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Intra- and intergenerational discounting in the climate game

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The difficulty of avoiding dangerous climate change arises from a tension between group and self-interest[1–3] and is exacerbated by climate change's intergenerational nature[4]. The present generation bears the costs of cooperation, whereas future generations accrue the benefits if present cooperation succeeds, or suffer if present cooperation fails. Although temporal discounting has long been known to matter in making individual choices[5], the extent of temporal discounting is poorly understood in a group setting. We represent the effect of both intra- and intergenerational discounting[4,6,7] through a collective-risk group experiment framed around climate change. Participants could choose to cooperate or to risk losing an additional endowment with a high probability. The rewards of defection were immediate, whereas the rewards of cooperation were delayed by one day, delayed by seven weeks (intragenerational discounting), or delayed by several decades and spread over a much larger number of potential beneficiaries (intergenerational discounting). We find that intergenerational discounting leads to a marked decrease in cooperation; all groups failed to reach the collective target. Intragenerational discounting was weaker by comparison. Our results experimentally confirm that international negotiations to mitigate climate change are unlikely to succeed if individual countries' short-term gains can arise only from defection.

Present-day political practice interprets the avoidance of 'dangerous climate change'[8] as allowing no more than 2 °C global-mean warming above pre-industrial conditions, implying that global anthropogenic greenhouse gas emissions must be reduced by 50% of present emissions by the year 2050[9–11]. Reducing greenhouse gas emissions requires serious effort, and, as Schelling noted, 'to invest resources now in reduced greenhouse emissions is to transfer consumption from ourselves—whoever 'we' are who are making these sacrifices—for the benefit of people distant in the future'[4]. Here we test how groups of human subjects respond to the challenge of avoiding dangerous climate change in a setting that rewards defection immediately and rewards cooperation over three different time horizons to represent intra- and intergenerational discounting[6,7].

In the 'the tragedy of the commons', the neologism often used for global environmental issues, self-interest undermines common resource management—benefits of defection are individualized whereas costs of defection are shared[1]. The tragedy of the commons can be modelled with a public goods game, where each person in a group of participants can invest part or their entire operating fund into a common pool. Total investments are multiplied by a factor, usually 2, and then the earnings are equally divided among all participants, regardless of whether and how much they contributed. It pays to defect but, if everyone rationalizes in this manner, the group forgoes the benefit of the valuable public good. In contrast, everyone would have gained had everyone contributed. This conflict of interest between the individual and the group is the signature of social dilemmas[2,3]. Public-goods experiments can provide insights into human behaviour, and show that introducing punishment[12,13], reputation[14], or their interaction[15], as well as the threat of shame or the promise of honour[16] can lead to increased cooperation.

Threshold public-goods experiments are a variant that require a minimal investment into the common pool for the public good to be provided[17]. Collective-risk interactions[18–20] are a close variation of threshold public goods, and attempt to capture the seriousness of environmental problems by requiring some minimum amount of cooperation to avert the risk of losing benefits due to, for example, 'dangerous climate change'[8,9,21]. Groups of N participants receive an operating fund and interact repeatedly and know in advance about the target amount, which is the minimum the group must raise to receive an additional monetary endowment. If the target is reached or exceeded, the hypothetical dangerous climate change is averted, and everyone receives the endowment. If the group does not reach the target, the endowment is lost with a specified probability.

The collective-risk experiment has several rounds, and the subdivision into rounds of incremental investments to build towards the target, combined with the ability to see the investments by all participants at each round, is important from a behavioural perspective as it provides an opportunity to build trust and assess the likelihood of achieving the target. Given that the target investment lies in the future, the experimental design also allows participants to make up for less cooperative participants, but only to a certain extent. No single player is capable of ensuring the group's success, and a majority of unconditional defectors guarantees that the target cannot be met. Such sharp thresholds may not exist in real life, but the acute decline in the probability of success due to the majority presence of defectors seems realistic. Note also that in reality, payoffs from the public good may not be in the same currency as the investment. For example, investing public funds in technologies that reduce greenhouse gas emissions may lead to a better quality of life for everyone, but return actual monetary benefits to only a few.

