Title: High Risk and High Reward Decision-Making for Climate Change Mitigation

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Abstract:

As the urgency of mitigating climate change rises, investment in low risk, incremental technologies may not be sufficient to prevent damage. To understand when people are willing to make risky investments in mitigation, we used a series of economic games wherein players must contribute enough as a group to avoid simulated climate change. Players could defect, make a certain contribution, or a risky contribution with a high potential gain. Using risk sensitive decision theory, a theory developed in evolutionary biology, we predicted that players would make riskier contributions when total mitigation costs rose. Across four studies (combined N = 2,010), this prediction was confirmed, even when people made costly decisions on behalf of others. We discuss implications for framing persuasive appeals about climate change.

Main Text:

What kinds of technologies are people willing to support to fight climate change? Some technologies, like solar or wind power, create certain but relatively small reductions in greenhouse gas emissions. Others, like carbon sequestration devices, have the potential to create much bigger reductions—but with a greater possibility of failure. The Intergovernmental Panel on Climate Change (IPCC) reports that it is unlikely the rise in global mean temperature will remain below 2ºC without successfully employing these latter, riskier types of technologies [1].

Even if such technologies are necessary, would they find political support? We use experimental economic games to model decisions about risky climate technology [2,3]. Specifically, we test when people will prefer high risk/high reward options to low risk/low reward options to prevent (simulated) climate disaster. To make predictions, we draw on risk sensitive decision theory, a theory developed in evolutionary biology and increasingly used in the cognitive sciences [4–6]. This theory augments other approaches, such as expected utility theory and prospect theory, by incorporating the variance of potential outcomes—their riskiness—into decision-making.

A Global Social Dilemma

Climate change is one of the largest and most consequential challenges the world has faced [7]. Mitigation is difficult because it is a *global social dilemma*: All countries would be better off if all reduced their emissions sufficiently, but any given country benefits if they do not make any changes. If other members of the global community make the necessary sacrifices, why bother curtailing one's own production, consumption, or economic development—and the concomitant emissions? This social dilemma structure retards progress. The IPCC estimates that to keep mean global temperature rise below 2ºC, the planet must collectively keep the level of carbon dioxide-equivalent (CO_2eq) below 550 parts per million (ppm) by 2100 [1]. Continued delays in meeting this goal will eventually necessitate drastic action [8].

IPCC projections which assume use of higher risk mitigation options, such as carbon sequestration technologies, find a higher chance of successful mitigation than those that assume only an increased reliance on wind and solar power. If the global community continues to delay implementation of stringent energy conservation policies, successful carbon sequestration devices could make up the difference in emissions, keeping the planet well below CO_2eq levels of 550ppm. Differential returns to investment—and the risk associated with it—are considered by the IPCC to be crucial in meeting targets of atmospheric CO_2 in many scenarios, and indispensable in most so-called overshoot scenarios [8]. Greater returns to investment in climate mitigation are nearly always coupled with elevated risk [9]. Therefore, successfully solving the global climate change dilemma might require individual actors to invest in increasingly risky technology, even in the face of potential free riding in the provision of the public good of mitigation. Our goal is to test when and whether citizens support investment in risky climate technology.

A Behavioral Model of Climate Change Mitigation

Citizens' views about climate change and mitigation have been studied using surveys [10,11], laboratory experiments [12], and field studies [13,14]. Researchers have also used economic games, particularly the *climate change game* [2,15], which we use here. Economic games present players with monetary stakes and clear rules for how the decisions of multiple players are aggregated into payoffs [16]. For example, in the original climate change game, a group of players face a "climate threshold"—a monetary amount. Each player uses a personal account of money to contribute to the threshold. If total contributions of the group meet or exceed the threshold, the group avoids “climate disaster”—meaning they keep whatever money remains in their personal accounts. But if the group’s contributions are not sufficient, they face a high risk of climate disaster—the possibility of losing all remaining money. The original climate change game[1] manipulated the probability of disaster if the threshold was not met, finding that players were more likely to contribute when the probability of disaster increased [2]. Variants have studied the effects of inequality among players [15,17,18], the ability to pass problems along to others [19] or to the future [20], uncertain thresholds [21], and elected representation [22].

Economic games are also amenable to game theoretic equilibrium analysis. This allows researchers to compare players’ behavior to (e.g.) rational agents attempting to maximize personal earnings. Analyses of the standard climate change game show that players face a tension. Some equilibria include all players defecting—and taking their chances with climate disaster. Other equilibria involve players contributing sufficiently to meet the threshold and prevent climate change.

Studying laypersons’ risky decision-making about climate mitigation is important for several reasons. First, citizens, at least in democracies, can hold elites accountable for their climate decisions. Second, in at least some contexts, elites and citizens respond similarly in economic games [23]. Third, consumer preferences for mitigation strategies are increasingly shaping corporate behavior through shareholder and consumer activism [24–26]. Thus, studying citizen behavior is important for its own sake, as well as for its role in potentially illuminating elite behavior.

Risk Sensitive Decision-Making

[1] This game is typically called the “collective risk social dilemma.” Here, we reserve “risk” for the uncertainty inherent in players’ choices in our game. In the original game, “risk” referred to the possibility of catastrophic climate change happening based on all the players’ actions, a correct usage but which invites confusion in the present context.

We extend the climate change game to include differential returns to investment: Players not only choose whether to invest money toward the climate threshold but also whether to invest in a low risk/low reward option or a high risk/high reward option. To predict players' decisions, we draw on risk sensitive decision theory [5,27–29]. Instead of focusing solely on the expected value or utility of options, risk sensitive decision theory also incorporates the riskiness of options and the needs of the decision-maker. This theory augments existing theories, such as prospect theory or expected utility theory; it does not replace them. Risk sensitive decision theory predicts that risk preferences are sensitive to context. When needs become high enough, decision-makers will shift to picking risky options. Here, this would mean that as the total necessary costs of climate change mitigation increase, then citizens might become risk-seeking in their choice of climate mitigation technology. Thus, risk sensitive decision theory is particularly applicable to threshold games such as the climate change game.

Notably, risk sensitive decision theory has been, to our knowledge, only applied to single-player, decision-theoretic contexts. It has never been applied to a multi-player, strategic context in which game theory applies. So, in addition to addressing the applied question of how people make risk sensitive climate decisions, our experiments also address basic questions about risky decision-making in groups with the potential for free riding.

Studies 1 and 2: Risk Taking in the Climate Change Game

Applied to the climate change game, risk sensitive decision theory predicts that, as the threshold rises, people will become more willing to invest in the high risk, high reward technology. To test this, in Study 1 (n = 501, see Table S9 for distribution of all subjects across experimental conditions) and Study 2 (n = 499), participants played a one-shot version of the climate change game in groups of four (see Table S4 for participant demographic information).

The game was over the internet through Amazon's Mechanical Turk [30,31]. Players made decisions denominated in U.S. cents; these stake sizes are standard in this setting. The game was explicitly framed as being about climate change mitigation (see SI Materials: Study 1 and 2 for full instructions).

Players were each given two pots of money. The first pot was a "personal account" of 20¢. The second pot was an "endowment" of 80¢ (in Study 1) or 40¢ (in Study 2). The size of the endowments was the only design difference between the two studies. We included this difference to ensure the results were not unduly sensitive to the endowment size. Each 4-person group was randomly assigned a "climate threshold," a monetary amount that, between-groups, was drawn from 60, 80, 100, 120, or 140¢. If the group contributed enough total money to meet or exceed their threshold, each player kept their remaining money. If they did not meet the threshold, there was a 90% chance they lost all remaining funds; this represents climate disaster. The 90% risk of loss is consistent with previous studies with the climate change game [2,15].

Importantly, players could not use their endowments to contribute to the threshold; endowments represent valuable private and public resources (e.g. infrastructure) that can be lost or damaged if climate change occurs but cannot easily be used for mitigation. Thus, players could only contribute their 20¢ personal account. Players made their contribution decisions independently and simultaneously. They had three options. First, they could defect and keep their entire personal account. Second, they could directly contribute their entire personal account and add a certain 20¢ toward the threshold. Note that even if all four players contributed in this manner, their contributions would only reach 80¢—they could not possibly reach the three highest thresholds. This motivates their third option: They could contribute their entire personal account as a risky contribution that had a 50% chance of adding 0¢ and a 50% chance of adding

40¢ toward the threshold. If a sufficient number of group members choose this option it is in principle possible to meet the higher thresholds, though some luck is necessarily involved. Certain and risky contributions had identical expected values. Contributed personal accounts disappeared regardless of the game's outcome. A schematic of the game is shown in Figure 1.

