Science Advances
AAAS

advances.sciencemag.org/cgi/content/full/5/4/eaau7296/DC1

Supplementary Materials for

Individual solutions to shared problems create a modern tragedy of the commons

Jörg Gross* and Carsten K.W. De Dreu

*Corresponding author. Email: mail@joerg-gross.net

Published 17 April 2019, *Sci. Adv.* **5**, eaau7296 (2019)
DOI: 10.1126/sciadv.aau7296

This PDF file includes:

Theoretical motivation

In this paper, we investigate how groups coordinate collective action problems when having the ability to solve shared problems individually. Public goods and collective action problems have been traditionally modelled as a conflict between selfish and pro-social preferences (*3*–*5*, *9*). Selfishness is in the best interest for the individual, while cooperation is in the best interest for the group, leading to the famous tragedy of the commons (*20*) – the failure to solve collective action problems and establish public goods. This tragedy ultimately leads the group being worse off compared to the cooperative outcome.

With the advent of market economies, specialization, and global increase in wealth, modern societies enable some or all of its members to avoid the tragedy of the commons by providing individual solutions to collective problems. For example, public transportation allows many people to travel from A to B but also requires people to contribute (e.g., by buying train tickets and paying taxes) and coordinate (e.g. by being at a certain time at the same place). Private transportation by car is an individualized solution to the same problem that avoids co-dependence on others, yet also is energetically more wasteful and can be personally costlier. Further, in modern two-tier health-care systems, privatized health-care providers exist next to publicly-funded health-care plans. Increasingly, retirement planning in Western countries is a mixture of private investment plans and government-regulated public goods provisions (*33*), and next to publicly funded law enforcement, many citizens acquire home security from private companies or own firearms.

How the availability of individual solutions influences public goods provisions and collective action problems is largely unknown. Here, we model the co-existence of collective and individual action with our (in)dependence commons dilemma. In this dilemma, each group member has to either invest enough resources into their individual pool and reach an individual threshold c_i or collectively invest resources into a public pool and reach a public threshold c_c in order to keep any personal units not invested. By independently varying c_i and c_c, the relative costs of individual and collective action can be manipulated, thereby changing the degree of interdependence, the cost of self-reliance, and the incentive to coordinate collective action. In particular, we define the degree of interdependence in this setting as $i = c_i/(c_c/n)$.

The option to solve shared problems individually provides agents with a risk-free solution that decreases the dependence on the cooperativeness of other agents and allows to avoid the inherent free-rider problem of public goods provisions. People might prefer individual solutions because it allows them to be self-reliant. When interdependence declines, as in modern-day public goods problems, the existence of affordable individual solutions to shared problems, hence, create a third strategy, next to selfish payoff-maximization and pro-social investments: the option to be independent of groups. We refer to actions that make individuals independent of the public goods problem as individualism or self-reliance.

Importantly, having individual solutions to shared problems also transforms the collective action problem. From a normative perspective, choosing the individual solution can be considered rational, if *i* is sufficiently low and/or if the agent believes that not enough other group members are willing to cooperate. If the agent believes that others are willing to cooperate sufficiently, cooperation can only be considered rational if the cost of cooperation (the resources needed to make cooperation successful) is lower than the cost of the individual solution. If the agent believes that others are willing to over-invest into cooperation, free-riding (defined as paying a cost of cooperation less than the fair-share) can be considered rational. From this perspective, conditional cooperators may opt for self-reliance if they believe that others will not cooperate enough in order to avoid a situation in which others take advantage of their cooperation. In general, agents may also opt for self-reliance to avoid the strategic uncertainty that comes with working in groups.

This intuition is captured in fig. S1, showing the best response based on first-order beliefs and the individual solution cost c_i as a fraction of the public solution cost c_c. Over-contributions and under-contributions (free-riding), resembling the classic dilemma of (step-level) public goods, emerge when the cost of the individual solution rise and groups become more interdependent (increase in *i*). On the contrary, individualism should emerge when beliefs in the cooperativeness of other group members is low and/or the individual solution is relatively affordable compared to the public solution (decrease in *i*).

An alternative interpretation of individualism, next to strategic uncertainty avoidance and pessimistic beliefs in the cooperativeness of others, is that people differ in their intrinsic preferences for self-reliance, opting for self-reliance because they genuinely value independence or like to avoid the social entanglements that come with public goods provisions. Since (strategic) risk is differentially dispersed for group cooperation and self-reliance – self-reliance only depends on own action in our setup and is risk-free, while cooperation always carries the danger of free-riding or group failure – our experiments do not allow us to directly disentangle whether the option to be self-reliant is driven by (a) beliefs and concerns for risk or (b) a third dimension of motives underlying public goods provisions, next to selfish and pro-social preferences: the preference to be independent of groups. We, thus, can only provide indirect evidence in the manuscript and below, that tentatively point to the possibility that self-reliance is not only driven by risk-concerns, but also by valuing independence for its own sake.

Importantly, independent of assuming a mixture of beliefs across agents or dispersed intrinsic preferences for individualism, the availability of affordable individual solutions to shared problems lead to wasteful coordination failures, revealing a 'modern tragedy of the commons' – a conflict between collective efficiency and the demand for individual freedom and independence.

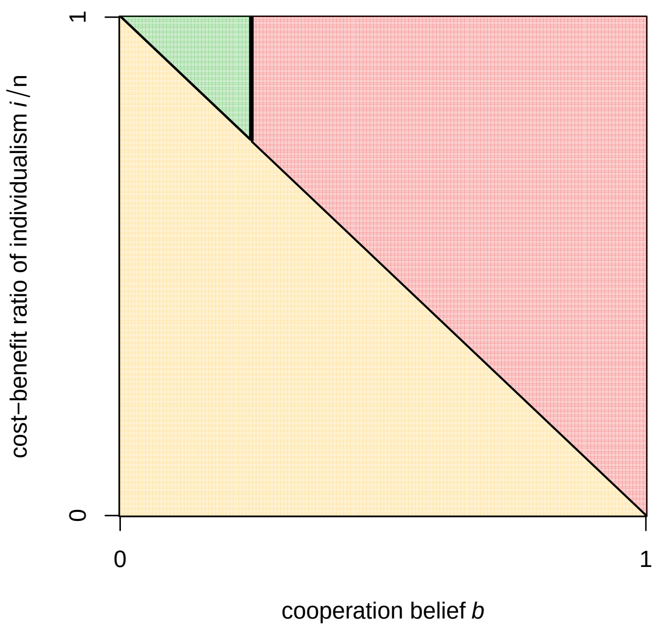


Fig. S1. Best response function. Best response function based on first-order beliefs of others' cooperativeness (i.e., the relative share of the contributions by the other group members to reach the public solution) and relative cost of individualism. Agents should choose the individual solution (yellow) if i/n+b < 1. Already pessimistic beliefs in cooperation can trigger cooperation, if individual solutions are relatively costly (green). When the belief is 1/n, agents should exactly contribute their fair share to the public solution (black vertical line), if i/n > (n-1)/n. With increased optimism in the cooperativeness of others and increased individualism costs, agents should contribute less than their fair share and free-ride on the contributions of others (red).

