing them across the globe has been a quest dating more than 40 years back (Hofstede, 1980), and the criticism of using Western concepts in Asia has been well addressed during the years with thorough analyses (Connection, 1987).

The questions asked to the participants in the questionnaire (Triandis et al., 1998) reflect situations that are close to those that occur in everyday university student life, with ambiguous situations that can be interpreted in line to collectivist values; in individualistic cultures, instead, these same ambiguous situations are likely to be turned into an individualistic perspective. For instance, this is a sample question from the set of 15 questions: "You and your friends decided spontaneously to go out to dinner at a restaurant. What do you think is the best way to handle the bill?" A Horizontal Collectivist would likely answer, "Split the bill equally, without regard to who ordered what"; a Vertical Individualist instead, "Split it according to how much each person earns"; a Vertical Collectivist would answer, "The group leader pays the bill or decides how to split it"; a Horizontal Individualist, "Compute each person's charge according to what that person ordered." For the complete set of questions, see SI.

Social value orientation

A Social Value Orientation test (Liebrand et al., 1986) was administered to assess whether participants choose between options that offer points to themselves or to another person, and to check whether this prosocial act has got a role in their pro-environmental choices.

Reinforcement learning analysis

To dig deeper into the data, a Deep Q-Network (DQN) (Mnih et al., 2013) was modelled on a simulated PGG with the same parameters of the actual PGG. Differently from a less precise agent-based model, the fictious players of the artificial intelligent model should behave in a more realistic way by learning and adapting their behaviour from previous rounds. The impact of social learning (observing others' contributions) on individual strategies was therefore studied together with the influence of the reward structures on cooperation levels. The reinforcement learning model was hence utilised to simulate how players behave in this PGG depending on what learnt in previous game rounds. Although still done very rarely on real-world data, we claim AI techniques can provide insights into the dynamics of observed behavioural patterns of a limited number of people and provide potential interventions for promoting cooperation, as long as the simulated model closely fits the real data.

To implement this analysis, three AI models were tested in succession, from the simpler to the more advanced one (Q-learning, Deep Q-Network DQN, and Multi-Agent Reinforcement Learning MARL). Given the limited amount of data collected over 10 rounds from 48 groups of 6 participants, we knew that an overly complicated model, although better fitting behavioural data (MARL, in this case), could have yielded unreliable results. To compare the efficiency of the models, we used mean squared error metrics (MSE) and considered the algorithm giving the lower error value. We chose the DQN algorithm, which handles continuous states and action spaces, learning through trial and error, similar to how individuals make decisions in PGGs. The DQN has successfully explained various real-world applications (Lillicrap et al., 2015).

The DQN defines the public goods game as an environment with states and actions. States are represented by round numbers, indicating the game's progression; actions are the contribution levels an agent can choose from (0 to 4 points). Once trained over the 80% of the data (8 out of 10 PGG rounds), the DQN agent was evaluated on unseen data and measured its performance comparing it to the remaining 20% (the last 2 rounds) by mean squared error MSE metrics.

Given the agents' inability to communicate directly, a Centralised Critic with Decentralized Actors CCDA architecture (Chaudhuri et al., 2021) was fine-tuned and fit into the model. This network takes the agent's observation about the state of the environment (the social dilemma choice) and outputs the final contribution action with a single central critic network. After each round, the central critic network's Q-value is broadcast to all agents as it happened during the game by showing this result at the end of each round to the players. Each agent, therefore, indirectly learns about the overall group performance without explicit communication and inferring about overall cooperation or defection, basing its assumptions from past round experience.

The RL model was parametrised to resemble the actual Public Goods Game (PGG) data more closely with the following characteristics. The model starts with an initial contribution level set to match the first round's average contribution of the actual PGG data. This ensures that the starting point is realistic and comparable. A linear decrease rate was calculated based on the difference between the initial and the final average contributions observed in the actual PGG data, spread evenly across the rounds. This rate reflects the gradual decline in contributions over time, simulating the participants' behaviour in the PGG influenced by some end-game effect.