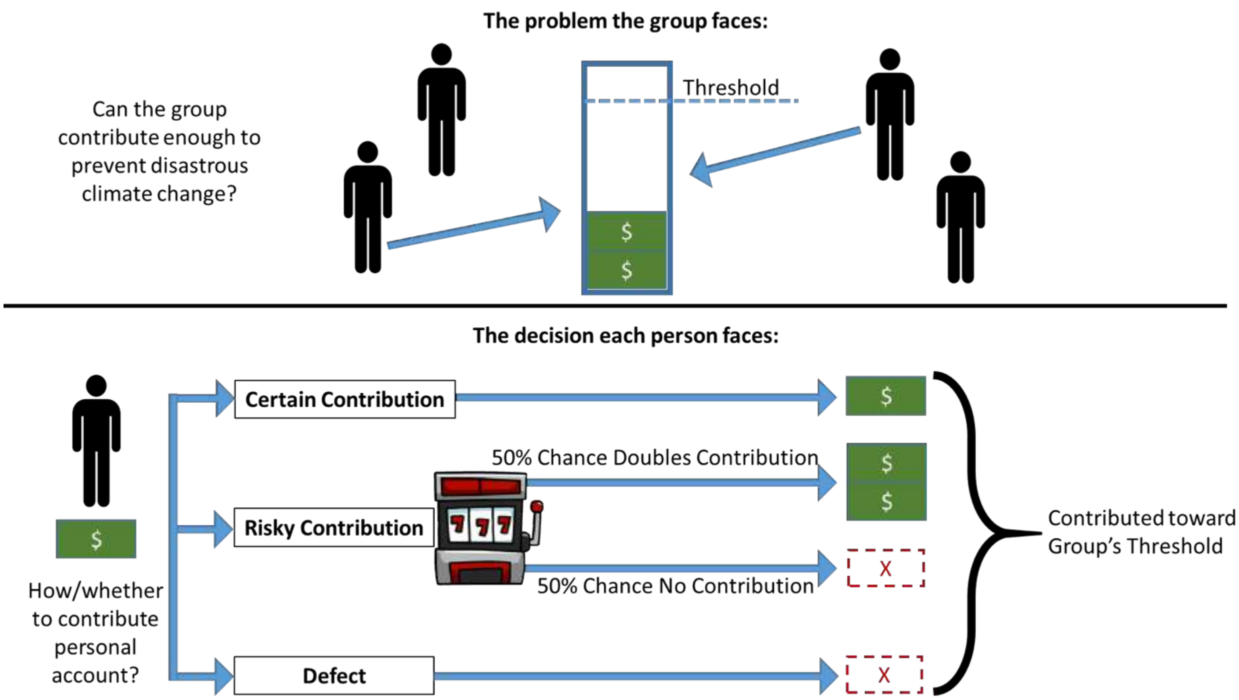

Fig. 1. *Schematic representation of the game structure.*

Given this design, contributors could earn a maximum of 80¢ (40¢) in Study 1 (Study 2) and defectors a maximum of 100¢ (60¢). Thus, the game has the structure of a threshold public goods game. In the supplemental information, we provide a game theoretic model of payoff-maximizing players. One equilibrium in this model, regardless of threshold size, is complete defection (see Supplementary Text: Game Theoretic Model). Alternatively, at every threshold there are also equilibria of cooperation and, importantly, the greater the threshold, the more players at cooperative equilibria should choose the risky contribution. Notably, the cooperative equilibria payoff dominate the complete defection equilibria. Thus, our primary prediction is that risky contributions will increase as the threshold increases.

We predicted based on risk sensitive decision theory that as the threshold increases, risky contributions should generally increase. As shown in Figure 2A & B, this is what we found: Risky contributions increased as the threshold increased (black bars). Thus, people were willing to make risky investments in (simulated) climate technology so long as the need is great enough. In Study 1, 24% of players chose the risky option at the lowest threshold; a peak of 47% of players chose the risky option at the 120¢ threshold. In Study 2, 24% of players chose the risky option at the lowest threshold; a peak of 49% of players chose the risky option at the 100¢ threshold. In both cases, the peak riskiness represented an approximate 100% increase over the lowest threshold.

Although we find in general that players are more willing to choose the risky option when thresholds rise, we also found that at the very highest thresholds some players switched from the risky option to the direct contribution option (see Figure 2A & B). This general trend was anticipated by the comparative statics of our game theoretic model, which predicts more players choosing certain contribution in the payoff dominant equilibria of the highest thresholds, compared to the payoff dominant equilibria of the middle-to-high thresholds (see Table S5).

To test these patterns statistically, we used a linear probability model. This method analyses dichotomous data but allows coefficients to be interpreted as typical regression coefficients [32]. The dependent variable in the model was a dichotomous variable coding for whether the participant chose the risky contribution or not. In the model, there were two predictor variables: the value of the threshold and, to capture the observed curvilinear pattern in the data, the squared value of the threshold (Table 1). Both variables were significant in both studies ($p < .05$, this and all other p-values are two-tailed tests), revealing that risky contributions generally increased until dropping back down at the highest thresholds.

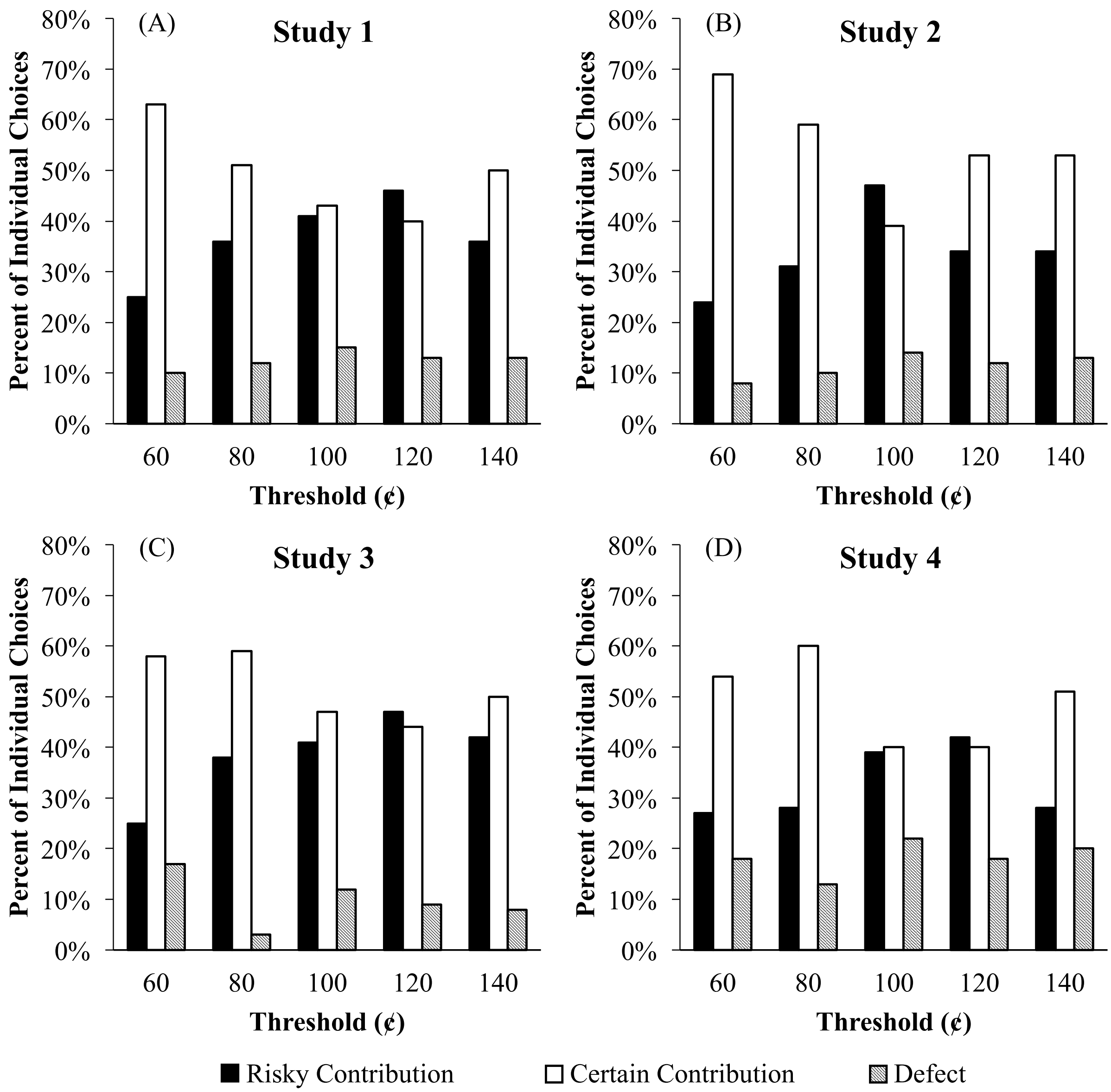

Fig. 2. *Percent of people who select each contribution option at each threshold in each study.*

Choosing Risky Contribution	Study 1	Study 2	Study 3	Study 4
Threshold	0.57* [0.15, 1.00] (0.21)	0.58* [0.17, 0.99] (0.21)	0.51* [0.08, 0.93] (0.21)	0.49* [0.08, 0.91] (0.21)
Squared Threshold	-0.45* [-0.85, -0.04] (0.21)	-0.49* [-0.88, -0.09] (0.20)	-0.34 [-0.74, 0.06] (0.20)	-0.42* [-0.81, -0.03] (0.20)
Constant	0.25** [0.16, 0.34] (0.05)	0.23** [0.14, 0.32] (0.04)	0.26** [0.17, 0.35] (0.04)	0.24** [0.15, 0.33] (0.05)

Note: $^*p < .05$, $^{**}p < .005$, two-tailed

Table 1. *Linear probability model illustrating effects of the threshold on the decision to make the risky contribution. For each cell in the table, the first element is the point estimate of the regression coefficient. The second element, in brackets, is the 95% confidence interval for the regression coefficient. The third element, in parentheses, is the standard error of the regression coefficient.*

Defection rates did not vary based on the threshold, averaging 13% across all thresholds (see Table S1). Instead, participants increased their certain contributions as the threshold reached its highest levels (Figure 3A, white bars). A series of linear probability models, with a dichotomous outcome variable of whether or not participants chose the certain contribution, revealed that certain contribution rates were a mirror image of risky contribution rates. There are again significant effects of threshold values and squared threshold values (ps $< .05$; Table S1).

