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Collective Risk Social Dilemma: Role of information availability in achieving cooperation against climate change

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Behaviour change via monetary investments is a way to fighting climate change. Prior research has investigated the role of climate-change investments using a Collective-Risk-Social-Dilemma (CRSD) game, where players have to collectively reach a target by contributing to a climate fund; failing which they lose their investments with a probability. However, little is known on how variability in the availability of information about players' investments influences investment decisions in CRSD. In an experiment involving CRSD, 480 participants were randomly assigned to different conditions that differed in the availability of investment information among players. Half of the players possessed a higher starting endowment (rich) compared to other players (poor). Results revealed that investments against climate change were higher when investment information was available to all players compared to when this information was available only to a few players or to no one. Similarly, investments were higher among rich players compared to poor players when information was available among all players compared to when it was available only to a few players or to no one. Again, the average investment was significantly greater compared to the Nash investment when investment information was available to all players compared to when this information was available only to a few players or to no one. We highlight some implications of our laboratory experiment for human decision-making against climate change.

Keywords: Collective Risk Social Dilemma, climate fund, information availability, investments, Nash equilibrium

Climate change has been a topic of growing concern for the entire world (Roberts, 2015). Earth's average surface temperature has already risen about 1.8 degrees Fahrenheit (1.0 degree Celsius) since the late 19$^{\text{th}}$ century, a change that is largely driven by increased Greenhouse Gas (GHG) emissions into the atmosphere (IPCC, 2015). Amidst increasing temperatures, real-world evidence shows that people continue to show a waiting approach towards climate change (Dutt & Gonzalez, 2012a; Dutt & Gonzalez, 2012b; Ricke & Caldeira, 2014).

Monetary investments against climate change, which are one of the indicators of behaviour change, provide important ways for our society to fight climate change (Webb, 2012). Climate negotiations are a way for deciding monetary investments against climate change and they enable us to reduce society's impact on climate change (Doulton & Brown, 2009; Sterman & Sweeney, 2007; Sterman, 2008). During negotiation process, there may be lower investments among negotiators. A likely reason for the lower investments could be socio-political or geo-political motivations (Barnett, 2007). For example, the United States pulled out of the recent Paris Agreement and the Green Climate Fund due to certain political motivations (Zhang, Chao, Zheng, & Huang, 2017). However, another reason for lower investments could be the information asymmetries present among negotiators. Due to information asymmetries, some negotiators may possess untrue or imprecise information about investments of other negotiators; whereas, some negotiators may possess accurate investment information.

An extreme form of information asymmetry may be where it becomes difficult to obtain information on one's climate actions. For example, in the recent Paris agreement, there was quite some debate over China's stance to not let international inspectors access their information about carbon-dioxide emissions (Zhang et al., 2017). An investigation of this extreme form of information asymmetry, where information may be withheld and not known to certain negotiators, is the primary focus of this paper.

Prior research has investigated climate negotiations in the laboratory using a Collective-Risk-Social-Dilemma (CRSD) game (Milinski, Sommerfeld, Krambeck, Reed, & Marotzke, 2008; Tavoni, Dannenberg, Kallis, & Löschel, 2011). In CRSD, negotiating players are provided initial endowments and they need to contribute money from their endowments to reach a pre-defined collective goal over several rounds of negotiations. If players fail to reach the collective goal, then climate change could occur with a known probability and negotiating players lose their leftover endowments completely (Milinski et al., 2008).

Understanding negotiations in the CRSD game has been an active area of research (Burton, May, & West, 2013; Tavoni et al., 2011; Milinski, Röhl, & Marotzke, 2011). However, existing literature involving CRSD has assumed negotiating players to possess complete information about investments made by opponents (i.e., no information asymmetry was assumed to exist among players), which may not be true in the real world. As discussed above, nations may withhold information about their investments against climate change in the real world (Zhang et al., 2017). Motivated by this observation, we investigate the influence of such information asymmetries among players on decision-making in the CRSD game in the laboratory.

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Furthermore, in real world climate change negotiations, it is likely that income inequalities may exist between negotiators (UNO, 2018). For example, some negotiators may belong to low-income nations and others may belong to high-income nations (UNO, 2018). These income-level differences may likely influence the decision-making during negotiations (Burton et al., 2013; Milinski et al., 2011; Dennig, Budolfson, Fleurbaey, Siebert, & Socolow, 2015). Motivated from this literature, in this paper, we also investigate how income-level differences among players influence their decision in CRSD.

In what follows, initially we discuss prior research involving the CRSD framework. Then, we discuss certain theories of decision-making that help motivate our hypotheses concerning information asymmetries and income-level differences. Next, we detail an experiment where we test our hypotheses in the CRSD game. In the end, we detail our results, discuss their theoretical underpinnings, and derive implications of our findings for the real world.

Collective Risk Social Dilemma (CRSD) Game

Prior research involving the Collective Risk Social Dilemma (CRSD) game has tested the effects of probability of climate change on investments made by negotiators (Milinski et al., 2008; Tavoni et al., 2011). These studies have revealed that people invest more against climate change when they are convinced that failure to invest will cause grave financial losses (Milinski et al., 2008). Furthermore, people invest more against climate change in the CRSD game when probability of experiencing a climate catastrophe is high compared to low (Hagel, Milinski, & Marotzke, 2017; Milinski et al., 2008). Studies have investigated how individuals behave if a collective target is missed under different risk situations. Results revealed that the assessment of risk arising from missing a collective target caused reduced contributions. However, risk reduction caused players to maximize their individual contributions (Hagel et al., 2017). Barrett and Dannenberg (2012) showed that when players are provided with a dangerous scenario of rise in global temperature in the CRSD game, climate negotiations turned into a coordination game. Research has also revealed that the presence of small groups can help achieve collective goals under stringent conditions (Santos, Vasconcelos, Santos, Neves, & Pacheco, 2012).