Game-theoretic predictions. The (in)dependence commons dilemma is a variant of a step-level public goods game. However, it deviates from commonly employed step-level public goods game in three important ways: (i) Not reaching the threshold leads to losing all remaining resource points rather than gaining a fixed price (see also *1*, *2*), (ii) group members have an additional strategy to avoid losing monetary units that only applies to them (individual solution), (iii) the game is implemented as a dynamic game, meaning that group members do not make a one-shot decision after which the game ends and payoffs are resolved, but observe the contribution of others and can update their beliefs and strategy throughout the game.

To derive tractable normative predictions, we consider the one-shot (in)dependence commons dilemma described as follows. There are *n* players who are each endowed with 100 resource points. Each player *k* simultaneously decides how much of the resource points she spends on the public solution $s_{k,c}$, or the individual solution $s_{k,i}$. A strategy of player *k* is then a pair $(s_{k,c}, s_{k,i})$, with $s_{k,i}, s_{k,c} \geq 0$ and $s_{k,i} + s_{k,c} \leq 100$. Pairs satisfying these constraints constitute the strategy set S_k of player *k*. Let c_c be the cost of the public solution and c_i the cost of the individual solution. Then, a public solution is realized if $\sum_k s_{k,c} \geq c_c$, whereas player *k* reaches her individual solution if $s_{k,i} \geq c_i$. If a public solution is reached, and/or if player *k* reaches her individual solution, then the payoff of player *k* is $\pi_k = 100 - s_{k,c} - s_{k,i}$. If neither solution is reached, then the payoff of player *k* is 0, instead. Resources invested towards the individual or public solution, while not reaching the respective target (c_c/c_i) are considered wasted. It follows that any strategy $(s_{k,c} > 0, s_{k,i} > 0)$ is dominated by $\left(s_{k,c} \geq 0, s_{k,i} = 0\right)$ or $\left(s_{k,c} = 0, s_{k,i} \geq 0\right)$. A rational, payoff-maximizing agents would never choose a strategy that assigns resources to both the individual and public pool, since only one solution needs to be reached.

In our experiments, we set *n* = 4, c_c = 160, while c_i was varied according to the treatment, taking values from the set {40,50,60,70,80}. With c_i > 40, players choosing their individual solutions is Pareto-dominated by all of the collective solutions. Further, an equilibrium in which all group members choose the individual solution is payoff-dominated by the equilibrium in which all group members invest 40 resource points to the collective solution for c_i > 40.

Equilibria take the shape $(\bar{s}_{k,c}, 0)_{k\in 1,\ldots,n}$, with $\bar{s}_{k,c} \leq c_i$ (individual rationality), and $\sum_k \bar{s}_{k,c} = c_c$ (collective solution reached without waste). Including the single symmetric solution, the number of pure-strategy equilibria with a collective solution is 1 ($c_i = 40$), 12341 ($c_i = 50$), 85721 ($c_i = 60$), 214221 ($c_i = 70$), 354321 ($c_i = 80$). The analogies of the (in)dependence commons dilemma with the classic step-level public goods games suggests that there may exist a symmetric mixed-strategy Nash-equilibrium with positive probabilities assigned to contributing to the public solution. In addition, there may be a large number of asymmetric mixed-strategy equilibria (see *34*). Note that compared to a classic step-level public goods game in which a certain contribution needs to be reached to attain a prize that is equally shared across group members, a situation in which all players choose $(0, 0)$ does not constitute an equilibrium since group members are always better off to reach their individual solution as long as $c_i < 100$.

In our experiments, participants contributed to their individual or the public pool over 10 periods, with feedback on the contribution decisions of others after each round. We specifically chose this dynamic setup to allow participants to update their belief on the cooperativeness of others, adapt their strategy, and reduce strategic risk-concerns. From a normative perspective, this complicates the equilibrium analyses and would require a technically more involved description of the strategy space that will also lead to much more numerous and complicated equilibria. However, already the analyses of the one-shot (in)dependence commons dilemma shows that there are many equilibria in which agents reach the public solution, demonstrating the coordination problem that agents face. Further, the coordination problem exacerbates with increases in c_i (keeping c_c constant), as the number of possible equilibria increase when individual solution become relatively less affordable

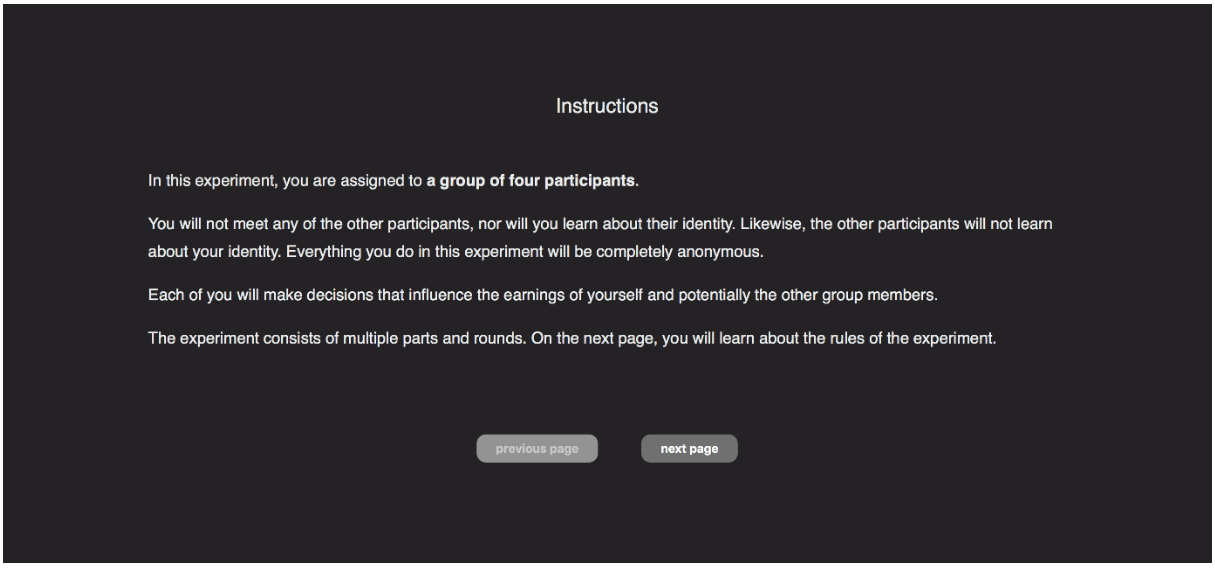
Experimental instructions and computer interface

To experimentally investigate the emergence of individualism as a function of interdependence, we ran computerized lab-experiments using the outlined (in)dependence commons dilemma. Participants first received instructions and examples on the computer screen (figs. S2-S7), followed by a set of comprehension questions (figs. S8-S10). In case of comprehension problems, participants could ask the experimenter or return to the instructions.