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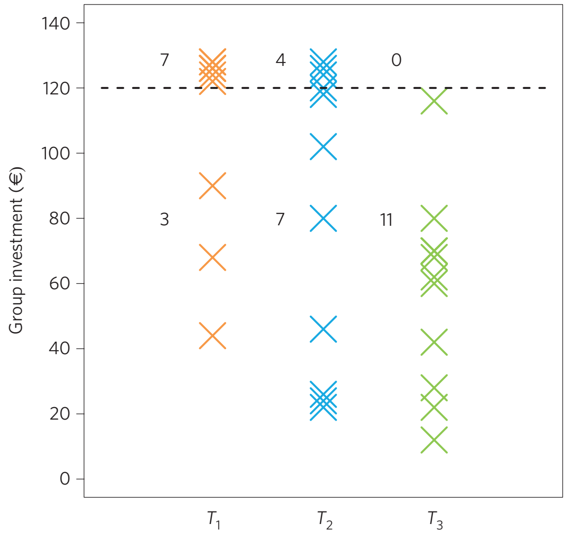

Figure 1 | Group investments by treatment. T_1 (red) received their endowment the following day, T_2 (blue) received their endowment 7 weeks later, and T_3 (green) invested their endowment into planting trees. The dashed line represents the €120 threshold that groups had to achieve to receive the endowment. In T_1 (red), 7 groups succeeded in reaching the target, 4 groups succeeded in reaching the target in T_2 (blue), and 0 groups succeeded in T_3, (green). The number of groups reaching the target differs significantly among the treatments (see text for statistics).

Recent experiments demonstrate that humans often fail to manage collective risk, even when the probabilities of loss are high. Only 5 of 10 groups succeeded in reaching a target amount (requiring 50% of the allotted funds) to avoid a 90% chance to lose their remaining funds[18]. These failures occurred although the experimental set-up in collective-risk experiments so far has been optimistic: participants have received both the benefits of defection and the rewards of cooperation immediately following the experiments[18–20]. In the real-world collective-risk dilemma of climate change, gains from defection can often be realized quickly, but the rewards of cooperation may be delayed by decades[4]. Therefore, another social condition that confounds collective-risk decision-making is a preference for benefits that occur closest to the present, also understood as temporal discounting.

Discounting theory asserts that obtaining less right now is often of greater value than a larger reward further away in time. Payoffs in the present are more valuable than those in the future owing to the risk that the payoff may not get realized or the beneficiary may not live to enjoy it. Although one cause of failure to sustainably manage resources is the competition between individuals[1], overexploitation of resources is likely even under private control owing to high rates of discounting[5], and even more likely when subsequent generations receive the benefits of cooperation[4,6]. High discount rates are common across the animal kingdom[22]. In humans, different regions of the brain activate according to whether a reward is immediate or delayed, suggesting that thinking about the future requires a different cognitive function[23].

Here we explore how discounting functions in group settings, which stands in contrast to previous literature that has focused largely on temporal discounting by individuals[24], and we investigate for the first time whether discounting affects group decisions as they relate to collective risk. In our set-up, groups of 6 participants had a collective-risk decision to make today with consequences in the future. Each subject received a €40 operating fund and at each of 10 rounds could choose one of just three possible options—to invest €0, €2 or €4 into a 'climate account'—and all decisions were anonymous but visible to the group. The subjects were informed that the total amount contributed to the climate account would be used to finance an advertisement on climate protection in the Hamburger Abendblatt, a daily German newspaper. However, participants received the 'little information' version[25] to explain the climate account (similar to what they might experience from the media), so that we could expect weak motivation to invest in publishing the advertisement (Supplementary Figs 1 and 2).

If at the end of 10 rounds the group reached the target of €120 (on average €20 per participant), they successfully averted 'dangerous climate change', and each participant received an additional €45 endowment. If the group failed to reach the €120 target, 'dangerous climate change with significant economic losses' was simulated, and the additional endowment of €45, or, in the case of T_3, money for the planting of oak trees (see below), was lost with a 90% probability (Detailed instructions for the experiment, text for the newspaper advertisement, receipt for the newspaper advertisement, and receipt for tree planting are all provided as Supplementary Information).