Two indexes were created to quantify the learning process from the players' own actions and the actions of others: a Self-Learning Index (SLI) and a Social Learning Index (SoLI). They indicate the extent to which participants adjust their contributions based on their previous contributions and on those of others in their group. The SLI measures how a participant's contribution in a given round correlates

to his or her contribution in the previous round. The SoLI index, instead, quantifies how much a participant's contribution is correlated to the average contribution of other players in their group in the previous round. Pearson's correlations were used to obtain these correlations.

Statistical and AI analyses and software

We acquired the empirical data from the Chinese players via z-Tree (Fischbacher, 2007) and analysed by Linear Mixed Models via R 3.2.4 (R Core Team, 2016) with the lmerTest package (Kuznetsova et al., 2017). For the reinforcement learning analyses, we coded in Python using TensorFlow 2.4 with Keras 2.4.

Results

Main effects

We conducted 3 treatments on the 144 subjects. All descriptive results are displayed in Supplementary Table S1. The results show that in T1, the direct pay condition, six out of eight groups reached the target with an average contribution of 2.14 points per round. The target was reached on average right at the end of the game, that is at the 10th round. In the delayed pay condition, T2, 4 out of eight groups reached the target, with an average contribution of 2.09 points after 10 rounds, also. In T3, the environment condition, five out of eight groups intended to plant trees, with an average of 2.24 points this time earlier, after nine rounds, indicating a higher propensity for cooperating together.

Moderation

In the next step, we explored the extent to which individual differences, i.e., endorsement of collectivist values, influence their contributions. First, we found a positive relationship between collectivism and contribution rate. Second, the presence of collectivist group members allowed to reach the investment threshold. Third, the influence of collectivistic values was especially significant in the third treatment.

The results we obtained from the Chinese sample show that (Figure 1) if in T1 there is an apparent propensity to invest in the public good, in T2 there is no such distinction. In T3, interestingly, 5 out of 8 groups were effective at investing in planting trees differently from the German model, whose none of their groups managed to reach the same threshold of 120 points to plant trees (see Supplementary Figure S1), with an average of 130 points earned at the end of the 10 rounds (Figure 2). The behavioural output is statistically different across these 3 treatments [$F_{(3,75)} = 5.72$, $p < 0.005$], as well as being different in the final groups' earnings, whether they did or did not reach the threshold [$F_{(2,81)} = 70$, $p < 0.001$] (Table 1).

The Individualism/Collectivism 15-item questionnaire established that we had a majority of horizontal collectivist students followed by horizontal individualists (see Supplementary Figure S3) and that the collectivistic values allow for the emergence of this type of environmentally driven group cooperation [$F_{(2,39)} = 4.9$, $p = 0.03$] (Table 2).

When an individual displays a higher collectivist orientation, her/his contribution to the group is larger (Figure 3). No significant difference was found between the vertical collectivists and the horizontal collectivist individuals.