Only after answering all comprehension questions correctly, participants were allowed to start with the experiment.

Participants were told that they are in a group of four participants and will each receive 100 resource points (referred to as monetary units, short MU, in the experiment), spread across 10 rounds. Figures S11-S14 shows the instructions and user interface of the experiment. Each group completed five blocks that varied in the degree of interdependence. Specifically, the cost of the public solution was fixed to c_c = 160 (public threshold), while the cost of the individual solution (c_i) was either 40, 50, 60, 70, or 80 (individual threshold; referred to as 'private threshold' in the experiment). Public and individual threshold were announced before each block (fig. S11). In each round, each group member then had to allocate their 10 resource points across (i) their own individual pool, (ii) a shared public pool, or (iii) keep (any of) them for themselves (fig. S12). After each participant made their allocation decision, they received feedback on how many units were allocated to their individual and the public pool in total so far (fig. S13). Hence, groups were confronted with a dynamic version of a step-level public goods game with a competing individual solution strategy, in which the investments into the public or individual pool accumulated over rounds. After the 10th and final round, participants received a final feedback screen showing whether they accumulated enough resource points and reached their individual or the group's public target and the final earnings for this block (fig. S14). Participants only had to allocate enough resources to one of the pools in order to solve the problem and prevent losing their remaining resource points.

Half of the groups were allocated to the punishment condition. In this condition, each contribution stage was followed by a punishment stage (fig. S15). In this punishment stage, each participant could assign up to 5 punishment points (referred to as deduction points, short DP, in the experiment) to each other group member. After each participant made their punishment decision, they received a reminder on how many punishment points they assigned and how many punishment points were assigned in total to each group member (fig. S16).



Instructions

In this experiment, you are assigned to **a group of four participants**.

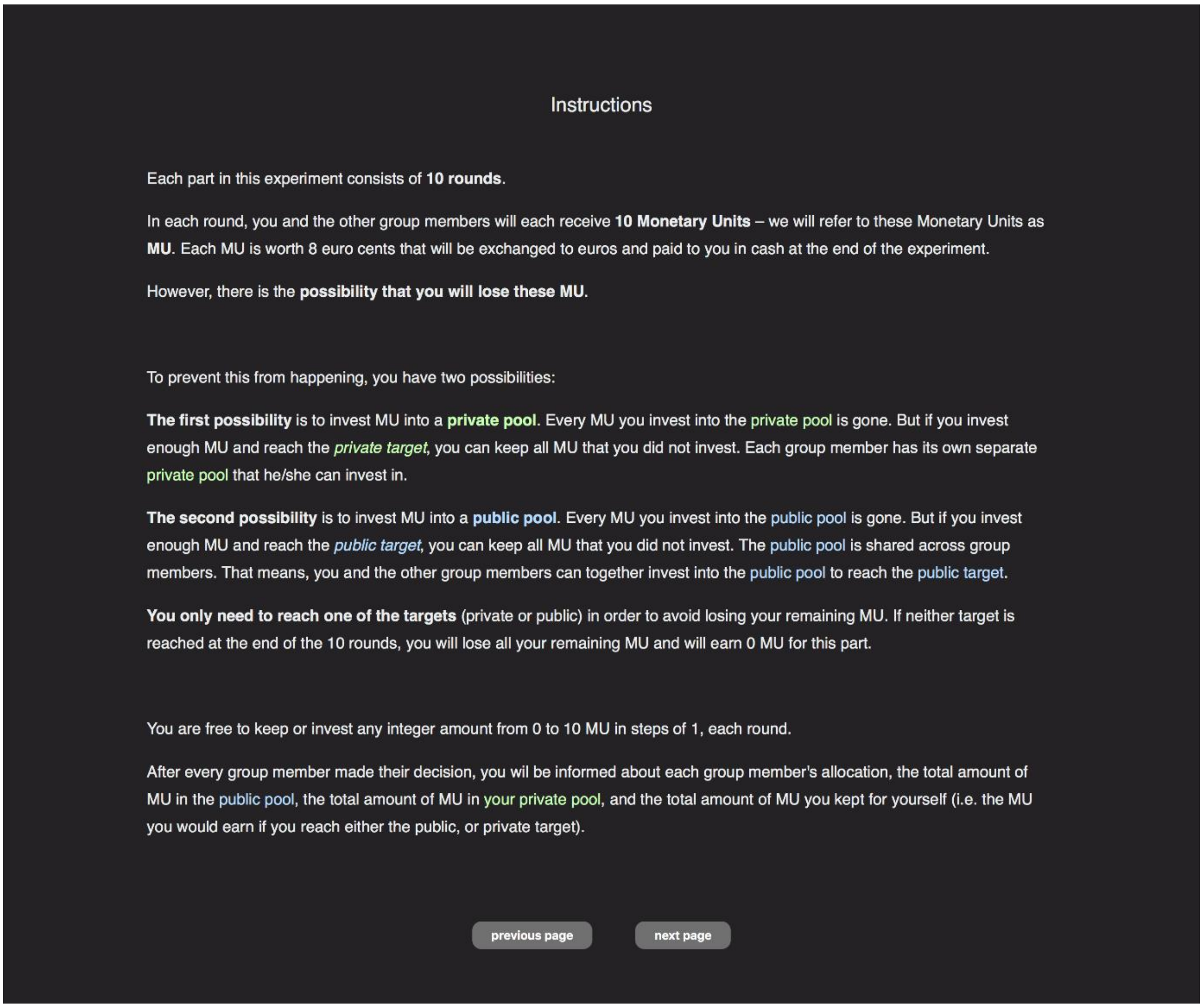
You will not meet any of the other participants, nor will you learn about their identity. Likewise, the other participants will not learn about your identity. Everything you do in this experiment will be completely anonymous.

Each of you will make decisions that influence the earnings of yourself and potentially the other group members.

The experiment consists of multiple parts and rounds. On the next page, you will learn about the rules of the experiment.

previous page next page

Fig. S2. First instruction page.