In addition, prior research has evaluated the effects of inequalities in initial endowments and players' pledges on investments against climate change in the CRSD game (Tavoni et al., 2011). Results showed that the initial endowment inequality made it harder to succeed in the CRSD game; however, players' pledges increased success dramatically (Tavoni et al., 2011). In this paper, we build upon this literature to investigate the effects of information asymmetries and income-level differences among players in CRSD. Thus, in some conditions in the CRSD game, all players possess investment information about other players. However, in other conditions in the CRSD game, either none of the players or only a subset of players possess investment information about other players. In addition, we create income-level differences between players by making some players invest against climate change in the initial rounds in CRSD (poor players), where other players do not invest against climate change (rich players). We believe that both information asymmetries and income-level differences are likely to influence people's investment decisions in the CRSD game.

Theoretical underpinnings of decision-making in CRSD

A number of theories in decision-making literature may provide the theoretical underpinnings to understand the resulting behaviour in CRSD in the presence of information asymmetries (Gonzalez, Ben-Asher, Martin, & Dutt, 2015; Kumar & Dutt, 2015; Mitchell, 1995; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007; Voulevi & Van Lange, 2012) and income-level differences (Burton et al., 2013; Dennig et al., 2015; Kahneman & Tversky, 1979; Milinski et al., 2011; Tversky & Kahneman, 1992). These theories may be connected at the cognitive level; however, they may also provide non-overlapping explanations about the resulting behaviour.

The influence of information asymmetries on climate change investments may be explained based upon certain cognitive theories (Gonzalez et al., 2015; Kumar & Dutt, 2015). For example, on account of instance-based learning theory (IBLT; Gonzalez et al., 2015; Kumar & Dutt, 2015), a cognitive theory of decisions from experience, we expect to find lower investments when information asymmetries are present among negotiators compared to when information asymmetries are absent. That is because, in classical games like prisoner's dilemma, cognitive models of decision-making based upon IBLT exhibit lower investments when information asymmetries are present compared to when information asymmetries are absent (Gonzalez et al., 2015). Such models combine not only personal investments; but, also investments of other negotiating partners (Gonzalez et al., 2015). When information asymmetries are present, model players may not be able to systematically combine their investments with those of their opponents and they may be able to maximize only their personal savings and not their public investments.

Furthermore, the influence of information asymmetries on climate change investments may be explained based upon theory of social norms (TSN; Schultz et al., 2007; Voulevi & Van Lange, 2012). According to TSN, social norms are a double-edged sword (Schultz et al., 2007; Voulevi & Van Lange, 2012; Dutt, 2011): investments could be higher or lower when players possess information about investments of others in their group compared to when they lack this information. For example, if opponents invest against climate change, then one expects this investment information's availability among players to increase the overall investments of the group. However, if opponents do not invest against climate change, then one expects this investment information's availability among players to decrease the overall investments of the group. That is because, according to TSN, people tend to follow others while deciding their own actions (Schultz et al., 2007; Voulevi & Van Lange, 2012).

The influence of information asymmetries on climate change investments may also be explained based upon picture theory (Mitchell, 1995) and that people are conscious about their public image (Fenigstein, Scheier, & Buss, 1975; Tajfel & Turner, 1979). According to picture theory (Mitchell, 1995), visuals are believed to have a great power to influence people's decisions. Also, public image of oneself may cause people to act differently compared to their private self (Fenigstein et al., 1975). Overall, on account of the theories of cognition and social norms, and the picture theory, people are likely to become consistent investors when investment information about others is made available to them. Thus, we expect

H1: Higher investments when information about investments of other players in a group is present compared to when this information is absent.

Furthermore, certain theories may explain the influence of income-level differences between rich and poor players on decision-making during negotiations (Burton et al., 2013; Milinski et al., 2011; Dennig et al., 2015). For example, using laboratory experiments, Milinski et al. (2011) showed that rich players are willing to substitute for missing contributions by the poor, provided the players collectively face intermediate climate targets. Also, Dennig et al. (2015) have demonstrated that poor people are more vulnerable to climate change impacts compared to rich people. Furthermore, a number of economic theories (Kahnemann & Tversky, 1979; Tversky & Kahnemann, 1992) and ethical theories (IPCC, 2015; Fleurbaey, 2008; Brown, 2013) may also help explain the effects of income-inequality on people's decision-making during negotiations. Due to economic theories on differences in reference levels of low and high income negotiators (Kahnemann & Tversky, 1979; Tversky & Kahnemann, 1992) as well as ethical theories of responsibility and fairness (IPCC, 2015; Fleurbaey, 2008; Brown, 2013), one expects:

H2: Higher investments from high-income (rich) negotiators compared to low-income (poor) negotiators in the CRSD game.

In addition, when investment information is known to all players, then we expect rich negotiators to contribute more compared to poor negotiators on account of the phenomena of reference dependence in prospect theory (Kahnemann & Tversky, 1979; Tversky & Kahnemann, 1992). According to reference dependence (Kahnemann & Tversky, 1979; Tversky & Kahnemann, 1992), in the presence of investment information, those with higher reference levels (or higher incomes) will likely invest more compared to those with lower reference levels (or lower incomes). In the presence of investment information, higher-income negotiators may also contribute more compared to lower-income negotiators due to a feeling of responsibility towards society as well as a societal perception of fairness (Brown, 2013). Overall, we also expect:

H3: Higher investments from rich players compared to poor players when information about investments of other players in a group is present compared to when this information is absent.

Finally, players possessing pro-environmental dispositions have been shown to contribute more against climate change (Burton et al., 2013). Pro-environmental dispositions may measure people's agreement or disagreement to different statements about the environment. Overall, we expect:

H4: Players with greater pro-environmental dispositions to likely invest higher amounts against climate change compared to players with smaller pro-environmental dispositions.

In the next section, we detail an experiment involving CRSD where we evaluated different hypotheses stated above.