We find that as the threshold increases fewer groups successfully meet the threshold and mitigate climate change (See Extended Data Figure 1, yellow and red lines). Table S6 shows how actual players' earnings compared to game theoretic predictions for payoff maximizing players. Finally, note that the two studies produced largely identical results, despite the endowment being twice as large in Study 1. This is reassuring, as had there been a difference, this might imply that only the richest of the developed nations—those which stand to lose the greatest levels of accumulated wealth—would make risky contributions to mitigation.

Study 3: Increasing the uncertainty of the risky choice

Our first two studies support the prediction that players will generally make risky contributions when the threshold increases. Because predictions from risk sensitive decision theory have never been tested in a group decision-making context, we were interested in exploring the boundaries of the effect. Therefore, in our third study (n = 500) we sought to replicate the results of our first two studies, but with an additional layer of uncertainty in the risky contribution. Study 3 is identical to Study 1, except we increase the number of possible outcomes in the risky option: If a player chose the risky contribution there was a 50% chance 0¢ were contributed and a 50% chance that a variable amount was contributed. This variable amount was 0, 20, 40, 60, or 80¢ with equal probability. As in the previous studies, risky contributions and certain contributions in Study 3 had identical expected values.

Again, consistent with the prediction from risk sensitive decision theory, we find that players are more likely to choose the risky option when the threshold is larger (Figure 2C). In Study 3, 25% of players chose the risky option at the lowest threshold; a peak of 48% of players chose the risky option at the 120¢ threshold, a nearly 100% increase. A linear probability model for Study 3 shows that when the size of the threshold is larger, players were more likely to choose risky contributions (p = 0.02; Table 1). Also as before, risky contributions decreased, or at least did not continue increasing, at the highest thresholds; this is consistent with the comparative statics for this game (Table S7). The squared threshold predictor is marginally significant (p = 0.10, Table 1).

There were not significant effects for defection rates (see Table S1) and certain contribution rates tended to follow a mirror image pattern of risky contribution (ps < .05, See Table S2). Also consistent with our previous two studies, as the size of the threshold increased the proportion of groups who successfully met the threshold decreased (see Extended Data Figure 1, green dashed line).

Study 4: Making Risky Decisions for Others

Though our first three studies confirm that risky contributions increase as the threshold increases, they all assume the costs and benefits of climate change mitigation accrue only to those making the mitigation decisions. However, most of the anticipated effects of climate change will fall on people not primarily involved in decision-making. For instance, the decisions of large industrialized nations currently affect developing nations, and the decisions of the present generation will primarily affect future generations [19,20,33]..

Thus, in our fourth study (n = 499) we tested whether the predictions of risk sensitive decision theory apply when people make personally costly climate decisions on behalf of others. In this study, players use their own endowments to meet the thresholds for other groups. The study is nearly identical to Study 1: players had personal accounts of 20¢, endowments of 80¢, and their group faced thresholds ranging from 80¢ to 140¢. Also as in Study 1, they chose between defection, certain contributions, and risky contributions with a 50% chance of contributing 0¢ and a 50% chance of contributing 40¢.

In the key change from Study 1, the contributions of a player's own group go toward a different group's threshold and thus determine whether or not that second group loses their endowments. The player's own group's threshold is being contributed to by yet another group. A group's own threshold is always the same as the other group to whose threshold they are contributing. Moreover, groups are not trading thresholds (see instructions in SI: Materials). Thus, the decisions of each player do not affect their own group's chance of meeting the threshold, but instead the chance that a second group's threshold is met. Comprehension checks revealed that players understood this feature of the game (see Table S8). Given that contributions are costly and all the benefits of mitigation accrue to another group, a payoff-maximizing player should always defect when playing for another group, and in fact there is somewhat more defection in Study 4 (18%) than in the Study 1 where participants contributed to their own group's threshold (13%; for the difference $t(999) = -2.22$, $p = 0.03$).

Nonetheless, many players still chose to contribute. Furthermore, the pattern of mitigation decisions across thresholds replicates the previous three studies (Figure 2D). In Study 4, 27% of players chose the risky option at the lowest threshold; a peak of 42% of players chose the risky option at the 120¢ threshold, an approximately 55% increase. Again, the rate of defection did not vary across thresholds (see Table S1). A linear probability model shows that the threshold and the threshold squared predict risky contributions ($p = 0.021$ and $p = 0.037$, respectively; Table 1). The results again confirm the predictions of risk sensitive decision theory as participants were motivated by the size of the threshold. Importantly, this occurred even though their contributions, risky or certain, did not affect their own chances of keeping their endowments. These findings optimistically reveal individual willingness to contribute to mitigation for others, rather than only their own personal gain.

General Discussion

Our studies provide behavioral data about when people are willing to heed the calls of the IPCC and invest in risky but potentially more efficacious technology. In our game, when the difficulty of preventing catastrophic climate change increased, people were increasingly likely to take risks necessary to prevent climate change. Moreover, as the threshold increased there was no increase in defection rates. In addition to these optimistic results, we also found in Study 4 that players made similar—and costly—decisions even when they could only affect the outcomes of others. Our studies combined over 2,000 participants and it is clear from Figure 2 that the pattern of results was nearly identical across all four studies. Although there have been recent concerns about the replicability of behavioral science research [34,35], the effect observed here appears replicable, at least within our experimental setting.

We also found that as the threshold reached its highest levels people shifted from risky contributions to certain contributions. At least within our framework, this behavior is quite replicable, and is consistent with our game theoretic analysis. These results are intriguing, but further research is needed to better understand the implications of these results for the global climate dilemma.

To better inform policies and methods of disseminating information about the dangers posed by climate change, future studies may explore how to inform people about mitigation costs. Different modes of presentation affect how people perceive the problem [36]. Individual differences such as personality traits [37] and partisanship [38] similarly influence the risk perceptions and mitigation behaviors and attitudes. Although we had no a priori predictions, we found that players' risk-taking attitudes independently predicted risky climate choices (Table S3).

This research also speaks to basic questions about decision-making. In past research, risk sensitive decisions involve only the decision-maker herself. Here, however, the situation was game theoretic—outcomes depended on the decisions of multiple players. Nonetheless, behavior followed the basic pattern predicted by risk sensitive decision theory: greater risk taking as the threshold increased. This is intriguing because our game allowed for free riding and defection, possibilities that only exist in social dilemmas. Despite this, contributions and risk taking did not collapse. Moreover, game theoretic analysis of Study 4 predicts no differences in behavior (i.e. all defection), but the results are nonetheless virtually identical to the other three studies, suggesting a more general underlying behavior.

While initial investigations of risk sensitive decision behavior primarily studied non-human animals' foraging decisions [39,40], this study confirms other recent examples of the flexibility of the cognitive ability to weigh the expected outcomes and variance of options when attempting to achieve a variety of goals [4,5,28]. Our model and results show that evolutionary and rational choice explanations can be complementary. In this case, though our game theoretic analysis reveals multiple equilibria, risk sensitive decision theory offers an explanation of equilibrium selection. We hope our application of this theory will encourage more researchers to integrate biological, economic, and psychological theory into the analysis of such games.

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Methods

Participants in all four studies were recruited online and participated through Amazon's Mechanical Turk [30]. In Study 1 (N = 502), 78% of participants were U.S. citizens, and all participants in Study 2 (N = 503), Study 3 (N = 508), and Study 4 (N = 499) were U.S. citizens. Each participant was given a 50 cent show-up fee and could earn a bonus up to $1.00 in each study except in Study 2, in which they could earn a bonus up to $0.60 [31].

Participants first read the full instructions for the game, and then answered a series of comprehension questions designed to assist their understanding. Participants were not eliminated based on their comprehension question scores, but were given further clarifying information after any incorrect responses. They then made their incentivized contribution decision. We randomly assigned players to groups of four to calculate their bonuses; all bonuses were granted through Amazon's Mechanical Turk. See Table S6 for average earnings in each study and condition.

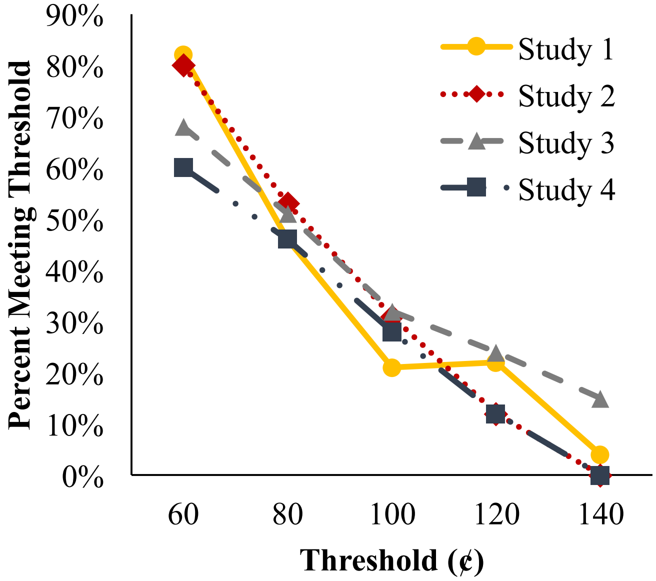
Following the decision task, each participant completed the Eckel-Grossman measure of risk preferences. They then answered a series of demographic questions and questions regarding their beliefs about climate change. See Table S4 for demographic information about participants in each study, and SI: Materials for all instructions and questions used in each study.

Data Availability

The datasets generated during the current study are available from the corresponding author on reasonable request.

Extended Data Figure 1

The percent of groups successfully meeting each climate change threshold.