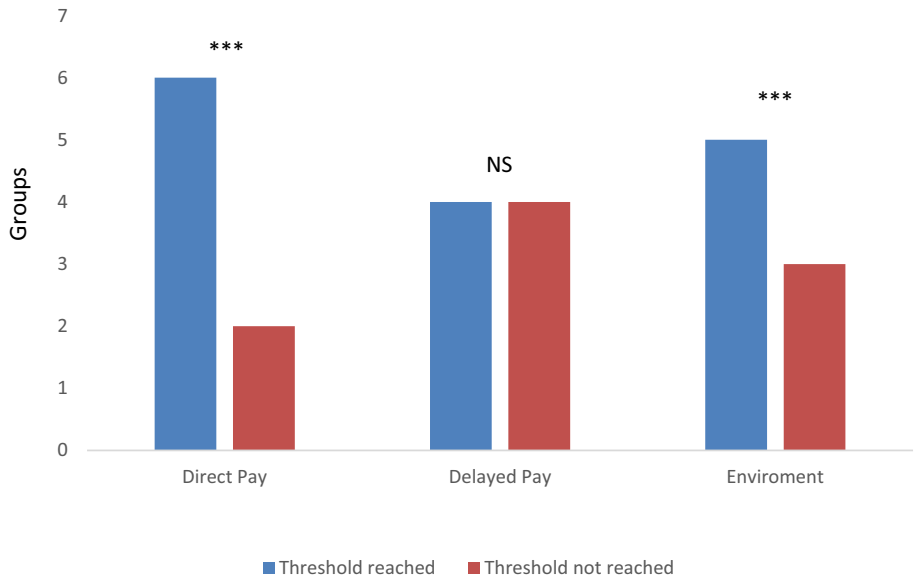

FIGURE 1
Whether the groups reached the monetary threshold of the PGG necessary for meeting the environmental target, split in the three treatments.

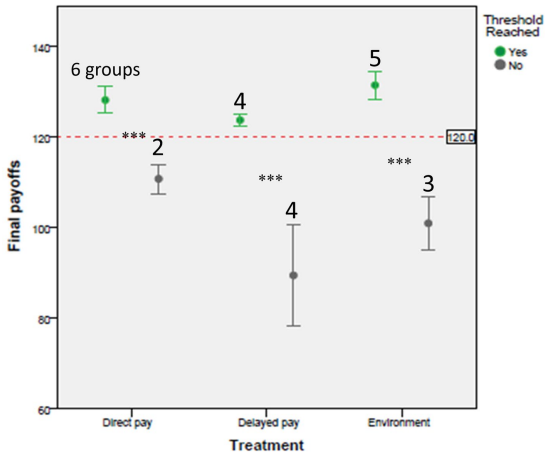

FIGURE 2
A total of 24 groups took part in this experiment split in three different treatments. In the third treatment, in particular, five groups managed to reach the threshold; hence their cooperative effort was enough for planting trees. The error bars represent SD of the mean values. The distributions of the contributions to the PG are reported in Supplementary Figure S2.

It is mainly thanks to the collectivists that the contributions to the public good are high throughout the 10 rounds of T3 (Figure 4, purple line). On average, they provide more than 3 points of the 4 available, displaying prosocial behaviour. The other participants, instead, tend to lower their trust in the group by decreasing their contributions across the rounds' iterations [typically ascribed as "end effect" (Andreoni, 1988; Abele et al., 2010)]. In detail, the average contribution per round started at approximately 2.22 points of the 4 available in the first round and gradually decreased to about 1.72 by the tenth round.

Reinforcement learning analysis

In this simulation, the rewards and states change dynamically with each round, reflecting the actual PGG. The agents in the reinforcement learning model make decisions based on the current state and receiving feedback by the mock environment in the form of rewards and new states.

To choose the learning model with closest fit to reality, we analysed the mean squared errors in succession: Q-learning output a 41.65 MSE, DQN 0.0185 (with iterations over 100 epochs), and MARL 0.45. Although the MARL algorithm is the one that should depict better interacting players competing over a PG, the algorithm is too complex for our limited amount of data. We therefore settled on the DQN analysis with the CCDA function to describe the learning process of our players (see Supplementary Figure S5 for the decreasing MSE throughout 100 epochs and the S. I. part with the Python code used to build the model). The model starts with an initial contribution level set to match the first round's average contribution of the actual PGG data. A linear decrease rate is calculated based on the difference between the initial and final average contributions, reflecting a gradual decline in contributions by the players over time, simulating participants' behaviour in the PGG. In addition to a low MSE, the actual PGG and the model produced by the RL analysis are compared by matching the contributions over rounds (Supplementary Figure S6).