Method

Participants

Students were recruited through an email advertisement for a climate change study at the Indian Institute of Technology Mandi, India. There were 480 participants (54 females; 426 males), who were divided into 80 groups per condition with 6 participants per group. Participants comprised of undergraduate and graduate students in computer engineering, mechanical engineering, electrical engineering, basic sciences, and humanities and social sciences. Ages ranged from 18 to 30 years (M = 20 years; SD = 1.56 years). The groups took 45-50 minutes to finish the study. Participants were paid INR 30 ($\sim$ USD 0.5) as the base payment for participation. In addition, participants could get a performance incentive based upon the units left in their private account at the end of 13$^{\text{th}}$ round. The performance incentive was calculated as 1 unit in the private account = INR 0.5 in real money. On average across all conditions, participants earned 27 units (INR 13) as payment.

Procedure

The experiment comprised of the following three sequential sections: Questionnaire; Instruction and Demographic Information; and Game Play. In the Questionnaire section, which preceded the Game Play section, participants were given survey questionnaires that tested their pro-environmental predisposition (New Ecological Paradigm; Dunlap et al., 2000). In the Instructions and Demographics section, participants were asked to self-report their basic demographic information (like age, gender, and major) and then asked to read instructions concerning the study. The instructions were adapted from (Tavoni et al., 2011), which formed the basis for our study. In the Game Play section, participants were asked to play the CRSD game within their group for 13 repeated rounds.

Experimental Design

Four hundred and eighty participants were randomly assigned to one of four between-subjects conditions that differed in the amount of information possessed by negotiating players (20 groups per condition): Info-all, No-info, Info-rich, and Info-poor. In each condition, a group of 6 randomly-matched players made monetary investments in a climate fund to avert climate change across 13 repeated rounds. All players in a group started with an equal payoff of 52 units in their private account. In each round, participants decided an investment between 0, 2, and 4 units to put in a climate fund with a goal of reaching 156 units by the end of 13$^{\text{th}}$ round.

Collective Risk Social Dilemma (CRSD) game

In CRSD, negotiating players are provided initial endowments. Players need to contribute money from their endowments to reach a pre-defined collective goal over several rounds of negotiations. If players fail to reach the collective goal, then climate change could occur with a known probability and negotiating players may lose their leftover endowments completely. In order to reach the collective target, players need to make individual sacrifice, with benefits to all but no guarantee that others will also contribute. From the point of view of players, it seems tempting to contribute less so as to save money to induce others to contribute more. Hence, there is a dilemma and the risk of failure (Milinski et al., 2008).

Figure 1 shows the investment screen used across all conditions. As shown in Figure 1, the investment screen displayed the current trial number, total endowment left with the player, a timer, and different investment options. The timer indicated the time left for players to make their investment decisions. The timer lasted for 30 seconds but the screen did not switch after the timer expired until players made their decisions. Players had to select one out of the three options to indicate the amount they wanted to invest into climate protection. Once players had selected the amount, they pressed the NEXT button to proceed to the next round. The first three rounds were automated, where the computer randomly made 3 players to contribute 4 units (poor) and made the remaining 3 players contribute 0 units (rich). The description about different conditions is presented in the next section.

Information availability

In Info-all (No-info) condition, at the end of each round, all players (none of the players) in the group got feedback about other players' individual investments to the climate fund from the start of the game and in the preceding round. In the Info-rich (Info-poor) condition, at the end of each round, only the 3 rich (poor) players got feedback about other players' individual investments to the climate fund from the start of the game and in the preceding round. Figure 2 and 3 show the feedback screen presented to players in different conditions in the CRSD game. For example, as shown in Figure 2, in Info-all condition, at the end of a round, all players in the group got feedback about other players' individual investments to the climate fund from the start of the game and in the preceding round. Also, players were given information about the total investment made by their group to the climate fund in the preceding round along with the total cumulative investment made by their group since the start of the game.

In the Info-rich condition, the rich players could see the investments made by all other players (see Figure 2), but the poor players could not see the investments made by other players (see Figure 3). Similarly, in the Info-poor condition, the poor players could see the investments made by all other players (see Figure 2), but the rich players could not see the investments made by other players (see Figure 3). Across all conditions, if the collective investment of a group to the climate fund remained less than 156 units, then the group failed to reach the collective goal and climate change occurred with a 50% chance. If climate change occurred, then it made everyone lose their incomes that they had not invested in the climate fund till the last round.

NEP-R questionnaire

Before performing in the CRSD game, participants were given the New Ecological Paradigm-Revised (NEP-R) questionnaire that tested their pro-environmental predisposition (Dunlap et al., 2000). The NEP-R consists of 15 statements, which tests people's environmental pre-deposition on different issues. Among the 15 statements, agreement on eight statements reflect endorsement of the paradigm and agreement of the remaining seven statements reflect the endorsement of the popular world view. In addition to NEP-R questionnaire, participants were given questions that tested their reasoning for making decisions. For more information on these questions, please refer to the supplementary material.

Nash Investment

Nash equilibrium is a term used in game theory to describe an equilibrium where each player's strategy is optimal given the strategies of all other players (Osborne & Rubinstein, 1994). Thus, Nash equilibrium is a proposed solution of a non-cooperative game involving two or more players in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only their own strategy (Osborne & Rubinstein, 1994). In the CRSD game, given 13 rounds, 6 players, and a target of 156 units, a number of Nash equilibria are possible as the contributions from players in a group could be unequal – some may put 0s, some may put 2s, while others may put 4s. However, a fair Nash equilibrium in CRSD could be one that is symmetric, i.e., where all players are assumed to contribute equally and optimally to reach the target investment. The symmetric Nash investment in the CRSD game is assumed to be 2 units per player per round. That is because, when each of the 6 players in a group contributes 2 units per round across 13 rounds, the cumulative investment results in 156 units.

Dependent Variables and Statistical Analyses

We used the average cumulative investments across groups in different information conditions as one of the dependent variables. For each group, the average cumulative investment after a certain round was computed by averaging of the cumulative investments made by all players in a group up to the chosen round.