Supplementary Materials for

High Risk and High Reward Decision Making for Climate Change Mitigation

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Supplementary Tables:

Table S1.

Results of linear probability models from each study with the choice to defect as the dichotomous dependent variable and the threshold and squared threshold as independent variables.

Choosing to Defect	**Study 1**	**Study 2**	**Study 3**	**Study 4**
Threshold	0.13 [-0.17,0.44] (0.15)	0.16 [-0.12, 0.43] (0.14)	-0.20 [-0.46, 0.06] (0.13)	-0.03 [-0.37, 0.32] (0.18)
Squared Threshold	-0.11 [-0.39, 0.18] (0.15)	-0.11 [-0.37, 0.16] (0.14)	0.15 [-0.10, 0.40] (0.13)	0.06 [-0.27, 0.38] (0.17)
Constant	0.10** [0.04, 0.17] (0.03)	0.23* [0.02, 0.13] (0.03)	0.14** [0.09, 0.20] (0.03)	0.17** [0.10, 0.25] (0.04)

Note: *$p < .05$, **$p < .005$, two-tailed

Table S2.

Results of linear probability models from each study with the choice to make the certain contribution as the dichotomous dependent variable and the threshold and squared threshold as independent variables.

Choosing the Certain Contribution	Study 1	Study 2	Study 3	Study 4
Threshold	0.71** [-1.15, -0.27] (0.23)	-0.74** [-1.17, -0.31] (0.22)	-0.30 [-0.74, 0.13] (0.22)	-0.47* [-0.91, -0.02] (0.23)
Squared Threshold	-0.56* [0.14, 0.97] (0.21)	0.60** [0.18, 1.01] (0.21)	0.19 [-0.22, 0.61] (0.21)	0.36 [-0.06, 0.78] (0.21)
Constant	0.64** [0.55,0.74] (0.05)	0.70** [0.61, 0.79] (0.05)	0.59** [0.51, 0.69] (0.05)	0.59** [0.49, 0.68] (0.05)

Note: **p* < .05, ***p* < .005, two-tailed

Table S3.

Results of linear probability models from each study with the choice to make the risky contribution as the dichotomous dependent variable and the threshold and its interaction with risk preferences as the independent variables.

Choosing Risky Contribution	**Study 1**		**Study 2**		**Study 3**		**Study 4**	
Threshold	0.13 [-0.05, 0.31] (0.09)	0.99** [0.35, 1.64] (0.33)	0.16† [-0.03, 0.35] (0.10)	0.62† [-0.03, 1.27] (0.33)	0.04 [-0.14, 0.23] (0.09)	0.54 [-0.10, 1.18] (0.33)	0.16† [-0.02, 0.34] (0.09)	0.34 [-0.30, 0.98] (0.33)
Risk Preference	0.29* [0.08, 0.51] (0.11)	0.42** [0.16, 0.68] (0.13)	0.31* [0.08, 0.54] (0.12)	0.29* [0.01, 0.57] (0.14)	0.09 [-0.12, 0.30] (0.12)	0.14 [-0.11, 0.40] (0.13)	0.38** [0.16, 0.61] (0.11)	0.30* [0.02, 0.58] (0.14)
Risk Preference X Threshold	-0.01 [-0.37, 0.36] (0.18)	-1.10† [-2.36, 0.16] (0.64)	-0.19 [-0.55, 0.18] (0.19)	-0.06 [-1.36, 1.24] (0.66)	0.33† [-0.02, 0.67] (0.18)	-0.05 [-1.28, 1.18] (0.63)	-0.25 [-0.61, 0.11] (0.18)	0.36 [-0.92, 1.64] (0.65)
Squared Threshold	--	-0.86* [-1.48, -0.24] (0.31)	--	0.46 [-1.09, 0.16] (0.31)	--	-0.48 [-1.09, 0.12] (0.31)	--	-0.18 [-0.79, 0.42] (0.31)
Risk Preference X Threshold Squared	--	1.10† [-0.11, 2.33] (0.62)	--	-0.11 [-1.36, 1.13] (0.63)	--	0.36 [-0.82, 1.54] (0.07)	--	-0.59 [-1.79, 0.61] (0.62)
Constant	0.20** [0.08, 0.31] (0.06)	0.09 [-0.04, 0.22] (0.07)	0.18** [0.06, 0.29] (0.06)	0.11† [-0.02, 0.26] (0.07)	0.26** [0.15, 0.38] (0.06)	0.20* [0.06, 0.34] (0.07)	0.15* [0.03, 0.26] (0.06)	0.12 [-0.01, 0.26] (0.07)

Note: Risk preferences did not interact with either of the threshold variables. However, once the interactions were entered into the model, the original threshold variables tended to be no longer significant. We suspect this is due to multicollinearity problems: there are four variables in these models that are based at least in part on the threshold variable. *p < .05, **p < .005, two-tailed

Table S4.
Demographic information in each study.

	Study 1	Study 2	Study 3	Study 4
Average Age	35	37	27	35
Percent Male	61%	49.50%	48.20%	50.40%
Percent with Some College or more	86.86%	82.97%	85.20%	87.17%
Percent Republican	21.12%	21.04%	22.00%	25.25%

Table S8.
Correct response rates for each comprehension question in each study.

% Correct	Study 1	Study 2	Study 3	Study 4
Question 1	85%	83%	82%	70%
Question 2	79%	79%	87%	82%
Question 3	58%	62%	61%	57%
Question 4	--	--	--	64%

Note: See SI: Materials for comprehension questions. We did not eliminate people who incorrectly answered questions. Instead, we provided them with additional information to ensure they understood the structure of the game. In Study 4, Question 1was the key question assessing whether players understood that the game involved playing on behalf of others.

Table S9:
Distribution of subjects across experimental conditions.

Threshold	Study 1	Study 2	Study 3	Study 4
60¢	93	102	99	94
80¢	105	103	98	104
100¢	96	101	105	100
120¢	101	96	95	97
140¢	106	97	103	103
Total N	501	499	500	498

Supplementary Discussion: Game Theoretic Model

In our game, there are $n = 4$ symmetric players in a group. They face a threshold, t. If the group does not contribute enough to meet or exceed the threshold, then they lose all their payoffs with probability $1 - k = .90$; if they do meet or exceed the threshold, then they keep whatever they did not contribute with certainty. When they game begins they have two sources of payoffs. The first is an endowment, w, which cannot be contributed toward the threshold. The second is a personal account, which can be contributed to the threshold. Without loss of generality, for our model the personal account is worth 1. Thus, t and w are denominated in "personal account units". To convert these back into real currency, multiply by $0.20.

If players choose to contribute their personal account, they have two options. First, they can contribute their personal account through the certain contribution, contributing 1 toward the threshold. Second, they can contribute personal account with a risky contribution. If they choose the risky contribution, there is a 50% chance they contribute 0 and a 50% chance they contribute 2 toward the threshold. If multiple players in a group choose the risky contribution, each contribution is independent of the others. We assume that $3 \leq t \leq 8$: No player can meet the threshold alone and consideration of threshold above 8 is trivial because they can never be met. (We note that we did not empirically study thresholds of 8.) Notice that contributions necessarily occur in steps; thus, t can only meaningfully take on integer values (e.g., strategically $t = 3.3$ is equivalent to $t = 4$). Players can also choose to defect and not contribute their account.

Player i's strategy is $s_i \in \{r, c, d\}$, for *r*isky contribution, *c*ertain contribution, and *d*efection. S is the set of all players' strategies in the group and S_{-i} for all players not i. A player's loss because of contributing their personal account, a_i, is 1 if they chose the risky contribution or certain contribution and 0 if they defected. Given this, we can define a payoff function:

$$V_i(s_i, S_{-i}) = (w + 1 - a_i)P_m + k(w + 1 - a_i)(1 - P_m)$$

In this function, P_m is the probability that the threshold is met or exceeded given the players' strategies. (Although P_m is a function, not a constant, to simplify the presentation of the equation we do not represent this explicitly.) Thus, the payoff function shows a player's expected payoffs given S. Note that even if the threshold is not met, there is still a probability k that players keep their remaining earnings.

For Studies 1 and 2, to derive P_m it is useful to start by determining the minimum number of *successful* risky contributions, x, that are required for a group to meet the threshold. If A represents the total contributions of the group, then $A = n_c + 2x$, where n_c is the number of players who chose the certain contribution. (Analogously, n_r will later be the number of players who chose the risky contribution.) To meet the threshold, it must be that $A \geq t$. Thus, $n_c + 2x \geq t$. From this, we can derive the minimum number of successful risky contributions to meet the threshold, x^*, which is the smallest nonnegative integer that satisfies $x^* \geq (t - n_c) / 2$. (Because t can be both odd and even positive integers, $(t - n_c) / 2$ will not always be an integer, yet x must always be an integer.)

Given this, we can compute the probability of meeting the threshold given the players' strategies:

$$P_m = \sum_{x=x*}^{n_r} \binom{n_r}{x} \left(\frac{1}{2}\right)^{n_r}$$

This function computes the sum of the probability that the number of successful risky contributions is just sufficient to meet the threshold and the probabilities that more than the minimum number of risky contributions are successful. The quantity $\binom{n_r}{x}$ is the binomial coefficient. Given the way that summation is defined, if $x^* > n_r$ then it follows that $P_m = 0$. Given the way that factorials are defined, if $x^* = 0$, then it follows that $P_m = 1$.