The SLI (Self-Learning Index) and SoLI (Social Learning Index) values for each treatment condition are as follows: T1: −0.46, and −0.015; T2: −0.43, and 0.085; T3: −0.45, and 0.035. The evolution of these indexes over rounds for each treatment condition is visualised in Figure 5.

The SLI values are negative across all treatments, indicating a general trend whereby participants tend to decrease their contributions after investing more in previous rounds. Individuals seems to adjust their contributions downwards after initially contributing higher amounts. The SoLI values vary across treatments, with only T2 showing positive indexes, indicating that participants tend to increase their contributions in response to higher average contributions from others. In contrast, T1 and T3 show near-zero SoLI values, suggesting less influence from the social context. The positive SoLI in T2 hints at a stronger social learning component, where participants align their contributions more closely with their competitive peers, given the higher future discounting and corresponding risk aversion effects. Learning and social influence dynamics change as the game progresses and players accumulate experience and change perception about the group's behaviour.

Discussion

Like other common-pool resources such as forests, water or the atmosphere, the all-inclusive climate change can be enumerated as a commons problem and studied by implementing Public Good Games (e.g., Tavoni et al., 2011). This paper has analysed the propensity of various Chinese subjects to cooperate in group when asked to invest funds with short-term gains, or for the long-term purpose of reducing climate change without quick personal gains. The behaviours that emerged showed higher rates of cooperation than expected from similar studies. Is this due to the environmental motifs of the game? First, despite the social dilemma component of the PGG design, which incentivizes individuals to freeride, the threshold level required for success in the game may have increased the average contribution behaviour compared to the classical PGG framework. Secondly, Chinese subjects have usually fared low in contribution amounts in game theory experiments (Hong et al., 2008). However, in this case, our participants tested in Yunnan province invested an average of 2 points out of 4 available, which is not bad considering the coordination effort necessary in any PGG (Wang et al., 2023). Thirdly, the uncertainty and ambiguity of T2 and T3, which bring forward in time the likeliness to reap benefits from the cooperation efforts, should induce in the players a higher sense of risk aversion behaviour (Dreber et al., 2015). However, we see that the more collectivist players do not let cooperation fail over the uncertainty of the future, but allow the trust to be restored within the groups, as to reap some benefits out despite lower personal profits (similar to what happened in the step-level PGGs of Zhang et al. (2019), when an artificial prosocial player was added to the group). However, these dimensions of uncertainty and ambiguity are a second-order concern in terms of payment differences. The first-order dilemma difference, still, relates to the game condition providing direct financial benefits to the players (T1) versus the other treatments. These differential discount factors across treatments certainly influenced how players contributed to the public

TABLE 1 Summary of linear mixed model effect sizes of treatment difference, whether the threshold was reached, and these two terms' interaction.

	Sum sq	Mean sq	NumDF	DenDF	*F* value	Pr (>F)
Treatment	0.0358	0.0179	2	75.34	5.7262	0.0048
Threshold	0.2187	0.2187	1	81.77	69.9972	<1e-07
T*T	0.0546	0.0273	2	113.66	8.7418	0.0003

TABLE 2 Summary of effect sizes for threshold reached and collectivism orientation.

	Sum sq	Mean sq	NumDF	DenDF	*F* value	Pr (>F)
Threshold	0.0010	0.0010	1	39.44	1.8128	0.1859
Ind/Coll	0.0022	0.0022	1	39.49	4.0407	0.0513
Interaction	0.0027	0.0027	1	39.34	4.9056	0.0326

In this LMM, the interaction element has been mainly considered. A more thorough model is reported in Supplementary Table S2.