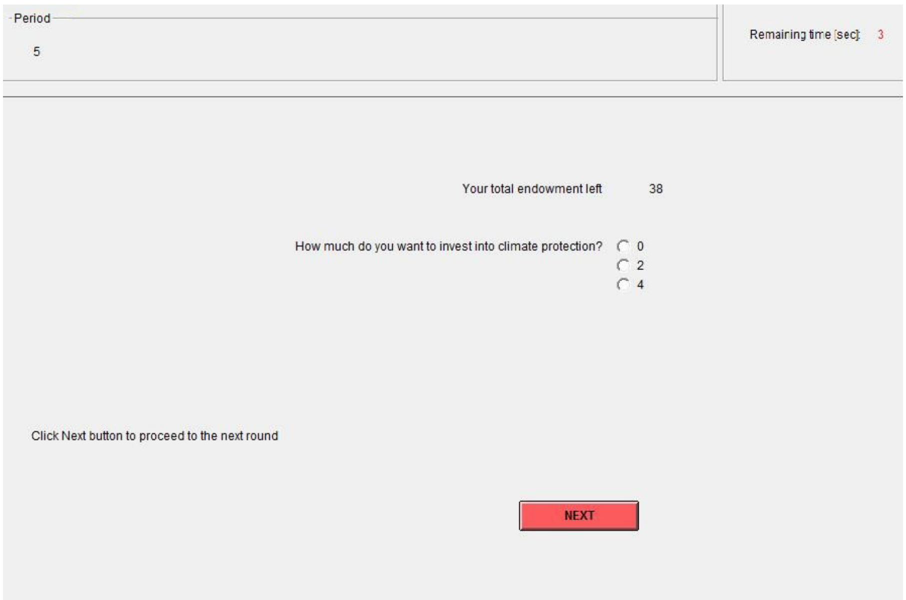

Figure 1. Investment screen across different information conditions in the CRSD game. The investment screen displayed the endowment from which players had to invest between 0, 2 or 4 units into climate protection.

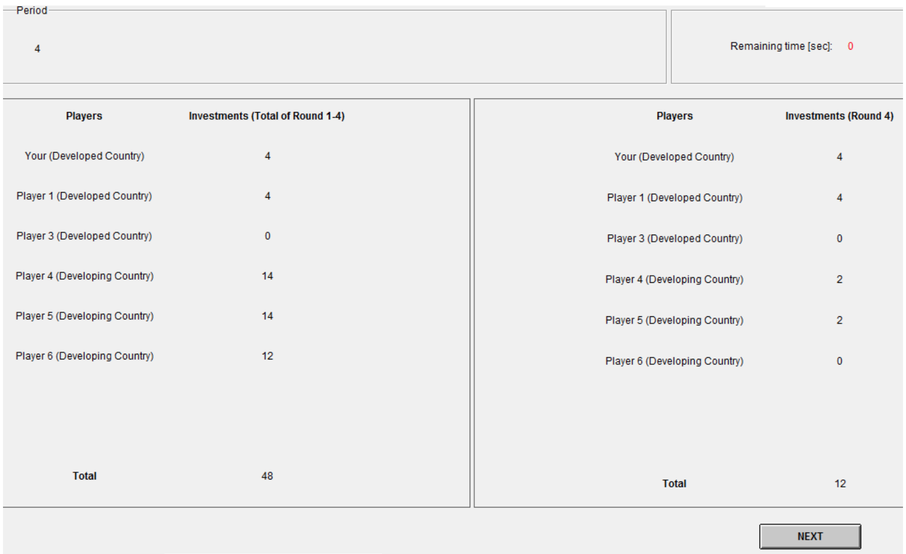

Figure 2. Feedback screen presented to all players in Info-all condition, rich players in Info-rich condition, and poor players in Info-poor condition, respectively.

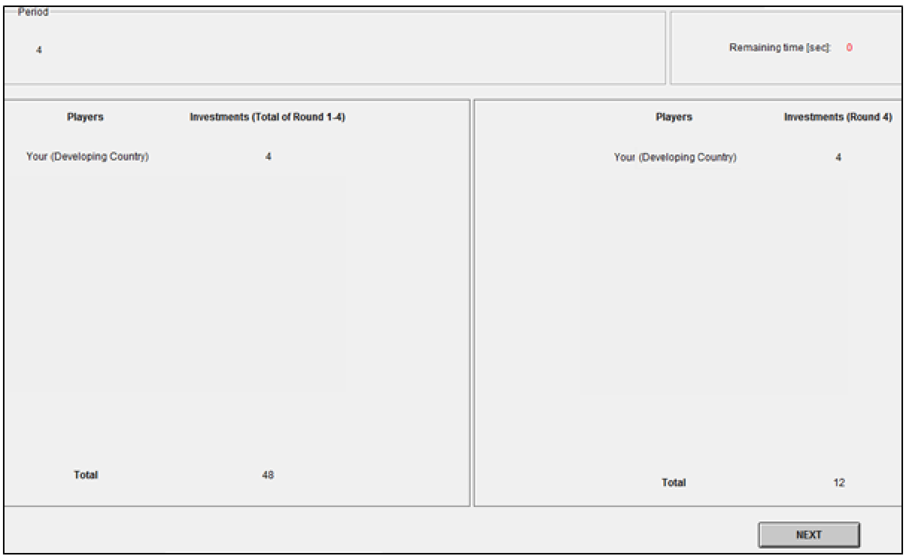

Figure 3. Feedback screen presented to all players in No-info condition, rich players in Info-poor condition, and poor players in Info-rich condition, respectively.