Instructions

Each part in this experiment consists of **10 rounds**.

In each round, you and the other group members will each receive **10 Monetary Units** – we will refer to these Monetary Units as **MU**. Each MU is worth 8 euro cents that will be exchanged to euros and paid to you in cash at the end of the experiment.

However, there is the **possibility that you will lose these MU**.

To prevent this from happening, you have two possibilities:

The first possibility is to invest MU into a **private pool**. Every MU you invest into the private pool is gone. But if you invest enough MU and reach the *private target*, you can keep all MU that you did not invest. Each group member has its own separate private pool that he/she can invest in.

The second possibility is to invest MU into a **public pool**. Every MU you invest into the public pool is gone. But if you invest enough MU and reach the *public target*, you can keep all MU that you did not invest. The public pool is shared across group members. That means, you and the other group members can together invest into the public pool to reach the public target.

You only need to reach one of the targets (private or public) in order to avoid losing your remaining MU. If neither target is reached at the end of the 10 rounds, you will lose all your remaining MU and will earn 0 MU for this part.

You are free to keep or invest any integer amount from 0 to 10 MU in steps of 1, each round.

After every group member made their decision, you wil be informed about each group member's allocation, the total amount of MU in the public pool, the total amount of MU in your private pool, and the total amount of MU you kept for yourself (i.e. the MU you would earn if you reach either the public, or private target).

previous page next page

Fig. S3. Second instruction page.

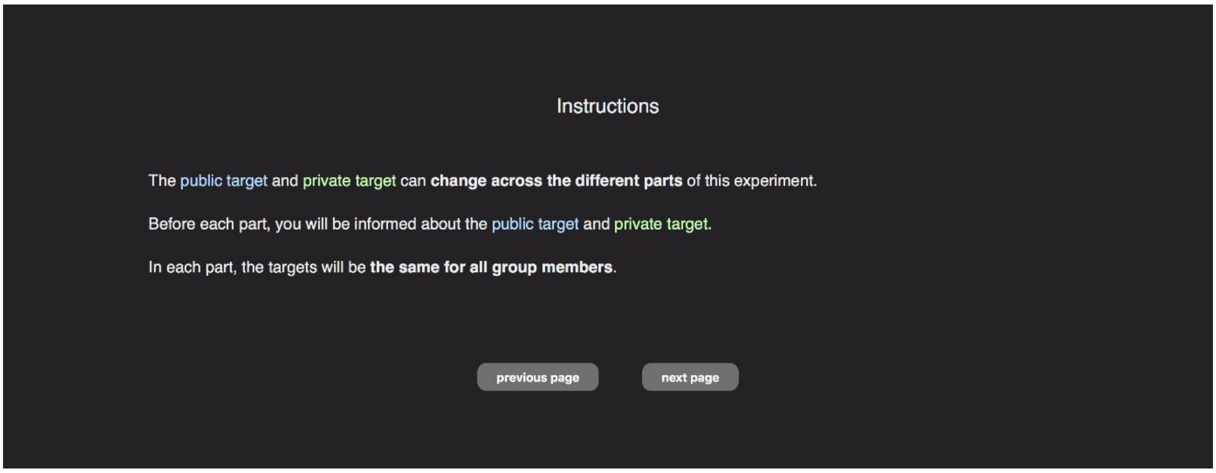


Fig. S4. Third instruction page.

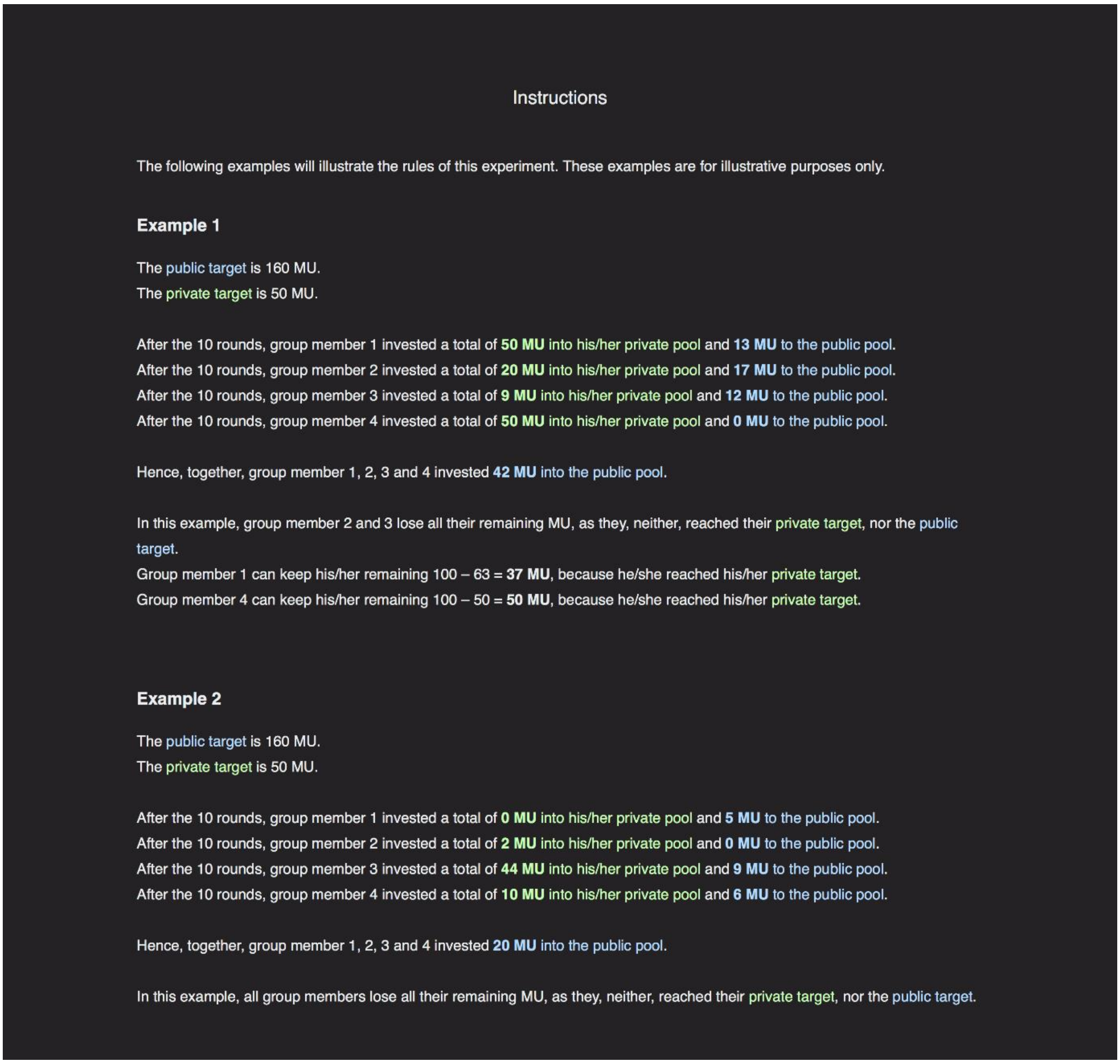


Fig. S5. Examples page.