Now that we have derived exact expressions for payoffs and the probability of success, we can compute the equilibria for Studies 1 and 2. First, we note that at all levels of the threshold there is an equilibrium of complete defection; however, this equilibrium is never payoff dominant. Second, although the stepwise nature of contributions precludes a smooth transition in equilibria as the threshold increases, we can summarize our equilibrium findings by saying that as the threshold increases, the payoff dominant equilibrium tends to include more players who chose the risky contribution.

Table S5 shows the equilibria for the game as a function of t (excluding complete defection equilibria). In our experiments Study 1 uses an endowment of \$0.80, which corresponds to $w = 4$, and Study 2 uses an endowment of \$0.40, which corresponds to $w = 2$. Except for $t = 4$, no equilibria are affected by the size of the endowment. Notably, except for threshold $t = 4$, the payoff dominant equilibria for a given threshold require just as many players to invest as in the non-dominant (but non-pure defection) equilibria.

Table S5. Equilibria for the games of Studies 1 and 2.

t	Payoff Dominant Equilibria	Additional Equilibria (if any)	Avg. number of risky contributors in payoff dominant equilibria
3	{3 c, 1 d}	{2 r, 1 c, 1 d}	0
4	Both *w:* {4 c} Small *w*: {3 r, 1 d}, {1 r, 2 c, 1 d}	Large *w:* {4 r}, {2 r, 2 c}	Large *w*: 0 Small *w:* 1.3
5	{3 r, 1 c}, {1 r, 3 c}	--	2
6	{4 r}	{2 r, 2 c}	4
7	{3 r, 1 c}	--	3

Note: At $t = 8$ there is an equilibrium of 4 risky contributions. Study 1 had large *w*; Study 2 had small *w*.

Our analysis therefore suggests that players seeking to maximize their earnings should be become more willing to take the risk as the threshold initially increases, followed by a plateau and perhaps a dip in risky contributions as the threshold further increases.

Table S6 shows players' expected earnings at the payoff dominant equilibria, their actual average earnings, plus the maximum earnings possible and the payoff to all defect. With one exception ($t = 3$), the payoff dominant equilibria require all players to invest. (For purposes of the table, we consider only the symmetric equilibrium at $t = 4$ for Study 2.) Thus, in general, at equilibrium, all players earn the same amount.

Table S6. Earnings to payoff dominant equilibrium, along with all defect expected earnings and maximum possible earnings.

	Study 1		Study 2		Study 3		Study 4	
t	Earnings in Payoff Dominant Equilibrium	Actual Earnings (% of Eq. Earnings)	Earnings in Payoff Dominant Equilibrium	Actual Earnings (% of Eq. Earnings)	Earnings in Payoff Dominant Equilibrium	Actual Earnings (% of Eq. Earnings)	Earnings in Equilibrium	Actual Earnings (% of Eq. Earnings)
3	$0.85	$0.82 (96%)	$0.45	$0.33 (73%)	$0.85	$0.56 (66%)	$0.10	$0.49 (490%)
4	$0.80	$0.46 (58%)	$0.22	$0.24 (110%)	$0.80	$0.41 (51%)	$0.10	$0.42 (420%)
5	$0.44	$0.20 (45%)	$0.22	$0.13 (59%)	$0.37	$0.35 (95%)	$0.10	$0.37 (370%)
6	$0.31	$0.24 (77%)	$0.15	$0.07 (47%)	$0.28	$0.30 (107%)	$0.10	$0.22 (220%)
7	$0.17	$0.09 (53%)	$0.09	$0.04 (44%)	$0.22	$0.18 (82%)	$0.10	$0.03 (30%)
All Defect Expected Earnings	$0.10	—	$0.06	—	$0.10	—	$0.10	—
Maximum Possible Earnings	$1.00	—	$0.60	—	$1.00	—	$1.00	—

Note: "Eq." = Payoff Dominant Equilibrium. For $t = 4$ in Study 2, we consider only the symmetric equilibrium of certain investment. For $t = 3$, the amount shown is the average earnings at the payoff dominant equilibria. At this threshold, one player in the payoff dominant equilibrium should defect, with expected earnings of $1.00 in Studies 1 and 3 and $0.60 in Study 2. The other three players should choose certain investment, with expected earnings of $0.80 in Studies 1 and 3 and $0.40 in Study 2. "Maximum Possible Earnings" = earnings for a defecting player whose group nonetheless did not experience climate change.

Study 3, in which even the amount of a successful risky contribution is uncertain, has somewhat different properties. For this game, it still must be the case that the amount contributed is at least as great as the threshold, $A \geq t$. But now $A = n_c + 4x_4 + 3x_3 + 2x_2 + x_1$, where x_i is the number of successful risky contributions that pay amount i. Thus, x^* is now a vector of x_i^*s such that $4x_4^* + 3x_3^* + 2x_2^* + x_1^* \geq t - n_c$. Not only are there are many such vectors, there are also multiple possible permutations of gamble outcomes that lead to identical vectors. Define $X(t, n_c, n_r)$ as the number of permutations of risky outcomes that lead to the threshold being met or exceeded and $Y(t, n_c, n_r)$ as the total number of permutations of risky contribution outcomes, regardless of whether the threshold is met. P_m is then X / Y.

Table S7 shows the equilibria for Study 3 as a function of t. Study 3 used a large endowment, $w = 4$ (or \$0.80). Unlike the previous studies, only when $t \geq 5$ are there equilibria of complete defection. This is because when $t = 3$ or 4, an individual player can meet the threshold and has a high enough possibility of doing so to make it worth taking the risk (though a single player making a risky contribution is not an equilibrium). When they exist, pure defection equilibria are never payoff dominant; we do not show them in the table. Also unlike the previous studies, in Study 3 it was possible for groups to meet ts as high as 16. At $t = 9$, there was a payoff dominant equilibrium of all make the risky contribution (plus an equilibrium of all defect). When $t \geq 10$, there is only a single equilibrium of all defect. Note that in our experiment we only ran conditions up to $t = 7$.

Table S7. Equilibria for the game of Study 3.

t	Payoff Dominant Equilibria	Additional Equilibria (if any)	Avg. number of risky contributors in payoff dominant equilibria
3	{3 c, 1 d}	{3 r, 1 d}	0
4	{4c}	{3 r, 1 c}	0
5	{3 r, 1 c}	--	3
6	{4 r}	{2 r, 2 c}	4
7	{4 r}	{3 r, 1 c}	4

Note: At t = 8 or 9 there is an equilibrium of four risky contributions. At higher levels of t, the only equilibrium is complete defection.

Again, we find that as the threshold increases, the number of risky contributions should increase until it plateaus. Table S6 shows the expected earnings of players at the payoff dominant equilibrium and compares this to their actual earnings.

For Study 4, in which players' contributions only affect a different group, payoff maximizing players should never contribute. Thus, the unique equilibrium is complete defection. Given this, in expectation players will earn \$0.10. Table S6 shows the actual payoffs of players in Study 4.

Supplementary Methods: Materials

Study 1 Materials

Stony Brook University | The State University of New York

This research study being is conducted by the Department of Political Science at Stony Brook University. Thank you for agreeing to participate in our experiment.

COMPENSATION DETAILS

There are two ways to earn money in this experiment:

1) For just participating today, you will earn 50¢. **You will earn this money no matter what else happens in the experiment.**

2) By participating in this study, you will also have the possibility to earn **bonus money, up to 100¢**, within a group of you and three other Mturk workers. Exactly how much bonus money you earn depends on the decisions you and the other three people in your group make.

Please read the instructions carefully because it determines how you earn real money.

Survey Completion

0% 100%

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OVERVIEW OF STUDY

Today, we will introduce you to an experiment simulating the consequences of climate change. Global climate change is seen as a serious environmental problem faced by humankind.

Today's experiment will focus on technological solutions to mitigating climate change. Multiple options exist to use technology in this way.

Some options include small, incremental technological changes. These small changes are certain to help combat the problem, but only by a fairly modest amount. An example of this is investment in solar power.

Other options include investing in technology that has the potential to have massive effects in combating climate change. The downside of this type of investment is that such technology might not succeed. So, with this type of investment very good things might happen, but it is uncertain whether they will happen at all. An example of this is investment in carbon scrubbing from the atmosphere.

In this experiment, you will be randomly assigned to participate with three other people through MTurk. In this four-person group, you will make decisions that simulate investing in different technologies, like those described above, to try to prevent the negative effects of climate change from happening.

Each member of the group will make their own decision independently—that is, you will make your investment decision without knowing what the other people in your group choose. But, whether your group stops climate change will depend on the decisions of all the group members.

For each group, using the decisions that each of the four group members made, we will determine the bonus earnings for each member.

Survey Completion

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Each member of the group is going to start with a pot of bonus money, called an **endowment**. Your own individual endowment is 80¢. Each other member of your group also has an endowment of 80¢. The endowment represents things like land, roads, and infrastructure—things valuable to a country and its people, but that cannot easily be used to stop climate change.

Each member of the group is also going to start with a separate pot of bonus money, called a **personal account**. Your personal account is 20¢. Each other member of your group also has a personal account of 20¢. The personal account represents money that could be spent on technology to mitigate climate change.

When the experiment begins, there is a 90% chance your group could lose all its bonus money, both your personal accounts and your endowments. This risk represents the negative effects of climate change.

But you and your group can stop this 90% risk from occurring at all. Your group will receive a **threshold**, which is a dollar amount. Your group's threshold is: 120¢. Each member of your group will independently decide whether to invest their personal account toward the threshold, which represents investment in climate mitigation technology. And, further, if a person does invest, they will have to decide whether to invest in technology that has a small certain effect or to invest in technology with the potential to have a large effect.