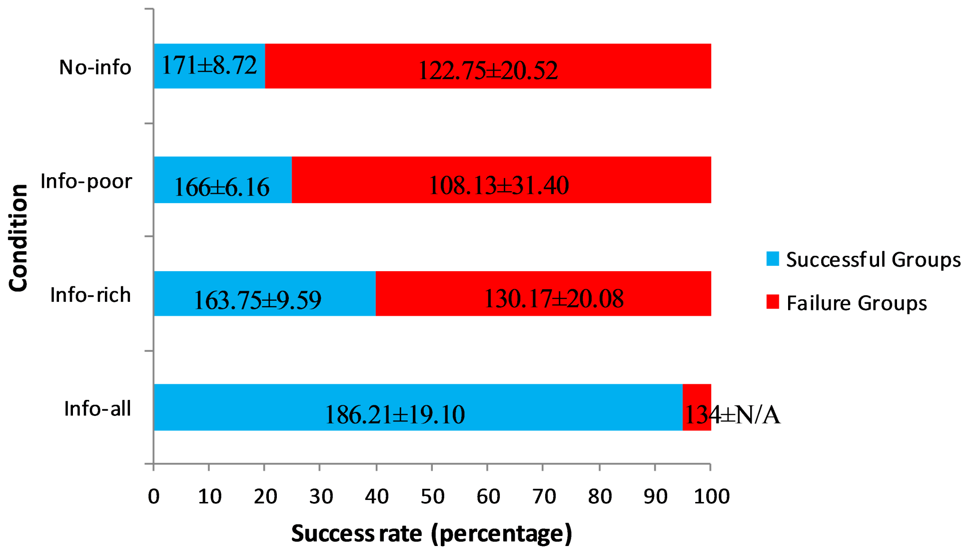

Figure 4. Success rates and average cumulative investments across different information conditions. Success rate and average cumulative investment over 13 rounds by successful and failure groups in avoiding dangerous climate change. The blue section indicates success rates of successful groups; whereas, the red section indicates success rates of failure groups. The numbers within each section indicates average cumulative investments. Numbers after the "±" symbol indicate the standard deviation (the N/A value in Info-all condition is because only one failure group existed in this condition).

For example, if the first, second, and third players in a group contributed 0, 2, and 4 units, respectively, in the first two rounds in CRSD, then after 2 rounds, the cumulative investment of these players would be 0, 4 and 8 units, respectively. Thus, the average cumulative investment would be 4 units [= (0 + 4 + 8) / 3). If a group's cumulative investment was greater than or equal to 156 units at the end of the 13th round, then the group was termed as successful; otherwise, the group was termed as failure. Success rate was defined as the proportion of groups out of all groups in a condition where the groups' cumulative investments were greater than or equal to 156 units at the end of the 13th round. For example, if there were 10 groups out of a total of 20 groups in the Info-all condition where the groups' cumulative investments were greater than or equal to 156 units at the end of the 13th round, then the success rate would be 0.50 (= 10 / 20).

Results

In order to test our expectations regarding the investments across different conditions and rounds, we performed one-way and mixed-factorial ANOVAs with different dependent measures, and conditions and rounds as the independent measures. We also compared the average investment per player (found by averaging the investments of all players) against Nash investment per player. To test the expectations regarding rich and poor players, we performed one-way ANOVAs with different dependent measures, and rich and poor groups as the independent measure. Furthermore, we also performed correlation analyses where we correlated NEP-R scores with cumulative investments. All statistical analyses were performed at an alpha level of .05 and a power threshold of 0.8.

Success rates and average cumulative investments across successful and failure groups

In order to test hypothesis H1, we performed a one-way ANOVA to evaluate whether success rates were influenced by the different information conditions. Information availability had a significant effect on success rates ($F(3, 32) = 9.52$, $p < .05$, ${\eta_p}^2 = .47$). Figure 4 shows the success rates by successful and failure groups in avoiding dangerous climate change.

Table 1. Post-hoc tests for success rates across different information conditions.

Success rate in one condition versus the other condition (Mean, Standard Deviation)	*p*
Info-all (0.95, 0.22) > No-info (0.20, 0.41)	< .05
Info-all (0.95, 0.22) > Info-rich (0.40, 0.50)	< .05
Info-all (0.95, 0.22) > Info-poor (0.25, 0.44)	< .05
No-info (0.20, 0.41) ~ Info-rich (0.40, 0.50)	~ 0.18
No-info (0.20, 0.41) ~ Info-poor (0.25, 0.44)	~ 0.71
Info-rich (0.40, 0.50) ~ Info-poor (0.25, 0.44)	~ 0.32

Table 1 shows the post-hoc tests for comparing success rates in different conditions. Post-hoc tests revealed that success rates were significantly higher in Info-all condition compared to No-info, Info-rich, and Info-poor conditions. There was no significant difference in success rates between Info-rich and Info-poor conditions and between Info-rich and No-info conditions. Similarly, success rates were similar in No-info and Info-poor conditions. As per our expectation in H1, these results show that groups had higher success rates when all players possessed investment information about others' investments compared to when either this information was partially present with only some players in the group or completely absent from all players in the group. Success rates were similar when