There were three treatments, and in each treatment the remainder of the operating fund was paid out directly following the experiment irrespective of whether the collective target was met. However, the reward of cooperation, the €45 endowment per group member for meeting the €120 target, was distributed on three different time horizons. In one treatment (T_1), the €45 cash endowment was paid the next day; in the second treatment (T_2), the €45 cash endowment was paid 7 weeks later; in the third treatment (T_3), the €45 endowment was invested in planting oak trees that would sequester carbon (as well as provide habitat and greenery) and therefore provide the greatest benefit to future generations, although in a currency different to the monetary endowments offered in T_1 and T_2 (ref. 26).

We interpret the difference between T_1 and T_2 as intragenerational discounting—in T_2, the same people benefit as in T_1, albeit at a later time. In contrast, the difference between T_3 and either T_1 or T_2 represents intergenerational discounting[5,6] (Methods). It is inherent in intergenerational discounting that benefits are highly diluted and spread among many people in the future[4], which is part of what makes intergenerational cooperation so difficult. We reasoned that groups would cooperate less the further away the rewards of cooperation, and cooperate least in the third treatment (T_3), where the benefits were intergenerational—that is, combining time preference as well as the redistribution of benefits (through greenhouse gas abatement)[4].

In T_1, where participants received their endowment the following day, 7 out of 10 groups succeeded in reaching the target. In T_2, where participants received their endowment 7 weeks later, 4 out of 11 groups succeeded. In T_3, where the endowment was invested in planting trees, 0 out of 11 groups achieved the €120 target. This difference in results among the treatments is statistically significant (Fisher exact with Freeman–Halton extension, two-tailed, $n_{T1} = 10$, n_{T2}, $n_{T3} = 11$, the group is the statistical unit, $P = 0.0021$; Fig. 1). Whereas intragenerational discounting—the difference between T_1 and T_2—was weak (Fisher exact, two-tailed, $n_{T1} = 10$, $n_{T2}, = 11$, $P = 0.1983$) and might have been stronger had the delay been, for instance, years rather than weeks, intergenerational discounting was significant, as demonstrated by comparing $T_1 + T_2$ with T_3 (Fisher exact, two-tailed, $n_{T1+T2} = 21$, $n_{T3} = 11$, $P = 0.0005$; Fig. 1).

Delaying the payoff for cooperation not only influenced whether the target sum was reached but also the total amount collected against the climate account (Fig. 2). Group investments in T_1 of €108.2 ± 9.6 (mean ± s.e.m.) were on average 30% higher than investments in T_2 (€83.2 ± 13.6) and 89% higher than those in T_3 (€57.3 ± 9.0)—a significant difference among the three treatments (Kruskal–Wallis, $\chi^2_{df=2} = 9.41$, $n_{T1} = 10$, n_{T2}, $n_{T3} = 11$, $P = 0.0091$).

Of the 6 members in each group, an average of 3.2 ± 0.5 donated at least their fair share of €20 or more over the course of 10 rounds

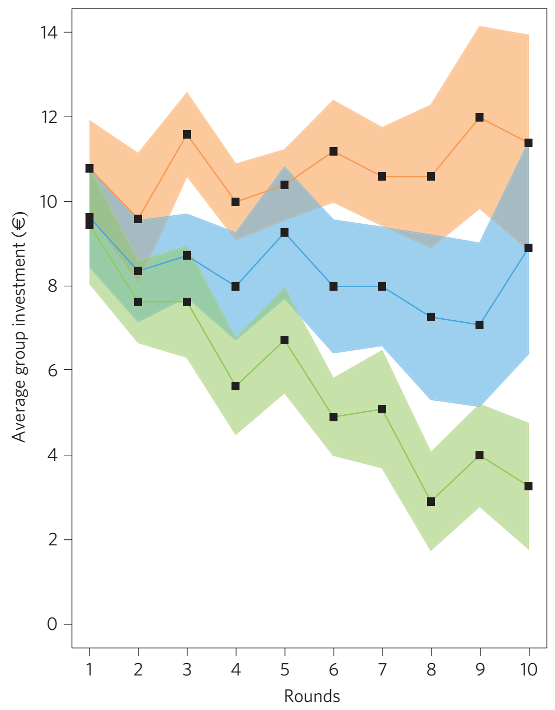

Figure 2 | Average group investment and standard error of the mean (coloured range) by treatment over the 10 rounds. Group investments across the three treatments were significantly different showing a trend of greater cooperation the closer in time the benefits were received. Investments were highest in T_1 (red), when the endowment was received the next day, compared with T_2 (blue), where participants received their endowment in 7 weeks, and much higher than those in T_3 (green).

in T_1, 2.5 ± 0.7 group members did so in T_2, and 0.6 ± 0.4 group members in T_3; the differences among the groups are statistically significant (Kruskal–Wallis, $\chi^2_{df=2} = 9.25$, $n_{T1} = 10$, n_{T2}, $n_{T3} = 11$, $P = 0.0098$). The other members in each treatment were defectors (that is, participants who gave less than €20).