If the combined outcomes of the investments of your group equal or exceed the threshold, then everyone will definitely keep all of their endowment and, if they have not invested it, they will also keep their personal accounts.

If the combined contributions are less than the threshold, then there is still a 90% risk that you will lose everything.

Either way, if you invest your personal account, then it simply disappears.

Survey Completion

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

Your group's threshold is 120¢. Each group member has a personal account of 20¢. They can choose from the above table whether and how they want to invest their personal account.

First, as shown in **Choice 1**, you can invest your personal account in technology with certain outcomes. If you do this, you will **directly contribute 20¢ to the threshold**.

Second, as shown in **Choice 2**, you can invest your personal account in a technology with uncertain outcomes. If you do this, the technology will **either contribute 0¢ or 40¢ to the threshold**. **Each of these outcomes has an equal chance of happening**—that is, for each of them there is a 1 in 2 chance it could happen. So, if you choose this investment, then a lot might be contributed, but it is also possible nothing might be contributed.

For both the first and second options, you have to use your entire personal account. You cannot both keep some and invest some.

Third, as shown in **Choice 3**, you can choose to **keep your personal account and not invest it**.

Remember, if you invest you personal account (Choice 1 or Choice 2), that money is gone regardless of what else happens in the experiment.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

Remember, the experiment starts with a 90% chance you will lose everything. But you can prevent that by contributing to the threshold.

For example, suppose your group combines to contribute only 100¢ to your threshold of 120¢. In this example, your group did not meet the threshold. Because you did not meet the threshold there is a 90% probability that everyone in your group will lose their entire endowment and their entire personal account (if they did not already invest their personal account). To be clear: in 9 cases out of 10 where your group does not meet the threshold, everyone in your group will lose both their personal account and their endowment.

Let's consider another example. Let's suppose your group combines to contribute 120¢ to your threshold of 120¢, therefore your group met the threshold. Because you met the threshold each member of the group will DEFINITELY receive their endowment and their personal account (if they did not already invest their personal account).

Survey Completion

0% 100%

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COMPREHENSION QUESTIONS

Please answer the following questions so we can make sure you understand the game before beginning. Please note that all amounts are expressed in cents.

NOTE: You will not be evaluated or paid based on your answers to these questions. We include them to help you understand the way the experiment works. Just answer the questions to the best of your ability. If you answer incorrectly, you will be given the correct answer.

Survey Completion

0% 100%

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Survey Powered By Qualtrics

If your group contributes enough in total to meet the threshold will you definitely keep your 80¢ endowment and (if you haven't invested it) your 20¢ personal account?

- Yes
- No

Survey Completion

0% 100%

>>

	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

If you decide to invest in the uncertain technology, how much will you contribute to the threshold?

- 40¢
- 0¢
- It is uncertain: there is an equal chance you will contribute 0¢ or 40¢ toward the threshold.

Survey Completion

0% 100%

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True or false: You can invest some of your personal account in certain technology and some of it in uncertain technology.

- True
- False

Survey Completion

0% 100%

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INVESTMENT DECISIONS

Please consider your options on the next page carefully. Your bonus depends on your decision on the following page, as well as the decisions of the three other MTurk participants who are part of your group.

For each group, using the decisions that each of the four group members made, we will determine the bonus for each member.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: **Certain Investment**	Invest 20¢	20¢ closer to threshold
Choice 2: **Uncertain Investment**	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: **No Investment**	Keep 20¢	0¢ closer to threshold

Your group threshold is 120¢.

Your endowment is 80¢.

Your personal account is 20¢.

Remember, you are in a group with three other people. Everyone else in your group also has an endowment of 80¢ and a personal account of 20¢.

All group members must each decide whether to contribute their personal account to the threshold and, if so, whether to invest in certain or uncertain technology.

Which of the following would you like to do?

- Choice 1: Invest my personal account in certain technology.
- Choice 2: Invest my personal account in uncertain technology.
- Choice 3: Not invest, and keep my entire personal account.

Survey Completion

0% 100%

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Risk Task

	Event A	Event B
Gamble 1	$28	$28
Gamble 2	$24	$36
Gamble 3	$20	$44
Gamble 4	$16	$52
Gamble 5	$12	$60
Gamble 6	$2	$70

This second task will **not** effect your payment.

For this second task we would like you to choose one of the gambles listed above. In each gamble, there is a 50% chance event A will occur and a 50% chance event B will occur.

For example, if you selected gamble 2 there would be a 50% chance of winning $24 and a 50% chance of winning $36.

Again, this is choice is not for real money. But imagine that real money is at stake.

Which gamble would you prefer?

- Gamble 1
- Gamble 2
- Gamble 3
- Gamble 4
- Gamble 5
- Gamble 6

Survey Completion

0% 100%

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Questionnaire and Demographic Information

How serious of a threat is global warming to you and your family?

- Not at all serious
- Not very serious
- Somewhat serious
- Very serious

How serious of a threat is global warming to people in the United States?

- Not at all serious
- Not very serious
- Somewhat serious
- Very serious

How serious of a threat is global warming to people in other countries?

- Not at all serious
- Not very serious
- Somewhat serious
- Very serious

Now, please answer a few questions on your thoughts about global warming.

When do you think global warming will start to have dangerous impacts on people around the world?

- It is having dangerous impacts now.
- It will have dangerous impacts in 10 years.
- It will have dangerous impacts in 25 years.
- It will have dangerous impacts in 50 years.
- It will have dangerous impacts in 100 years.
- It will never have dangerous impacts.

Which comes closer to your own view on global warming?

- Most scientists think global warming is happening
- Most scientists think global warming is not happening
- There is a lot of disagreement among scientists about whether or not global warming is happening
- I do not know enough to say

Please write any comments that you have about this study below.

Survey Completion

0% 100%

>>

Study 2

This research study being is conducted by the Department of Political Science at Stony Brook University. Thank you for agreeing to participate in our experiment.

COMPENSATION DETAILS

There are two ways to earn money in this experiment:

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Please read the instructions carefully because it determines how you earn real money.

Survey Completion

0% 100%

>>

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Other options include investing in technology that has the potential to have massive effects in combating climate change. The downside of this type of investment is that such technology might not succeed. So, with this type of investment very good things might happen, but it is uncertain whether they will happen at all. An example of this is investment in carbon scrubbing from the atmosphere.

In this experiment, you will be randomly assigned to participate with three other people through MTurk. In this four-person group, you will make decisions that simulate investing in different technologies, like those described above, to try to prevent the negative effects of climate change from happening.

Each member of the group will make their own decision independently—that is, you will make your investment decision without knowing what the other people in your group choose. But, whether your group stops climate change will depend on the decisions of all the group members.

For each group, using the decisions that each of the four group members made, we will determine the bonus earnings for each member.

Survey Completion

0% 100%

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Each member of the group is going to start with a pot of bonus money, called an **endowment**. Your own individual endowment is 40¢. Each other member of your group also has an endowment of 40¢. The endowment represents things like land, roads, and infrastructure—things valuable to a country and its people, but that cannot easily be used to stop climate change.

Each member of the group is also going to start with a separate pot of bonus money, called a **personal account**. Your personal account is 20¢. Each other member of your group also has a personal account of 20¢. The personal account represents money that could be spent on technology to mitigate climate change.

When the experiment begins, there is a 90% chance your group could lose all its bonus money, both your personal accounts and your endowments. This risk represents the negative effects of climate change.

But you and your group can stop this 90% risk from occurring at all. Your group will receive a **threshold**, which is a dollar amount. Your group's threshold is: 120¢. Each member of your group will independently decide whether to invest their personal account toward the threshold, which represents investment in climate mitigation technology. And, further, if a person does invest, they will have to decide whether to invest in technology that has a small certain effect or to invest in technology with the potential to have a large effect.

If the combined outcomes of the investments of your group equal or exceed the threshold, then everyone will definitely keep all of their endowment and, if they have not invested it, they will also keep their personal accounts.

If the combined contributions are less than the threshold, then there is still a 90% risk that you will lose everything.

Either way, if you invest your personal account, then it simply disappears.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: **Certain Investment**	Invest 20¢	20¢ closer to threshold
Choice 2: **Uncertain Investment**	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: **No Investment**	Keep 20¢	0¢ closer to threshold

Your group's threshold is 120¢. Each group member has a personal account of 20¢. They can choose from the above table whether and how they want to invest their personal account.

First, as shown in **Choice 1**, you can invest your personal account in technology with certain outcomes. If you do this, you will **directly contribute 20¢ to the threshold**.

Second, as shown in **Choice 2**, you can invest your personal account in a technology with uncertain outcomes. If you do this, the technology will **either contribute 0¢ or 40¢ to the threshold**. **Each of these outcomes has an equal chance of happening**—that is, for each of them there is a 1 in 2 chance it could happen. So, if you choose this investment, then a lot might be contributed, but it is also possible nothing might be contributed.

For both the first and second options, you have to use your entire personal account. You cannot both keep some and invest some.

Third, as shown in **Choice 3**, you can choose to **keep your personal account and not invest it**.

Remember, if you invest you personal account (Choice 1 or Choice 2), that money is gone regardless of what else happens in the experiment.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: **Certain Investment**	Invest 20¢	20¢ closer to threshold
Choice 2: **Uncertain Investment**	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: **No Investment**	Keep 20¢	0¢ closer to threshold

Remember, the experiment starts with a 90% chance you will lose everything. But you can prevent that by contributing to the threshold.