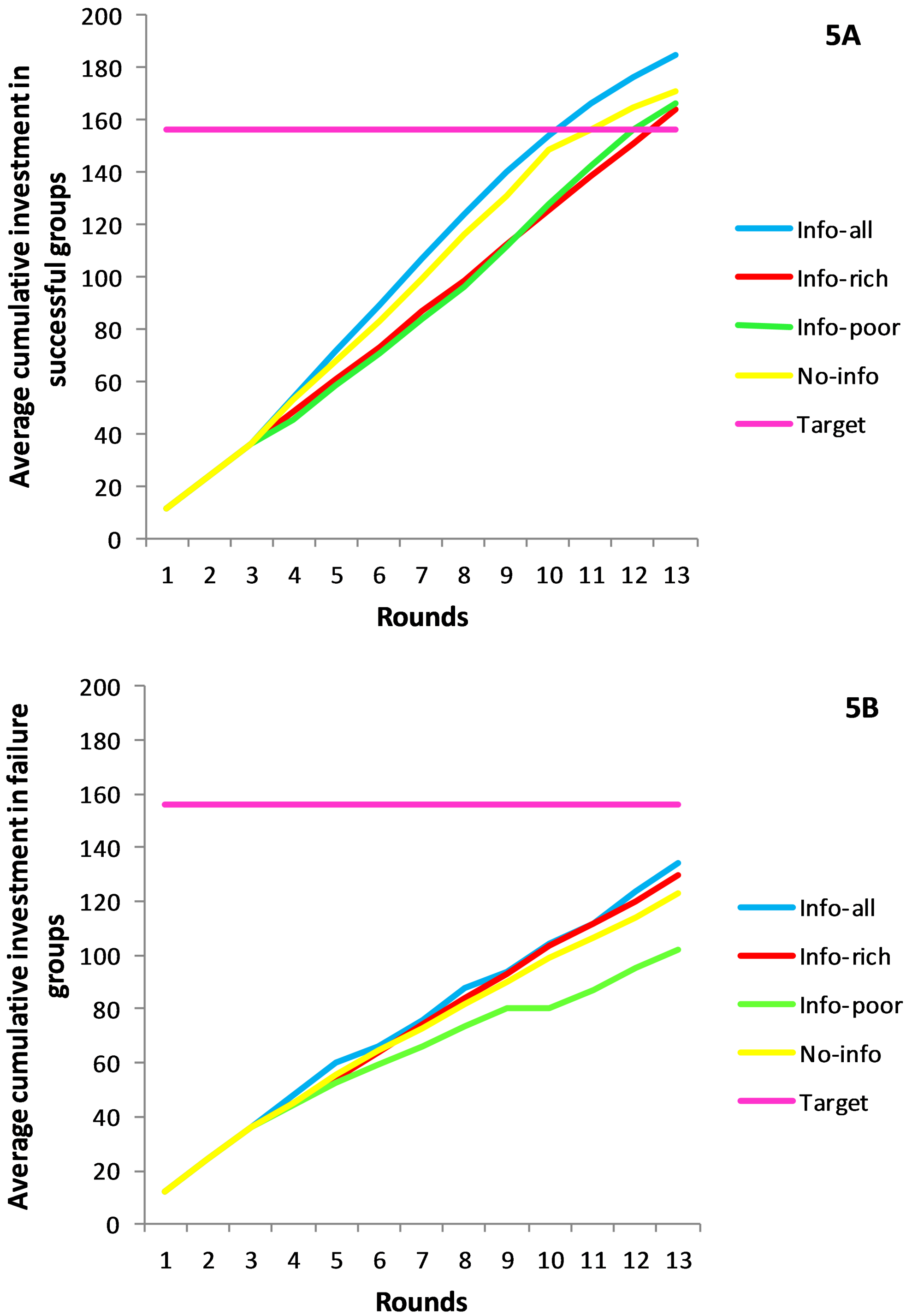

Figure 5. Average cumulative investments over rounds across different information conditions. Average cumulative investment across 13 rounds by successful groups (A) and failure groups (B) in avoiding dangerous climate change. The horizontal line shows the collective goal of 156 units to be achieved by the end of 13th round in the task.

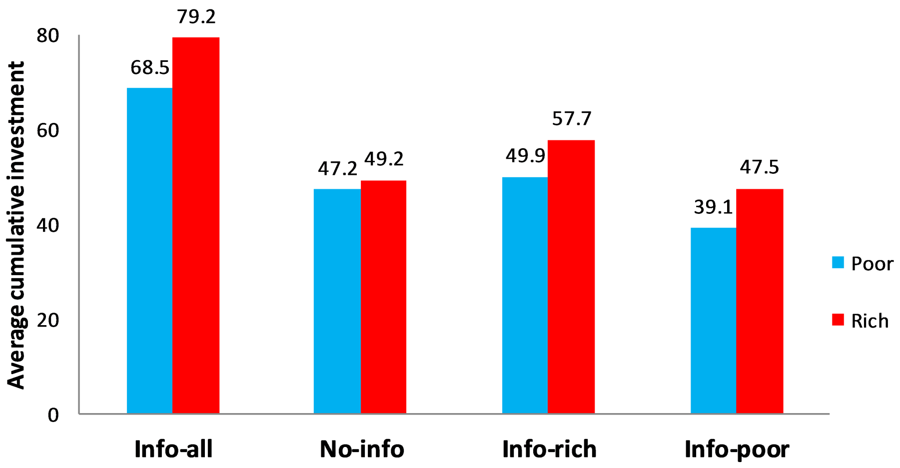

Figure 6. Average cumulative investments by rich and poor players. Average cumulative investments were calculated across 10 rounds (round 4th to round 13th).

the investment information was possessed by only the rich or only the poor players.

Furthermore, we performed a one-way ANOVA to check whether the average cumulative investments were influenced by the different information conditions. Figure 4 shows the average cumulative investments by successful and failure groups. Information availability had a significant effect on the average cumulative investments for successful groups ($F(3, 32) = 9.52$, $p < .05$, ${\eta_p}^2 = .47$); however, not for failure groups ($F(3, 40) = 1.80$, $p = .16$, ${\eta_p}^2 = .12$). Table 2 shows the post-hoc tests for average cumulative investments among successful groups. Post-hoc tests revealed that the average investment in Info-all condition was significantly higher compared to Info-rich, Info-poor, and No-info conditions. Furthermore, average cumulative investment in No-info condition was similar to that in Info-rich and Info-poor conditions. There was no significant difference in average cumulative investments between Info-rich and Info-poor conditions. As per our expectation in H1, these results show that average cumulative investments were higher when all players possessed information about others' investments compared to when this information was partially available to some players. Furthermore, average cumulative investments were similar when investment information was available to only the rich or only the poor players.

Table 2. Post-hoc test for average cumulative investments for successful groups across different information conditions.