In examining the frequencies of selfish (providing €0), fair-share (€2) and altruistic (providing €4) investments, the number of selfish investments was significantly different among treatments (Kruskal–Wallis, $\chi^2_{df=2} = 7.26$, $n_{T1} = 10$, n_{T2}, $n_{T3} = 11$, $P = 0.0265$), and was lowest in T_1 (18.8 ± 3.7), followed by T_2 (27.1 ± 5.3), and highest in T_3 (37.2 ± 3.0), when benefits were intergenerational. The overall number of altruistic investments was also significantly different among treatments (Kruskal–Wallis, $\chi^2_{df=2} = 8.00$, $n_{T1} = 10$, n_{T2}, $n_{T3} = 11$, $P = 0.018$), and highest in T_1 (12.9 ± 1.6), when the benefits of cooperation were available the following day, compared with T_2 (8.7 ± 1.7) and T_3 (5.8 ± 1.5). The number of fair-share investments between T_1 (28.3 ± 3.2), T_2 (24.2 ± 4.2) and T_3 (17.0 ± 1.8) was not significantly different. In Fig. 3 we present the average number of selfish, fair-share and altruistic investments for each round by treatment.

None of the 32 total groups demonstrated fair-share behaviour in the first round of play (€2 investment per participant), and none of the 11 groups that achieved the target did so by all participants giving €2 every round (the fair-share option, Fig. 3). Two groups in T_3 happened to receive the endowment despite not meeting the target owing to the 10% chance of this occurring, so €540 has been invested in planting trees (Supplementary Fig. 3).

Even though no group in T_3 reached the threshold, there is almost the same number of selfish, fair-share and altruistic investments in the first round of each of the three treatments (Fig. 3a–c). The number of altruistic investments is more or less constant over the following nine rounds in all treatments, whereas fair-share investments decline and selfish investments increase over the course of ten rounds in T_2 and T_3. The effect is most pronounced in T_3 (Fig. 3c), suggesting that the interactions between players have induced exchanging the fair-share for the selfish strategy. If we could know what caused this change of investment strategy, we might be able to suggest a way to prevent it from happening in the climate game.

This experiment is the first to examine the effects of discounting on collective risk. The payoff for each of the six players depends on how cooperative players choose to be, and the differences between treatments allow us to examine whether groups discount future gains and the effect of discounting on cooperation. As the game includes repeated rounds, participants can anticipate the others' level of cooperation and discount rates, and it further enables the participants to determine whether they should contribute strategically[27] and thus help the group to reach the threshold sum or whether they should prefer the defector's payoff. The results show the power of intergenerational discounting to undermine