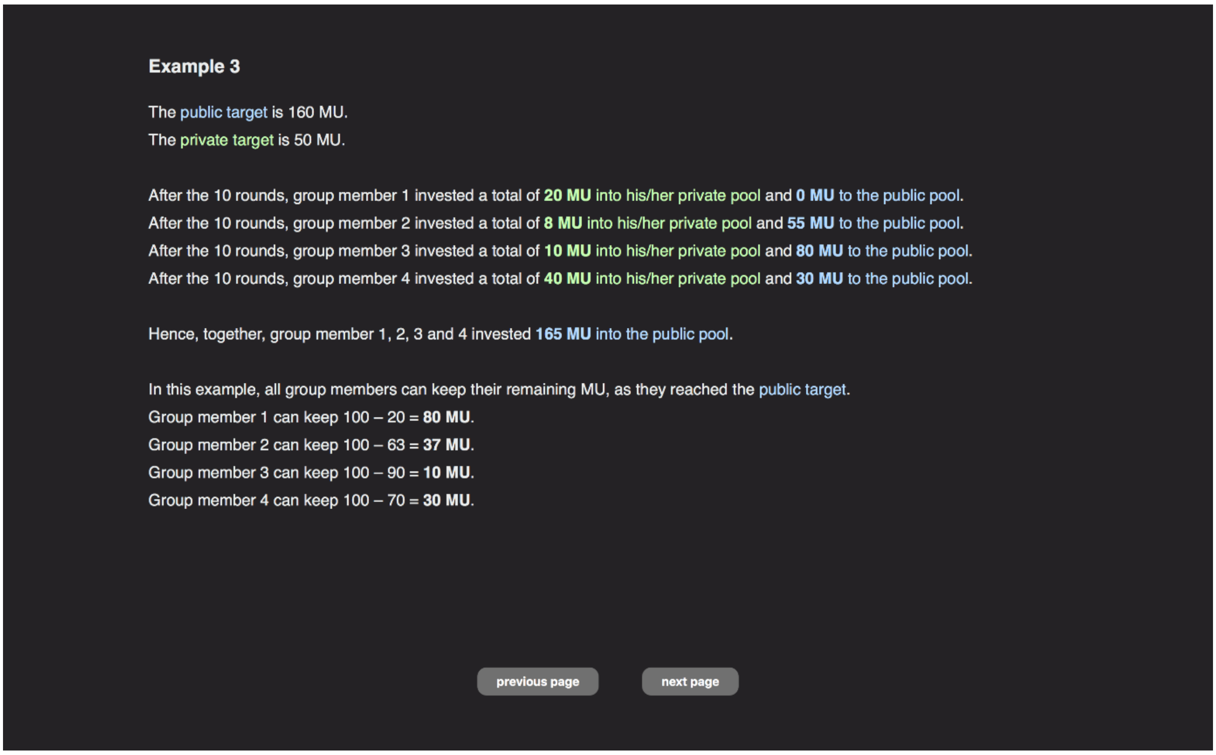


Fig. S6. Examples page (continued).