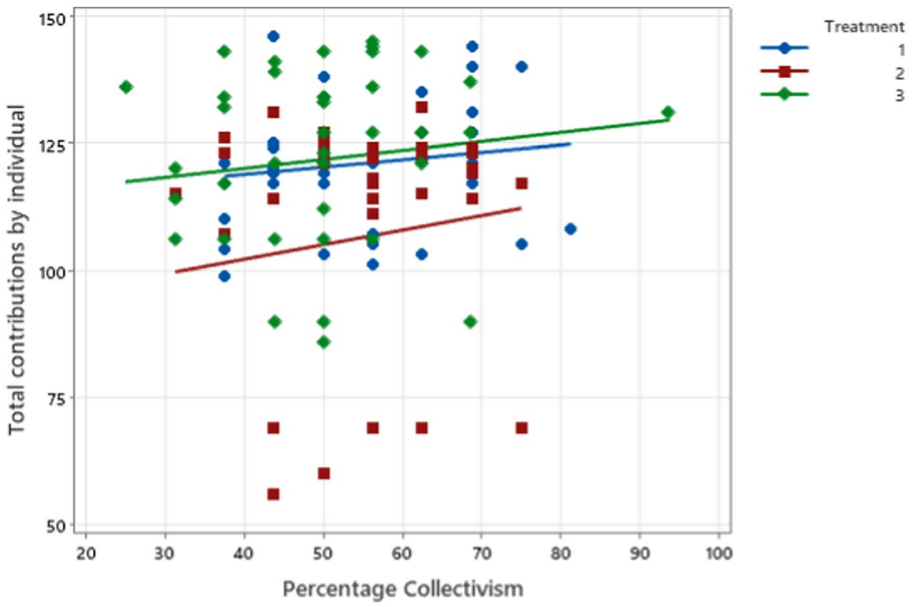

FIGURE 3
At the end of the 10 rounds, 144 participants varied in their contributions, inducing the public good to amount to between 50 and 150 points. Collectivism allows for more substantial investments.

good and influence how quickly participants learnt and adapted their strategies based on the observed behaviour of other similar-to-them students.

In the treatment with the highest discount factor, T1, participants are focussed on an immediate payoff and thus quicker to reduce their contributions if they do not see a following-round reciprocation. In T2, their efforts are to be rewarded only 1 month after the end of the game, thereby inducing a risk aversion sentiment and pushing the contributions to a lower value. In both these two first treatments, the funds to be invested toward the environment are used to print posters with ecological messages to be displayed at university. Note, though, that some of these were already present, such as stickers by the light switches to remind to turn them off when not needed. In contrast, in the last condition of T3, the valuation of future rewards becomes higher once their funds are used to plant trees. This more tangible resolution seems to encourage participants to adjust their contributions more gradually, reflecting a more strategic approach to maximising long-term benefits. Contributions remained higher in T3 compared to T1 and T2, as participants were more inclined to consider the long-term environmental benefits of their contributions.

The presence of players with varying degrees of prosocial behaviours adds complexity to the analysis. As normally expected from universities attended by students originating from different places across a vast country, players with a stronger prosocial orientation might be more likely to contribute to the PG regardless of the discount factor, driven by intrinsic motivations or the perceived social value of contributing. Having handed a Social Value Orientation test to the players as a control check, we saw how high contributors have a higher prosocial attitude and contribute more under uncertainty (Mill and Theelen, 2019). High contributors show more concern for group environmental outcomes (de Groot and Thøgersen, 2018), and they make decisions more frequently aligned with collectivist beliefs.