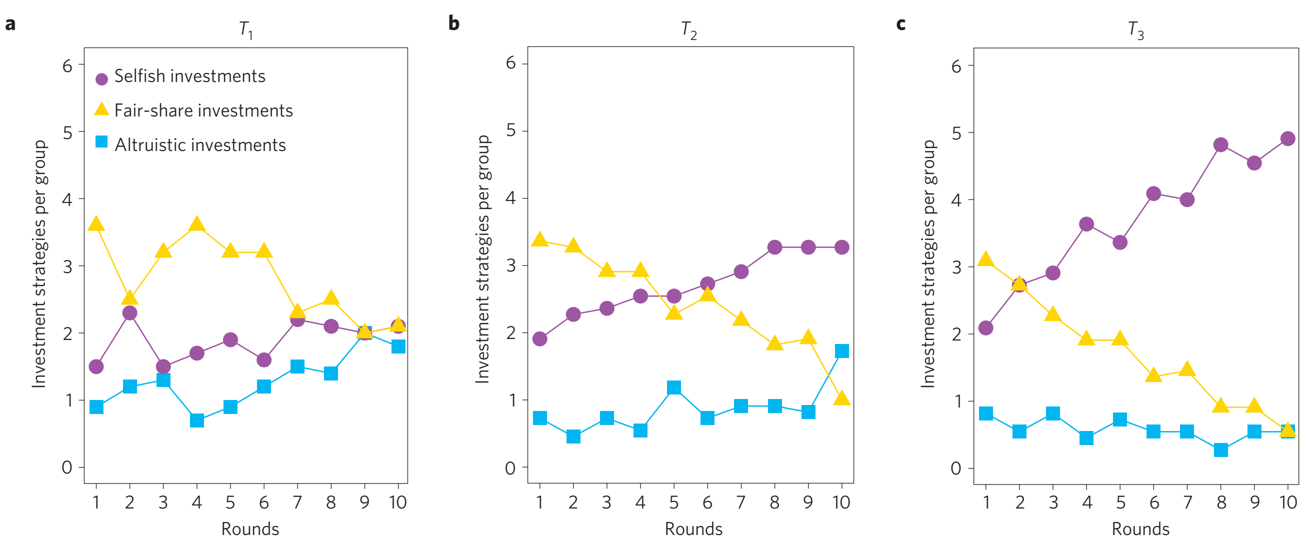

Figure 3 | The average number of selfish (providing €0), fair-share (providing €2) and altruistic (providing €4) investments per group of 6 players over the 10 rounds by treatment. a–c, T_1 (**a**) received their endowment the following day, T_2 (**b**) received their endowment 7 weeks later, and T_3 (**c**) invested their endowment into planting trees.

cooperation and thus support Schelling's[4] expectations. Immediate monetary rewards seem to matter most. Applying our results to international climate change negotiations paints a sobering picture. Owing to intergenerational discounting, cooperation will be greatly undermined if, as in our setting, short-term gains can arise only from defection. This suggests the necessity of introducing powerful short-term incentives to cooperate, such as punishment, reward or reputation, in experimental research as well as in international endeavours to mitigate climate change.

Methods

Experiments were performed with 192 students from Hamburg University in December 2012. There was a single group of 6 participants in the room at a time and each participant sat in front of a laptop computer. Participants were partitioned off from each other as well as the experimenter so as to avoid any audience effects. At the beginning of the experiment, participants received written instructions on the screen that they could advance at their own pace. Each participant also received a randomly assigned unique pseudonym (for example, Ananke, Despina, Japetus, Kallisto, Metis, Telesto) so that participants' decisions were anonymized at all times to both to the experimenter and other participants. All decisions were made on their personal computer screen using customized software. After every round, the decisions of the 6 subjects were displayed under their pseudonyms on all computers simultaneously. The accumulated sum of investments was not displayed on the computer screen. Instead, the subjects were given pencil and paper, and encouraged to take notes during the experiment. Participants who succeeded in reaching the target were given an invoice, which they could redeem the following day (T_1) or 7 weeks later (T_2), depending on the treatment (participants were told the 7 week delay was because funds were being used from the 2013 budget, which was true). In the case of T_3, the participants received instructions that if they succeeded in reaching the target, oak trees would be planted 'for the next generation' with the monetary investments and that the trees 'would not be used for commercial purpose and will store CO_2 for at least 80 years'. This served to remind students that the world's forests provide a carbon sink[26]. Also, after being cut, oak wood would not release assembled carbon assuming the wood is used for construction (as it often is). The Supplementary Information includes instructions for the experiment, proof that investments were used for a newspaper advertisement, and, for the two 'lucky' groups in T_3 that managed to avoid the 90% risk of forgoing tree-planting even though they did not reach the endowment, the receipts for planting oak trees. All participants received in cash what was left of their operating fund anonymously under their pseudonym. Participants were asked not to discuss the experiment with anyone else (detailed instructions for the experiment, text for the newspaper advertisement, receipt for the newspaper advertisement, and receipt for tree planting are all provided as Supplementary Information.).

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Author contributions

J.J., C.H. and M.M. designed the experiment; K.H. and M.M. carried out the experiments; T.R. wrote the software for performing the experiment; J.J., K.H. and T.R. prepared the data and statistics; all authors wrote the paper, prepared the figures, and reviewed the paper and results.

Additional information

Supplementary information is available in the online version of the paper. Reprints and permissions information is available online at www.nature.com/reprints. Correspondence and requests for materials should be addressed to J.J.

Competing financial interests

The authors declare no competing financial interests.