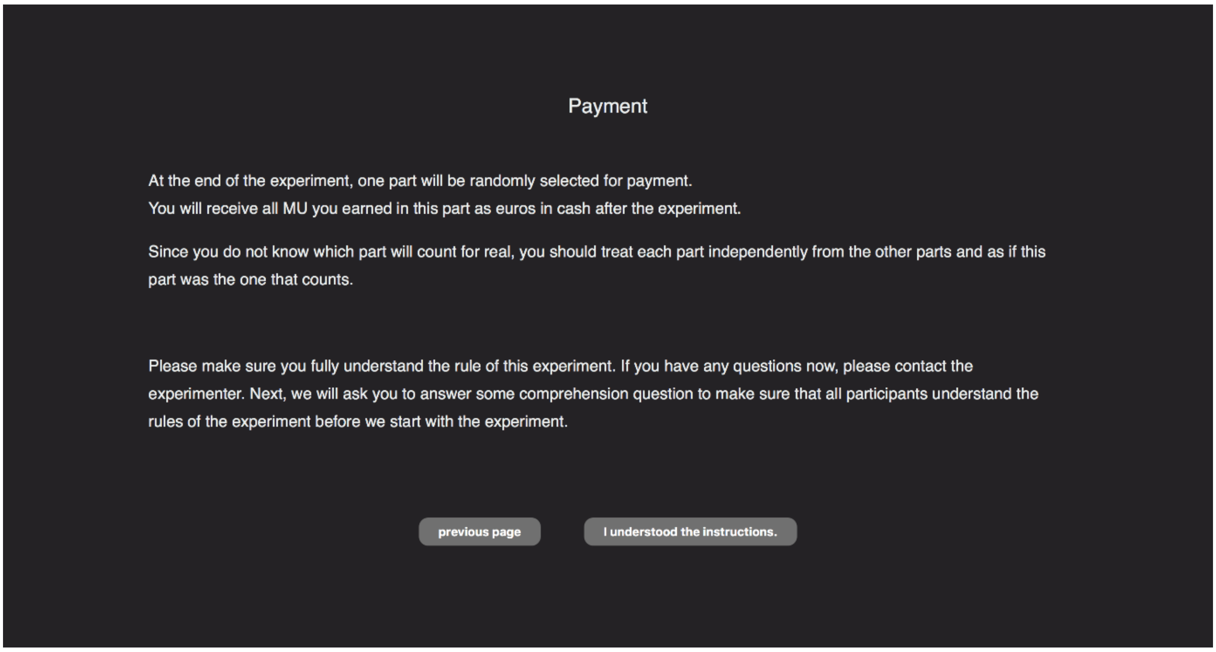
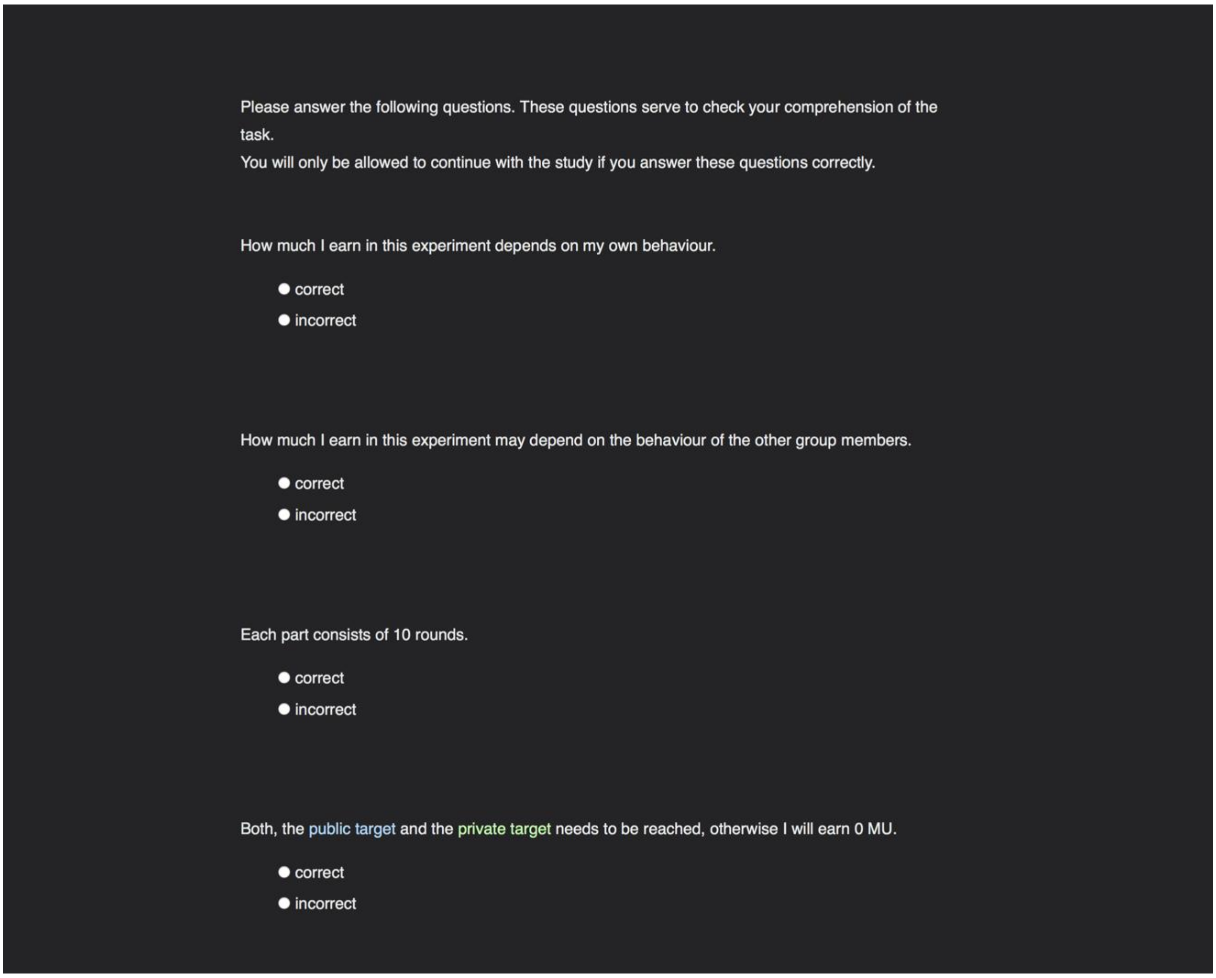


Fig. S7. Payment explanation.



Please answer the following questions. These questions serve to check your comprehension of the task.
You will only be allowed to continue with the study if you answer these questions correctly.

How much I earn in this experiment depends on my own behaviour.

- correct
- incorrect

How much I earn in this experiment may depend on the behaviour of the other group members.

- correct
- incorrect

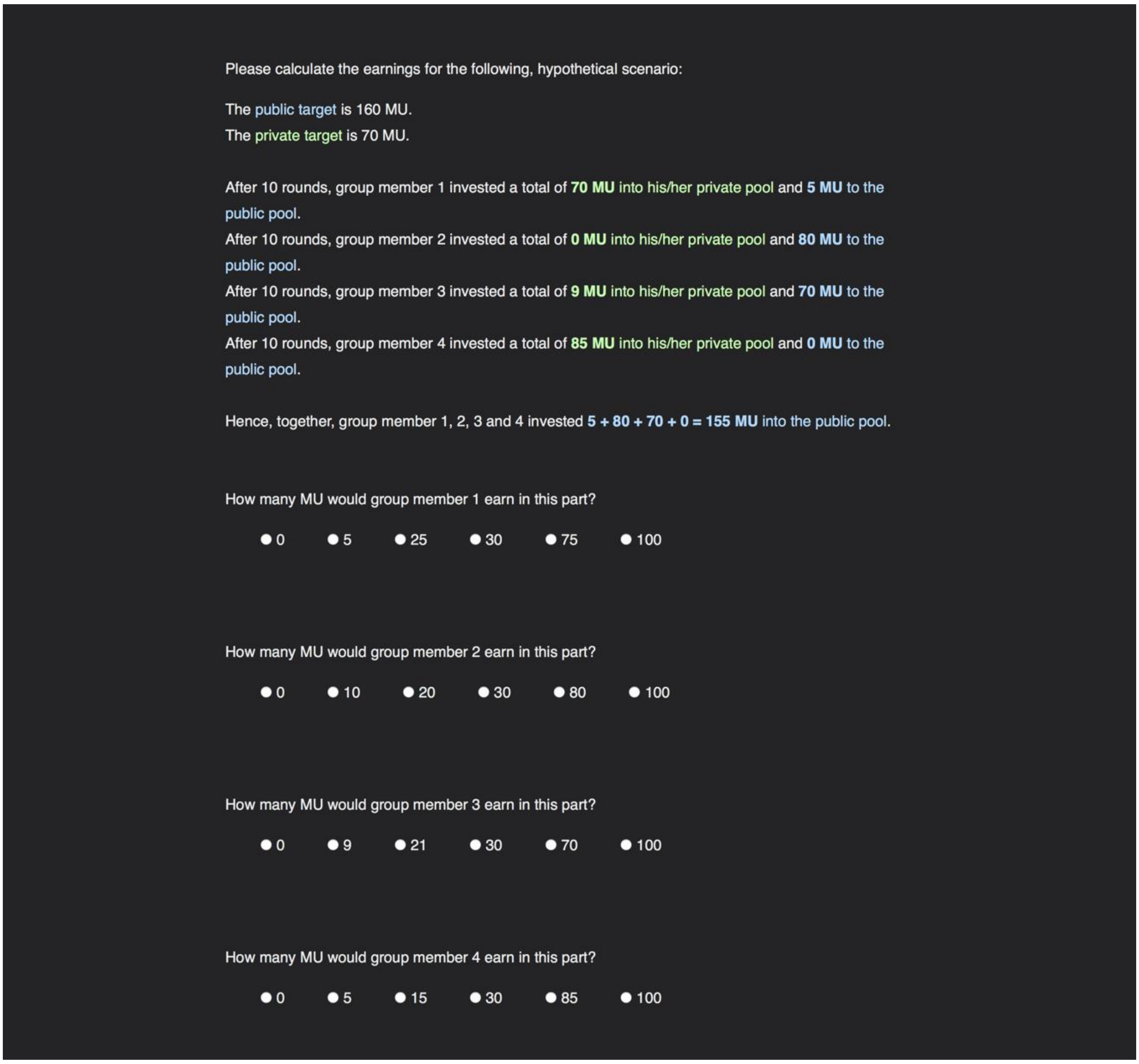
Each part consists of 10 rounds.