For example, suppose your group combines to contribute only 100¢ to your threshold of 120¢. In this example, your group did not meet the threshold. Because you did not meet the threshold there is a 90% probability that everyone in your group will lose their entire endowment and their entire personal account (if they did not already invest their personal account). To be clear: in 9 cases out of 10 where your group does not meet the threshold, everyone in your group will lose both their personal account and their endowment.

Let's consider another example. Let's suppose your group combines to contribute 120¢ to your threshold of 120¢, therefore your group met the threshold. Because you met the threshold each member of the group will DEFINITELY receive their endowment and their personal account (if they did not already invest their personal account).

Survey Completion

0% 100%

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COMPREHENSION QUESTIONS

Please answer the following questions so we can make sure you understand the game before beginning. Please note that all amounts are expressed in cents.

NOTE: You will not be evaluated or paid based on your answers to these questions. We include them to help you understand the way the experiment works. Just answer the questions to the best of your ability. If you answer incorrectly, you will be given the correct answer.

Survey Completion

0% 100%

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If your group contributes enough in total to meet the threshold will you definitely keep your 40¢ endowment and (if you haven't invested it) your 20¢ personal account?

- Yes
- No

Survey Completion

0% 100%

>>

	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

If you decide to invest in the uncertain technology, how much will you contribute to the threshold?

- 40¢
- 0¢
- It is uncertain: there is an equal chance you will contribute 0¢ or 40¢ toward the threshold.

Survey Completion

0% 100%

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True or false: You can invest some of your personal account in certain technology and some of it in uncertain technology.

- ○ True
- ○ False

Survey Completion

0% 100%

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INVESTMENT DECISIONS

Please consider your options on the next page carefully. Your bonus depends on your decision on the following page, as well as the decisions of the three other MTurk participants who are part of your group.

For each group, using the decisions that each of the four group members made, we will determine the bonus for each member.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

Your group threshold is 120¢.

Your endowment is 40¢.

Your personal account is 20¢.

Remember, you are in a group with three other people. Everyone else in your group also has an endowment of 40¢ and a personal account of 20¢.

All group members must each decide whether to contribute their personal account to the threshold and, if so, whether to invest in certain or uncertain technology.

Which of the following would you like to do?

- ○ Choice 1: Invest my personal account in certain technology.
- ○ Choice 2: Invest my personal account in uncertain technology.
- ○ Choice 3: Not invest, and keep my entire personal account.

Survey Completion

0% 100%

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[Risk Task and Demographic Questions Identical to Study 1]

Study 3

Stony Brook University | The State University of New York

This research study being is conducted by the Department of Political Science at Stony Brook University. Thank you for agreeing to participate in our experiment.

COMPENSATION DETAILS

There are two ways to earn money in this experiment:

1) For just participating today, you will earn 50¢. **You will earn this money no matter what else happens in the experiment.**

2) By participating in this study, you will also have the possibility to earn **bonus money, up to 100¢**, within a group of you and three other Mturk workers. Exactly how much bonus money you earn depends on the decisions you and the other three people in your group make.

Please read the instructions carefully because it determines how you earn real money.

Survey Completion

0% 100%

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OVERVIEW OF STUDY

Today, we will introduce you to an experiment simulating the consequences of climate change. Global climate change is seen as a serious environmental problem faced by humankind.

Today's experiment will focus on technological solutions to mitigating climate change. Multiple options exist to use technology in this way.

Some options include small, incremental technological changes. These small changes are certain to help combat the problem, but only by a fairly modest amount. An example of this is investment in solar power.

Other options include investing in technology that has the potential to have massive effects in combating climate change. The downside of this type of investment is that such technology might not succeed. So, with this type of investment very good things might happen, but it is uncertain whether they will happen at all. An example of this is investment in carbon scrubbing from the atmosphere.

In this experiment, you will be randomly assigned to participate with three other people through MTurk. In this four-person group, you will make decisions that simulate investing in different technologies, like those described above, to try to prevent the negative effects of climate change from happening.

Each member of the group will make their own decision independently—that is, you will make your investment decision without knowing what the other people in your group choose. But, whether your group stops climate change will depend on the decisions of all the group members.

For each group, using the decisions that each of the four group members made, we will determine the bonus earnings for each member.

Survey Completion

0% 100%

>>

Each member of the group is going to start with a pot of bonus money, called an **endowment**. Your own individual endowment is 80¢. Each other member of your group also has an endowment of 80¢. The endowment represents things like land, roads, and infrastructure—things valuable to a country and its people, but that cannot easily be used to stop climate change.

Each member of the group is also going to start with a separate pot of bonus money, called a **personal account**. Your personal account is 20¢. Each other member of your group also has a personal account of 20¢. The personal account represents money that could be spent on technology to mitigate climate change.

When the experiment begins, there is a 90% chance your group could lose all its bonus money, both your personal accounts and your endowments. This risk represents the negative effects of climate change.

But you and your group can stop this 90% risk from occurring at all. Your group will receive a **threshold**, which is a dollar amount. Your group's threshold is: 100¢. Each member of your group will independently decide whether to invest their personal account toward the threshold, which represents investment in climate mitigation technology. And, further, if a person does invest, they will have to decide whether to invest in technology that has a small certain effect or to invest in technology with the potential to have a large effect.

If the combined outcomes of the investments of your group equal or exceed the threshold, then everyone will definitely keep all of their endowment and, if they have not invested it, they will also keep their personal accounts.

If the combined contributions are less than the threshold, then there is still a 90% risk that you will lose everything.

Either way, if you invest your personal account, then it simply disappears.

Survey Completion

0% 100%

>>

	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance x¢ closer to the threshold (x has already been selected to be 0¢, 20¢, 40¢, 60¢, or 80¢)
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

Your group's threshold is 100¢. Each group member has a personal account of 20¢. They can choose from the above table whether and how they want to invest their personal account.

First, as shown in **Choice 1**, you can invest your personal account in technology with certain outcomes. If you do this, you will **directly contribute 20¢ to the threshold**.

Second, as shown in **Choice 2**, you can invest your personal account in a technology with uncertain outcomes. If you do this, the technology will **either contribute 0¢ or an unknown number of cents, x¢, to the threshold. Each of these outcomes has an equal chance of happening**—that is, for each of them there is a 1 in 2 chance it could happen. **Although you do not know what x is, <u>the computer has already chosen x for you</u>. The computer picked x from these amounts: 0¢, 20¢, 40¢, 60¢, or 80¢. Each amount is equally possible, giving each a 1 in 5 chance of occurring.** Altogether, if you choose this investment, then it's possible that 0¢ is contributed but it's also possible that x¢ is contributed, where x could be **0¢, 20¢, 40¢, 60¢, or 80¢**. (We will tell you what x was at the end of the study.)

For both the first and second options, you have to use your entire personal account. You cannot both keep some and invest some.

Third, as shown in **Choice 3**, you can choose to **keep your personal account and not invest it**.

Remember, if you invest you personal account (Choice 1 or Choice 2), that money is gone regardless of what else happens in the experiment.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance x¢ closer to the threshold (x has already been selected to be 0¢, 20¢, 40¢, 60¢, or 80¢)
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

Remember, the experiment starts with a 90% chance you will lose everything. But you can prevent that by contributing to the threshold.

For example, suppose your group combines to contribute only 80¢ to your threshold of 100¢. In this example, your group did not meet the threshold. Because you did not meet the threshold there is a 90% probability that everyone in your group will lose their entire endowment and their entire personal account (if they did not already invest their personal account). To be clear: in 9 cases out of 10 where your group does not meet the threshold, everyone in your group will lose both their personal account and their endowment.

Let's consider another example. Let's suppose your group combines to contribute 100¢ to your threshold of 100¢, therefore your group met the threshold. Because you met the threshold each member of the group will DEFINITELY receive their endowment and their personal account (if they did not already invest their personal account).

Survey Completion

0% 100%

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COMPREHENSION QUESTIONS

Please answer the following questions so we can make sure you understand the game before beginning. Please note that all amounts are expressed in cents.

NOTE: You will not be evaluated or paid based on your answers to these questions. We include them to help you understand the way the experiment works. Just answer the questions to the best of your ability. If you answer incorrectly, you will be given the correct answer.

Survey Completion

0% 100%

>>

If your group contributes enough in total to meet the threshold will you definitely keep your 80¢ endowment and (if you haven't invested it) your 20¢ personal account?

- Yes
- No

Survey Completion

0% 100%

>>

	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance x¢ closer to the threshold (x has already been selected to be 0¢, 20¢, 40¢, 60¢, or 80¢)
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

If you decide to invest in the unknown technology, how much will you contribute to the threshold?

- 40¢
- 0¢
- It is uncertain: there is a 50% chance you will not contribute anything to the threshold, but there is also a 50% chance you will contribute 0¢, 20¢, 40¢, 60¢, or 80¢.

Survey Completion

0% 100%

>>

True or false: You can invest some of your personal account in certain technology and some of it in unknown technology.

- True
- False

Survey Completion

0% 100%

>>

INVESTMENT DECISIONS

Please consider your options on the next page carefully. Your bonus depends on your decision on the following page, as well as the decisions of the three other MTurk participants who are part of your group.

For each group, using the decisions that each of the four group members made, we will determine the bonus for each member.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance x¢ closer to the threshold (x has already been selected to be 0¢, 20¢, 40¢, 60¢, or 80¢)
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

Your group threshold is 100¢.

Your endowment is 80¢.

Your personal account is 20¢.

Remember, you are in a group with three other people. Everyone else in your group also has an endowment of 80¢ and a personal account of 20¢.

All group members must each decide whether to contribute their personal account to the threshold and, if so, whether to invest in certain or uncertain technology.

Which of the following would you like to do?