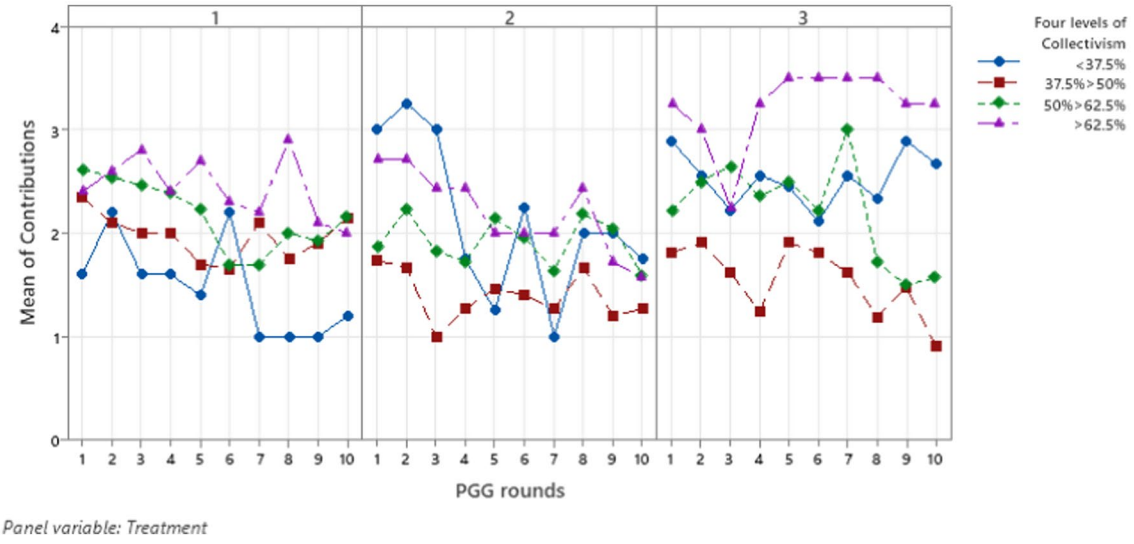

FIGURE 4
The time evolution of the average contribution per 10 rounds in T1, T2, and T3 split by the amount of collectivism surveyed in our population. In T3, we find more generous contributions from those players with a stronger collectivist orientation.