Average cumulative investment in one condition versus the other condition (Mean, Standard Deviation)	***p***
Info-all (186.21, 19.10) > No-info (171.00, 8.72)	< .05
Info-all (186.21, 19.10) > Info-rich (163.75, 9.59)	< .05
Info-all (186.21, 19.10) > Info-poor (166.00, 6.16)	< .05
No-info (171.00, 8.72) ∼ Info-rich (163.75, 9.59)	∼ 0.40
No-info (171.00, 8.72) ∼ Info-poor (166.00, 6.16)	∼ 0.55
Info-rich (163.75, 9.59) ∼ Info-poor (166.00, 6.16)	∼ 1.00

Average cumulative investments across rounds among successful and failure groups

We wanted to investigate the average cumulative investments across rounds among successful and failure groups. We analysed the pattern of average cumulative investments across rounds among successful and failure groups using one-way repeated-measures ANOVAs (see Figure 5A and 5B). Average cumulative investments increased over rounds for both successful groups ($F(3, 12) = 1461.96$, $p < .05$, ${\eta_p}^2$ =.98) and failure groups ($F(3, 12) = 204.13$, $p < .05$, ${\eta_p}^2$ =.84). Furthermore, we performed mixed-factorial ANOVAs to evaluate whether the average cumulative investments across rounds among both successful and failure groups were different in different information conditions. ANOVA results revealed that the average cumulative investments across rounds were indeed different in different information conditions among both successful groups ($F(36, 384) = 6.97$, $p < .05$, ${\eta_p}^2$ =.40) and failure groups ($F(36, 480) = 2.15$, $p < .05$, ${\eta_p}^2$ =.14). As seen in Fig 5(A), among successful groups, although there was an overall increase in investments across all conditions, yet the rate of increase was more in Info-all condition compared to all other conditions. On average, participants reached the goal in 10 rounds in Info-all condition compared to a higher number of rounds in other conditions. Furthermore, as seen in Fig 5(B), among failure groups, the rate of increase of average cumulative investment was similar in Info-all, No-info, and Info-rich conditions. However, average cumulative investments were lower in Info-poor condition compared to that in other conditions. Thus, in agreement with H1, the best case for achieving the collective goal was when investment information was present among all players. However, when groups failed, then the worst case was when investment information was available to only the poor players.

Average cumulative investments among poor and rich players

We expected rich players to invest more against climate change compared to poor players (H2). We analysed average cumulative investments between round 4^{th} and round 13^{th} by poor and rich players (see Figure 6). In agreement with H2, average cumulative investments for rich players were significantly higher than those for poor players ($58.4 > 51.2$; $F(1, 156) = 7.26$, $p < .05$, ${\eta_p}^2 = .04$).

Average cumulative investments among poor and rich players across different information conditions

We expected information availability to influence the investments of rich and poor players (H3). We performed one-way ANOVAs to investigate whether information availability influenced the average cumulative investments among rich and poor players, respectively, in different information conditions. Figure 7 shows the average cumulative investments between 4^{th} round and 13^{th} round by poor players (blue) and rich players (red) across different information conditions. Average cumulative investment was significantly higher among rich players compared to poor players in Info-all condition ($79.20 > 68.50$; $F(1, 39) = 4.70$, $p < .05$, ${\eta_p}^2 = 0.11$). However, average cumulative investment for rich and poor players was similar in all other conditions: No-info ($49.20 \sim 47.20$; $F(1, 39) = 0.17$, $p = .68$, ${\eta_p}^2 = 0.00$), Info-rich ($57.70 \sim 49.90$; $F(1, 39) = 2.79$, $p = .10$, ${\eta_p}^2 = 0.07$), and Info-poor ($47.50 \sim 39.10$; $F(1, 39) = 1.65$, $p = .21$, ${\eta_p}^2 = 0.04$). Thus, overall, these results agree with our expectation H3 about rich players contributing more compared to poor players when information was available among all players.

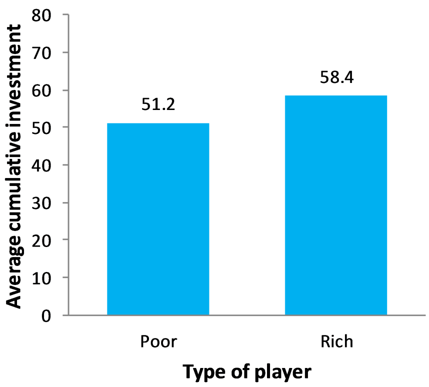

Figure 7. Average cumulative investments by poor (blue) and rich (red) players across different information conditions. Average cumulative investment was calculated between the 4^{th} round and the 13^{th} round in the game.

Average cumulative investment and NEP-R across different information conditions

We expected players' pro-environmental attitudes to influence their investments against climate change (H4). We analysed players' pro-environmental attitudes by using the New Ecological Paradigm-Revised (NEP-R) scale (Dunlap et al., 2000). Overall, in agreement with H4, the NEP-R score was significantly and positively correlated to cumulative investments across 13 rounds ($r(78) = .42$, $p < .001$). Correlations between NEP-R and cumulative investments were not significant in Info-all condition ($r(18) = .30$, $p = .19$); No-info condition ($r(18) = .22$, $p = .36$); and, Info-rich condition ($r(18) = .42$, $p = .06$). However, this correlation was significant for Info-poor condition ($r(18) = .50$, $p = .03$).

Correlation between NEP-R and cumulative investments was positive and significant for both poor players ($r(78) = .31$, $p = .01$) and rich players ($r(78) = .27$, $p = .02$). Overall, these results agree with our expectation in H4.

Deviations of average investment per player from Nash predictions

We analysed the deviations in players' investments from their Nash predictions between rounds 4 and 13. In the Info-all condition, the average investment per player was significantly greater compared to the symmetric Nash investment per player ($2.35 > 2.00$; $t(119) = 5.73$, $p < .05$, $r = .46$). However, in other conditions, the average investment per player was significantly lower compared to the symmetric Nash prediction: No-info ($1.70 < 2.00$; $t(119) = -4.66$, $p < .05$, $r = .39$), Info-rich ($1.84 < 2.00$; $t(119) = -2.31$, $p < .05$, $r = .21$) and Info-poor ($1.57 < 2.00$; $t(119) = 5.73$, $p < .05$, $r = .46$). The average investment per player was significantly lower compared to the symmetric Nash investment per player for both rich players ($1.95 < 2.00$; $t(239) = -.91$, $p < .05$, $r = .06$) and poor players ($1.70 < 2.00$; $t(239) = -5.14$, $p < .05$, $r = .31$).