- correct
- incorrect

Both, the public target and the private target needs to be reached, otherwise I will earn 0 MU.

- correct
- incorrect

Fig. S8. Comprehension questions.



Please calculate the earnings for the following, hypothetical scenario:

The public target is 160 MU.
The private target is 70 MU.

After 10 rounds, group member 1 invested a total of **70 MU** into his/her private pool and **5 MU** to the public pool.
After 10 rounds, group member 2 invested a total of **0 MU** into his/her private pool and **80 MU** to the public pool.
After 10 rounds, group member 3 invested a total of **9 MU** into his/her private pool and **70 MU** to the public pool.
After 10 rounds, group member 4 invested a total of **85 MU** into his/her private pool and **0 MU** to the public pool.

Hence, together, group member 1, 2, 3 and 4 invested **5 + 80 + 70 + 0 = 155 MU** into the public pool.

How many MU would group member 1 earn in this part?

● 0 ● 5 ● 25 ● 30 ● 75 ● 100

How many MU would group member 2 earn in this part?

● 0 ● 10 ● 20 ● 30 ● 80 ● 100

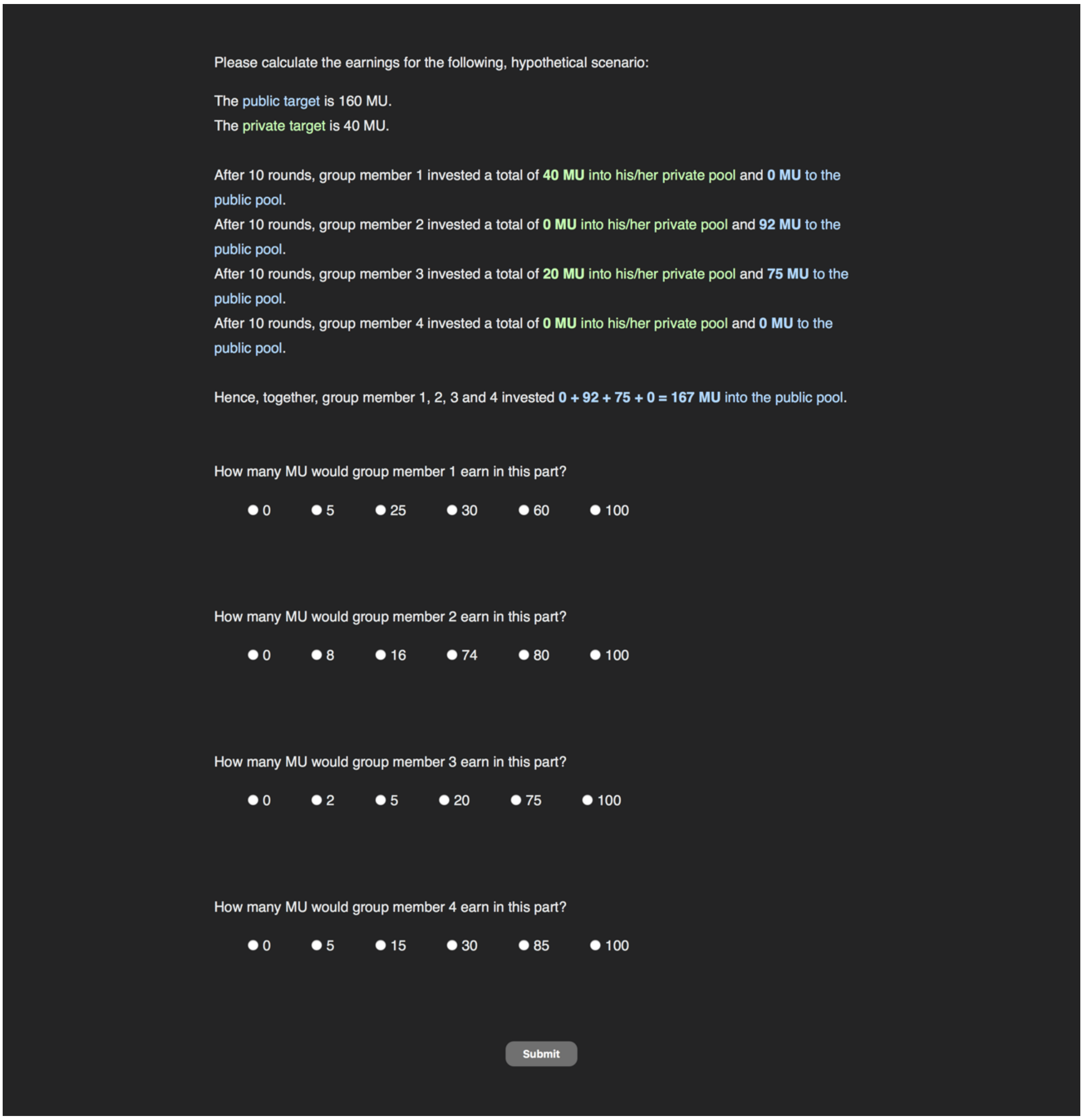
How many MU would group member 3 earn in this part?

● 0 ● 9 ● 21 ● 30 ● 70 ● 100

How many MU would group member 4 earn in this part?

● 0 ● 5 ● 15 ● 30 ● 85 ● 100

Fig. S9. Comprehension questions (continued).



Please calculate the earnings for the following, hypothetical scenario:

The public target is 160 MU.
The private target is 40 MU.

After 10 rounds, group member 1 invested a total of **40 MU** into his/her private pool and **0 MU** to the public pool.
After 10 rounds, group member 2 invested a total of **0 MU** into his/her private pool and **92 MU** to the public pool.
After 10 rounds, group member 3 invested a total of **20 MU** into his/her private pool and **75 MU** to the public pool.
After 10 rounds, group member 4 invested a total of **0 MU** into his/her private pool and **0 MU** to the public pool.