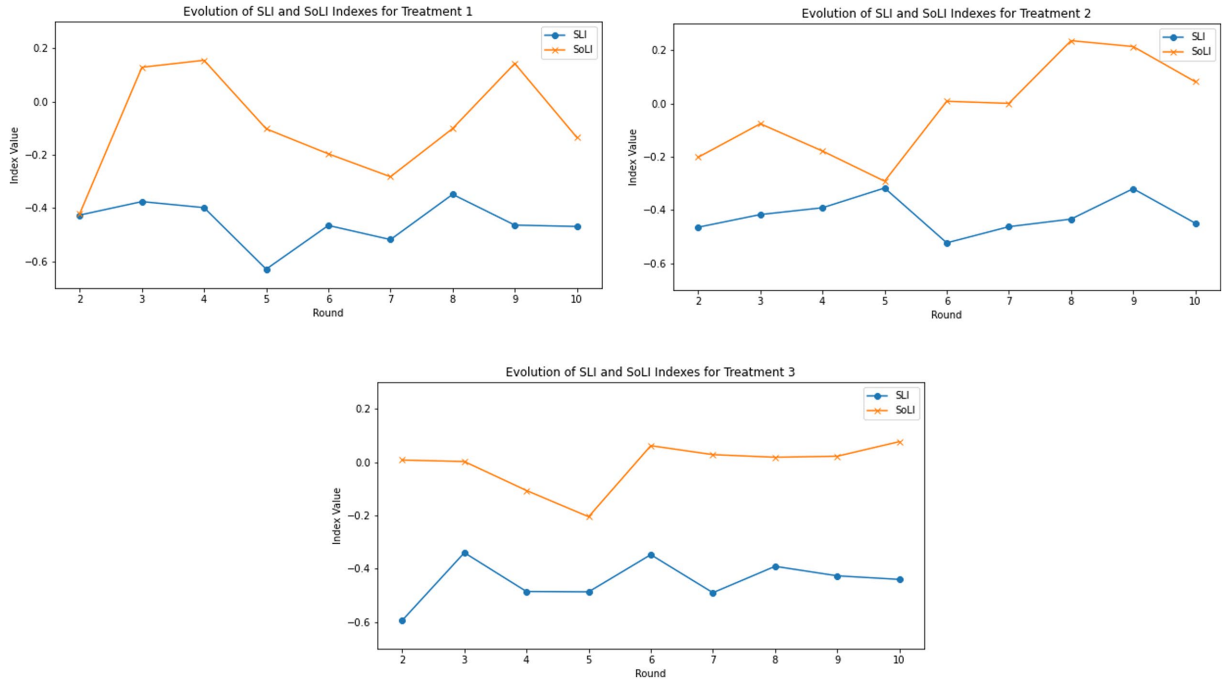

FIGURE 5
Evolution of the self-learning index and the social learning index throughout 10 rounds across the three treatments, calculated as the Pearson correlation of someone's previous-round contribution (SLI), and of the other participants' contributions during previous rounds (SoLI).

Although we did not have an embedded network structure in our games, network dynamics also play a role in the contributions game (e.g., Rand et al., 2011; Szolnoki and Perc, 2016). We do not witness some players withdrawing from the cooperative equilibrium by substantially decreasing their contribution, expecting the co-players to make up for their missing contributions at the following iterations of the game (Wang et al., 2023). Throughout recent times, people's sensibility toward topics related to pollution has increased. More than 3 out of 10 Chinese say water and air pollution are massive problems, and 7 out of 10 consider them at least a moderately big problem (Wike and Stokes, 2016). Half of those polled believe China should reduce air pollution even if it means slower economic growth, while just 24% think air pollution is the necessary price of a growing economy. Not just

perceived as global warming, but with years-long of extreme air pollution, especially in the highly developed east coast, we speculate that in general the Chinese have gathered substantial evidence about how damaged the environment is (Ebenstein et al., 2015; Chen et al., 2013) leading to feelings of public contagion with a significant effect on the willingness to cooperate in group so to donate funds to this cause. This solid awareness of ecological information (Biel and Thøgersen, 2007) may be similar to priming the experimental subjects well about the risks of climate change (and subsequent game loss) during the instructions of the experiment (Milinski et al., 2008), or similar to behaviour shown after having experienced a recent environmental catastrophic event (Albright and Crow, 2019).

The reinforcement learning analysis ascertained how participants not only learnt from the outcomes of their actions but also adapted to their group's overall behaviour. For instance, if a participant observes a trend of decreasing contributions, her/his contribution might be lowered in anticipation of similar behaviour from others. In T3, participants might be more inclined to sustain higher contributions for longer, as they place greater value on the intangible trees' payoffs, regardless of whether only following generations will reap the fruits out. This is evident from the relatively higher contributions in T3, before the investment decline after the 7th round, indicating a feeling of trust toward the aims of the experiment and a forward-looking approach in the decision-making process. The decline in contributions after the 7th round in T3 suggests a strategic shift among participants. As the game nears its end, participants might reassess their strategies, considering the limited remaining rounds to recoup the benefits of their contributions. This strategic shift reflects a learning process where participants weigh the immediate costs against the diminishing opportunities for future benefits while the threshold is reached.

Looking at the role of institutions in public goods provision, Tsai (2007a, 2007b) study in the same context of an authoritarian regime (China) finds that informal and normative institutions manifested in higher levels of public goods provision. This is another indication that our results make sense within the collectivistic and highly normative context in which Chinese subjects are fronted when faced with public goods' investment dilemmas. In addition, a strong sense of collectivism may induce the players to prefer the group rewards of T2 and T3, since additional earnings are not split as it occurs in T1. Collectivism may therefore operate through a different channel: how valuable a collective reward is. This argument does not invalidate the current findings, but suggests an alternative interpretation of why collectivism matters.