Discussion and Conclusion

In today's world, climate change is a pressing problem and behaviour change is critically needed for fighting climate change (Webb, 2012). Monetary investments against climate change are important indicators of the needed behaviour change (Doulton & Brown, 2009; Sterman & Sweeney, 2007; Sterman, 2008). Our results revealed that possessing information about investments of other players produced higher investments against climate change and higher success rates among successful groups (H1). Investments and success rates were similar when the investment information was possessed by only a subset of players (either rich or either poor only). Also, the contributions by rich players were more compared to poor players when investment information was present among players (H2). Also, the NEP-R scores were positively correlated with people's investments against climate change (H4).

A likely reason for higher investments when information was present among all players is due to the Theory of Social Norms (TSN; Schultz et al., 2007). As per TSN, peer pressure plays a significant role in driving monetary investments towards climate change: people are willing to contribute when they are able to see others contribute. The influence of information asymmetries on climate change investments may also be explained based upon picture theory (Mitchell, 1995) and that people are conscious about their public image (Fenigstein et al., 1975; Tajfel & Turner, 1979). According to picture theory (Mitchell, 1995), visuals are believed to have a great power to influence people's decisions. Thus, when people are able to visualize the investment information about other players during feedback, then this visualization causes them to invest more against climate change. Also, public image of oneself may cause people to act differently compared to their private self (Fenigstein et al., 1975). In general, players may not want to be portrayed publicly as those contributing less as that is likely to hurt their public image. Overall, players may tend to invest in ways that reduce the possibility of hurting their public image.

Still, another reason for higher investments in the presence of information could be due to the learning from investment outcomes of other players (Gonzalez et al., 2015; Kumar & Dutt, 2015). As per instance-based learning theory (IBLT), players maximize investments when they are able to combine their investment outcomes with investment outcomes of other players (Gonzalez et al., 2015). Players are likely able to activate investment instances in their memory when they observe contributions of other players. When information is present among all players, the activation of instances is relatively easy and this activation may likely cause people to invest significantly higher in the presence of information.

Interestingly, almost all groups were successful when investment information was available to all players. This result is in contrast to that found by Tavoni et al. (2011) and Milinski et al. (2008) where only 20% and 10% of the groups were successful when information was present among all players. Although we can only speculate about the reasons for the differences, one likely reason for this difference could be the fact that this study was run in India compared to those of Tavoni et al. (2011) and Milinski et al. (2008), where the latter studies were run in European Union (EU) with a different population. Recent research has shown that people in developing countries (like India) perceive climate change a much greater threat to themselves and to their families compared to respondents in the developed countries (in EU; Lee et al., 2015). Perhaps, the feeling of threat from climate change made our participants contribute more against climate change.

Furthermore, we found that the rich players' investments were higher compared to the poor players' investments. This result can be explained on the basis of reference-level dependence as part of prospect theory (PT; Kahnemann & Tversky, 1992; Tversky & Kahnemann, 1979). On account of PT, poor players' smaller incomes likely pushed their reference-levels lower compared to rich players' reference-levels. A higher reference-level of rich players compared to poor players causes rich players to invest more compared to the poor players. Another likely reason for rich players to contribute more compared to poor players is due to ethical theories of responsibility and fairness (IPCC, 2015; Fleurbaey, 2008; Brown, 2013). The higher income-levels of rich players gives them a feeling of responsibility towards reducing climate change. Also, societal perception of rich players contributing more portrays them to be fair (Fleurbaey, 2008; Brown, 2013).

In this paper, we used the Collective-Risk-Social-Dilemma (CRSD) framework (Burton et al., 2013; Dannenberg et al., 2015; Hagel et al., 2017; Jacquet et al., 2013; Milinski, Hilbe, Semmann, Sommerfeld, & Marotzke, 2016; Milinski et al., 2008; Tavoni et al., 2011) in a laboratory setting and our results regarding negotiations against climate change should be seen with this limitation in mind. Our experimental design in this preliminary study was canonical and the situation, where investment information may be withheld from other players, may be less common in the real-world. In real-world negotiations, information sharing about investments may likely be present among negotiators; however, this information may not be true. Thus, we plan to undertake future studies, where we vary the level of truth of investment information while people invest against climate change.

From our lab-based findings in this paper, our results are promising for negotiations against climate change. Overall, investments are likely to be higher when investment information is shared amongst all negotiating players. In the real-world, people are most likely to possess investment information about their opponents. In such situations, based upon our results, we expect investments against climate change to be maximized. In addition, real-world negotiations are likely to have negotiators from both nations with higher and lower income levels. Based upon our findings, again, the news is promising: We expect that in a mixed income-level environment, the higher-income negotiators will contribute more compared to the lower-income negotiators. In fact, the higher-income negotiators are expected to be closer to their optimal Nash investment levels. Also, we found that pro-environmental attitudes were positively correlated with investments. Thus, for real-world negotiations, investments are likely to be higher if negotiators possess pro-environmental attitudes towards our environment. Thus, choosing negotiators with pro-environmental attitudes may be a key for success of climate negotiations.

Overall, our results revealed that information asymmetry is an important factor impacting investments against climate change. However, there are several other factors that are also likely to influence investments and negotiations against climate change. For example, penalties for those contributing less are likely to increase people's investments. One way to increase investments could be by making this activity damaging to players, i.e., by giving players, who invest little, monetary penalties compared to those who do not show this behaviour. However, another way to increase investments could be by rewarding people's contributory behaviours (i.e., rewarding those who do invest more). Still, a third way could be to reward those who do invest against climate change and penalize those who do not invest against climate change. We plan to undertake some of these ideas as part of our future work involving CRSD.

Another factor that is likely to influence investments against climate change is the presence or absence of income disparity among players. In this paper, we did not vary this factor as all players possessed income disparity across all information conditions. However, as part of our future research, we plan to systematically vary income disparity among different information conditions to understand the interaction of these factors.

In this paper, we adapted instructions from Tavoni et al. (2011) and used them across all information conditions. However, instructions provided to participants may influence their investment decisions in certain ways (Zizzo, 2010). Thus, as part of our future research, we plan to frame instructions in different ways to evaluate their influence on investments against climate change in conditions involving information asymmetry. Some of these ideas form the immediate next steps in our research program involving negotiations against climate change.

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