- Choice 1: Invest my personal account in certain technology.
- Choice 2: Invest my personal account in uncertain technology.
- Choice 3: Not invest, and keep my entire personal account.

Survey Completion

0% 100%

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[Risk Task and Demographic Questions Identical to Study 1]

Study 4

Stony Brook University | The State University of New York

This research study being is conducted by the Department of Political Science at Stony Brook University. Thank you for agreeing to participate in our experiment.

COMPENSATION DETAILS

There are two ways to earn money in this experiment:

1) For just participating today, you will earn 50¢. **You will earn this money no matter what else happens in the experiment.**

2) By participating in this study, you will also have the possibility to earn **bonus money, up to 100¢**. We will explain next how this works.

Survey Completion

0% 100%

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OVERVIEW OF STUDY

Today, we will introduce you to an experiment simulating the consequences of climate change. Global climate change is seen as a serious environmental problem faced by humankind.

Today's experiment will focus on technological solutions to mitigating climate change. Multiple options exist to use technology in this way.

Some options include small, incremental technological changes. These small changes are certain to help combat the problem, but only by a fairly modest amount. An example of this is investment in solar power.

Other options include investing in technology that has the potential to have massive effects in combating climate change. The downside of this type of investment is that such technology might not succeed. So, with this type of investment very good things might happen, but it is uncertain whether they will happen at all. An example of this is investment in carbon scrubbing from the atmosphere.

Survey Completion

0% 100%

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In this experiment, you will be randomly assigned to participate in a group with three other people through MTurk. In this four-person group, you will make decisions that simulate investing in different technologies, like those described previously, to try to prevent the negative effects of climate change.

This is important: Your decisions do **NOT** affect whether your group experiences simulated climate change. Instead, the decisions that **your** group makes will affect whether a **second** four-person group of MTurk participants experiences climate change. This group of Mturk participants can be compared to future generations who might feel the impacts of climate change if we don't invest in mitigation technology.

At the same time, a **third** four-person group of MTurk participants is making investment decisions which will impact whether or not **your** group avoids climate change.

When you make the decisions in your group, each member of the group will make their own decision independently—that is, you will make your investment decision without knowing what the other people in your group choose. But, whether your group stops climate change for a second group will depend on the decisions of all your group members. And, whether or not your group avoids having simulated climate change happen to it depends on the decisions of a third independent group.

To summarize, your group will make decisions affecting a different group and a third group will make decisions affecting you. Importantly, your own group's decisions do **not** affect what happens to your own group.

Now let's show you the details of how you make your decision.

Survey Completion

0% 100%

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Each member of the group is going to start with a pot of bonus money, called an **endowment**. Your own individual endowment is 80¢. Each other member of your group also has an endowment of 80¢. In fact, every member of every group, not just yours, has an endowment of 80¢. The endowment represents things like land, roads, and infrastructure—things valuable to a country and its people, but that cannot easily be used to stop climate change.

Each member of every group is also going to start with a separate pot of bonus money, called a **personal account**. Your personal account is 20¢. Each other member of every group also has a personal account of 20¢. The personal account represents money that could be spent on technology to mitigate climate change.

When the experiment begins, there is a 90% chance every group could lose all its bonus money, both their personal accounts and their endowments. This risk represents the negative effects of climate change.

Your group will make decisions for a second group, and a third group will make choices which affect you. Your group, along with the second and third group, will each receive a **threshold,** which is a dollar amount. You will all receive the same threshold. Your group's threshold is: 100¢. The thresholds of the second and third group are also 100¢.

Your group then has a chance to stop climate change for the second group, to prevent the 90% chance they lose all their bonus money. Each member of your group will independently decide whether to invest their personal account toward the threshold, which represents investment in climate mitigation technology. And, further, if a person does invest, they will have to decide whether to invest in technology that has a small certain effect or to invest in technology with the potential to have a large effect.

If the combined outcomes of the investments of your group equal or exceed the threshold, then everyone in the second group will definitely keep all of their endowment and, if they have not invested it, they will also keep their personal accounts.

If the combined contributions are less than the threshold, then there is still a 90% risk that the second group will lose everything.

Either way, if you invest your personal account, then it simply disappears.

A third group is making the same choices for your group, deciding whether and how to invest their personal accounts to meet your threshold and stop you from losing your remaining personal accounts and endowments. This third group is not affected by your decisions, and they do not know the decisions you and your group members make.

To be clear, climate change can be prevented for one group, without definitely being prevented for another group. Groups are independent in this way.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

The threshold you are trying to meet for a second group is 100¢. You and each of your group members has a personal account of 20¢. They can choose from the above table whether and how they want to invest their personal account.

First, as shown in **Choice 1**, you can invest your personal account in technology with certain outcomes. If you do this, you will **directly contribute 20¢ to the second group's threshold**.

Second, as shown in **Choice 2**, you can invest your personal account in a technology with uncertain outcomes. If you do this, the technology will **either contribute 0¢ or 40¢ to the second group's threshold. Each of these outcomes has an equal chance of happening**—that is, for each of them there is a 1 in 2 chance it could happen. So, if you choose this investment, then a lot might be contributed, but it is also possible nothing might be contributed.

For both the first and second options, you have to use your entire personal account. You cannot both keep some and invest some.

Third, as shown in **Choice 3**, you can choose to **keep your personal account and not invest it**.

Remember, if you invest you personal account (Choice 1 or Choice 2), that money is gone regardless of what else happens in the experiment.

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

Remember, the experiment starts with a 90% chance the second group will lose everything. But you can prevent that by contributing to their threshold. There is also a 90% chance you will lose everything, and a third group can prevent that by contributing to your threshold.

For example, suppose your group combines to contribute only 80¢ to the second group's threshold of 100¢. In this example, your group did not meet their threshold. Because you did not meet their threshold there is a 90% probability that everyone in the second group group will lose their entire endowment and their entire personal account (if they did not already invest their personal accounts). To be clear: in 9 cases out of 10 where your group does not meet their threshold, everyone in the second group will lose both their personal account and their endowment.

Let's consider another example. Let's suppose your group combines to contribute 100¢ to the second group's threshold of 100¢, therefore your group met their threshold. Because you met their threshold each member of the second group will DEFINITELY receive their endowment and their personal account (if they did not already invest their personal account).

The decisions of the third group affect your earnings the same way your decisions affect the earnings of the second group. If the third group only contributes 80¢ to your threshold of 100¢, there is a 90% chance you and your group members will lose your endowments and personal accounts (if you have not already invested them). If the third group successfully contributes 100¢, then you keep your endowments and remaining personal accounts.

Remember, every decision is anonymous. You will not know the choices of your other group members or the outcomes of the other groups' investments when you make your decision. Furthermore, no one else will know what choice you make.

Survey Completion

0% 100%

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One last thing: This experiment involves many groups through Mturk. Although your group is making decisions affecting a second group and a third group is making decisions affecting your group, the second group is **not** making decisions affecting the third group. Instead, the second group is making decisions affecting some other random group that is not connected to your group at all. And, some other random group is making decisions affecting the third group.

Survey Completion

0% 100%

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COMPREHENSION QUESTIONS

Please answer the following questions so we can make sure you understand the game before beginning. Please note that all amounts are expressed in cents.

NOTE: You will not be evaluated or paid based on your answers to these questions. We include them to help you understand the way the experiment works. Just answer the questions to the best of your ability. If you answer incorrectly, you will be given the correct answer.

Survey Completion

0% 100%

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Do your investment decisions affect whether or not your group meets the threshold and stops the 90% chance your group loses your endowments and remaining personal accounts?

○ Yes

○ No

Survey Completion

0% 100%

>>

If your group contributes enough in total to meet the threshold of the second group will they definitely keep their 80¢ endowment and (if they haven't invested it) their 20¢ personal account?

○ Yes

○ No

Survey Completion

0% 100%

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	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

If you decide to invest in the uncertain technology, how much will you contribute to the second group's threshold?

- 40¢
- 0¢
- It is uncertain: there is an equal chance you will contribute 0¢ or 40¢ toward the threshold.

Survey Completion

0% 100%

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True or false: You can invest some of your personal account in certain technology and some of it in uncertain technology.

- True
- False

Survey Completion

0% 100%

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INVESTMENT DECISIONS

Please consider your options on the next page carefully. The bonuses of a second group of MTurk Participants depend on your decisions on the following page, as well as the decisions of the three other MTurk participants who are part of your group.

For each group, using the decisions that they and their other group made, we will determine the bonus for each member.

Survey Completion

0% 100%

>>

	Personal Account	Contribution to Threshold
Choice 1: Certain Investment	Invest 20¢	20¢ closer to threshold
Choice 2: Uncertain Investment	Invest 20¢	50% chance 0¢ closer to threshold 50% chance 40¢ closer to threshold
Choice 3: No Investment	Keep 20¢	0¢ closer to threshold

The threshold you are trying to meet for the **second group** is 100¢.

Your endowment is 80¢.

Your personal account is 20¢.

Remember, you are in a group with three other people. Everyone else in your group also has an endowment of 80¢ and a personal account of 20¢.

The second group is also made up of four people, each with an endowment of 80¢ and a personal account of 20¢.

All of your group's members must each decide whether to contribute their personal account to the second group's threshold and, if so, whether to invest in certain or uncertain technology.

Which of the following would you like to do?

- Choice 1: Invest my personal account in certain technology.
- Choice 2: Invest my personal account in uncertain technology.
- Choice 3: Not invest, and keep my entire personal account.

Survey Completion

0% 100%

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[Risk Task and Demographic Questions Identical to Study 1]