Other authors (Isaak et al., 2022), instead, have expected individuals from far Eastern cultures not to easily trust anonymous peers because not belonging to the same, close-knit group. This effect would be preponderant on the sustainment of cooperation in a PGG. Nevertheless, the anonymous participants of our experiment were aware that the other players were taken from other classes within the same university; they cannot therefore be considered entirely anonymous. Further experiments should be run to evaluate the strategic interaction structure of the game by assessing how a collectivist would behave when expecting to be matched with other collectivists, and when expecting to be matched with other individualists (Goldwert et al., 2024). The current analysis, in fact, only accounts for the percentage of collectivists per group and inspects the contribution of collectivists vs. individualists.

Comparing Japanese students with American students, an earlier psychological study questioned participants through a survey and found out that the feeling of connectedness to the group plays a major role in densely inhabited areas (Yuki, 2003). In-group and out-group phenomena may let competition emerge over collaboration (Liu et al., 2011; Jang, 2013), and individuals from collectivistic cultures may be more vigilant toward in-group members when these latter unethically freeride (Liu et al., 2019). Not all Eastern Asian countries can be bunched together in terms of collectivistic values, however. We in fact know that a long history of capitalism in the highly industrialised Japan, South Korea, Singapore, Hong Kong and Taiwan has led those citizens to behave in a mixed way more similar to WEIRD societies than, in particular, the Chinese and Vietnamese (Inoguchi and Tokuda, 2017). We expect this to be true, especially when testing subjects from the less developed South-West China, still thriving with minorities and traditional cultural values having gone partly lost in the Eastern coast of this country (Cheng and Berman, 2012). China is a very diverse country with traditions tied to local cultural and economic practices, as the rice farming hypothesis has well demonstrated (Talhelm et al., 2014). In relation to adherence to tight or loose social norms (Gelfand et al., 2011), Yunnan province fares in between a low and a high tolerance for deviant behaviour (Talhelm and English, 2020). Yunnan has historically been a province that the typical Chinese long to visit right due to its richness in environmental and anthropological resources. Yet, adherence to ecology and respecting nature in a modern way (Kurz et al., 2015) is something that need to be better drawn upon and analysed (Hu and Chen, 2016).

With the psychological survey (Triandis, 2001), we showed that the Chinese collectivistic values are to be correlationally imputed as one of the critical factors for our results. A feeling of connectedness toward the environment (de Groot and Thøgersen, 2018) is likely to be the determining factor present in younger generations in this part of the world. However, aware of the mental barriers that drive inaction toward the environment (Gifford et al., 2018), more in-depth and up-to-date analyses of the cultural and sociological motifs of pro-environmental behaviour are needed (Moser et al., 2022), not just within China, but across the globe (Yang et al., 2024). Priming participants with collectivists values through the treatment design could be just one of the many potential approaches to better prove the effect of this personality trait as a determinant for proenvironmental investments.

As informed by the reinforcement learning analysis (useful also for a dataset of finite size), policies could focus on encouraging higher initial contributions to the PG. It is well understandable that actors asked to invest personal funds into the environment should be primed with state incentives, matching contributions, or providing hands-on ecological information on the benefits of cooperation. Also, the observed decline in contributions over time highlights the need for interventions to sustain or increase contributions, especially during this first phase of rise in environmental temperature. If the investment decline is due to perceived unfairness or distrust, policies should also focus on enhancing transparency among participants by revealing the identity of contributors.

The willingness to invest resources for planting trees is just one of the several ecological behaviours that need to be modelled outside of universities' computer labs and with all age groups. During this transitionary phase toward a more sustainable world, on a regular basis, behavioural scientists should screen the populations in the lab and in the field (Goeschl et al., 2020) to find out the role of cultural differences and to adjust interventions by nudging specific environmental values (Schubert, 2017) and exert some leverage onto the public civic sense (Jacquet, 2015). The respect toward the environment shall become part of universal moral principles (Capraro and Perc, 2018).

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://github.com/ricpans/collect-clim-change.

Ethics statement

The studies involving humans were approved by the Yunnan University of Finance and Economics Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

RP: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Visualization, Writing – original draft. LS: Project administration, Resources, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fhumd.2025.1613898/full#supplementary-material

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