Hence, together, group member 1, 2, 3 and 4 invested **0 + 92 + 75 + 0 = 167 MU** into the public pool.

How many MU would group member 1 earn in this part?

● 0 ● 5 ● 25 ● 30 ● 60 ● 100

How many MU would group member 2 earn in this part?

● 0 ● 8 ● 16 ● 74 ● 80 ● 100

How many MU would group member 3 earn in this part?

● 0 ● 2 ● 5 ● 20 ● 75 ● 100

How many MU would group member 4 earn in this part?

● 0 ● 5 ● 15 ● 30 ● 85 ● 100

Submit

Fig. S10. Comprehension questions (continued).

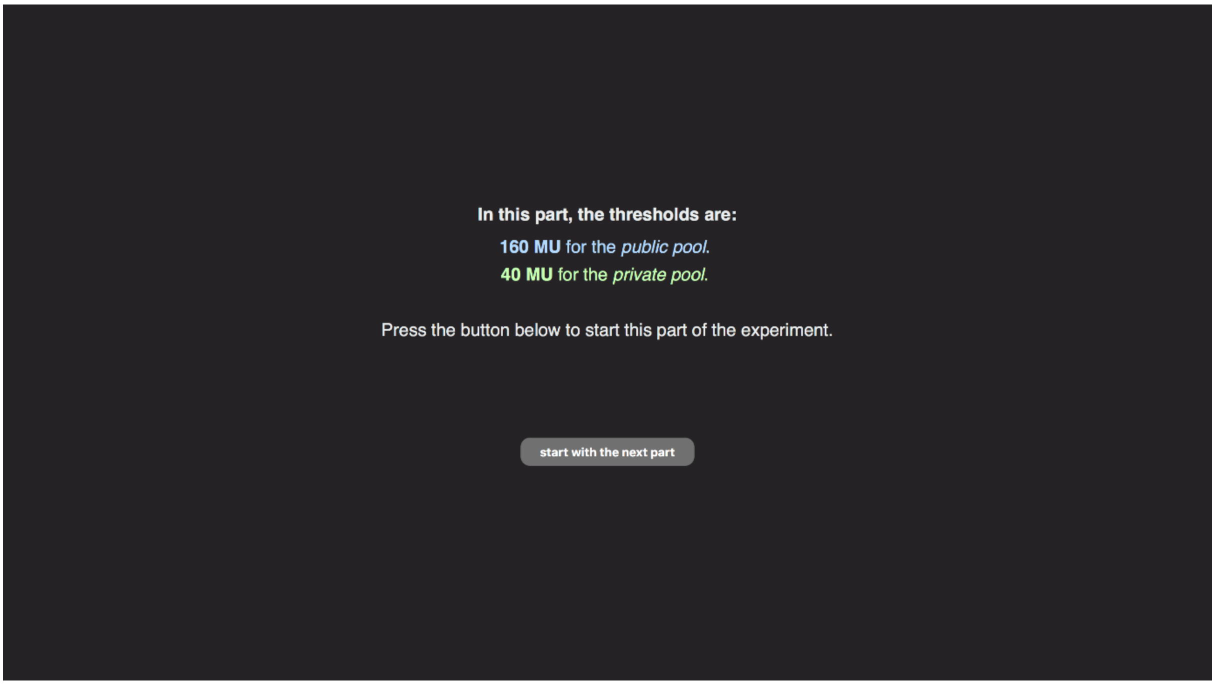


Fig. S11. Threshold announcement at the start of an experimental block.

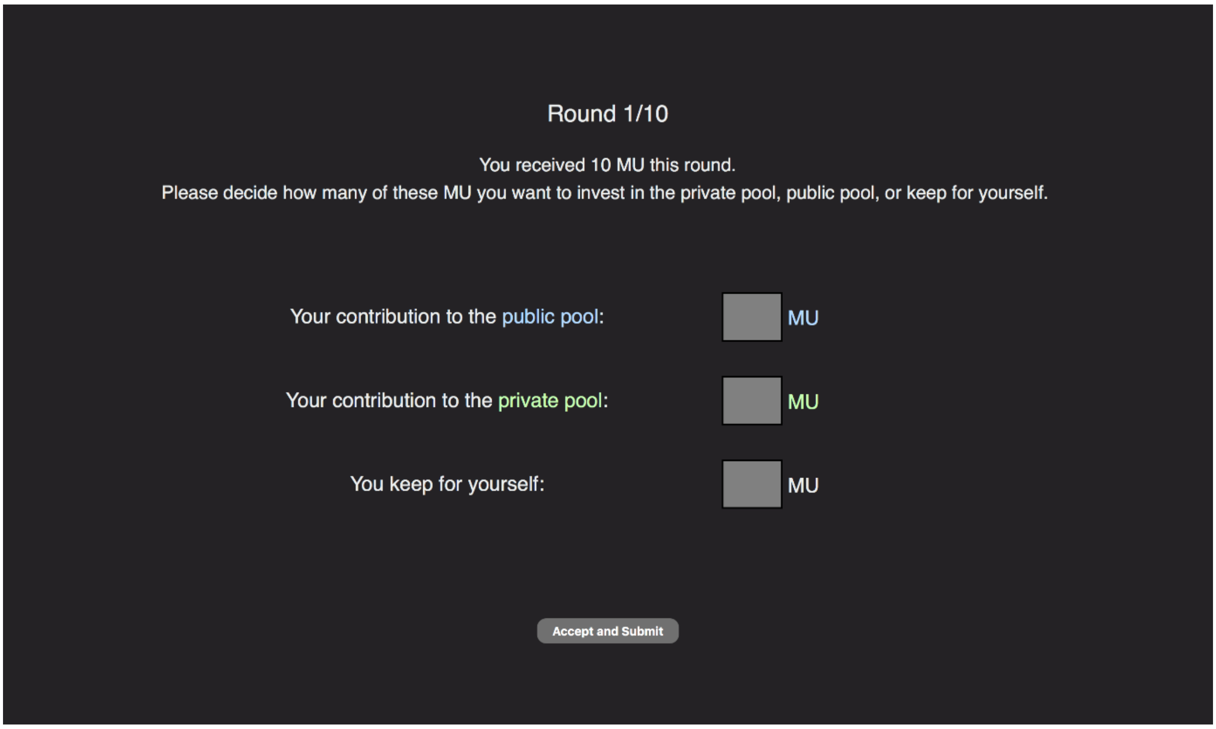


Fig. S12. Contribution stage.

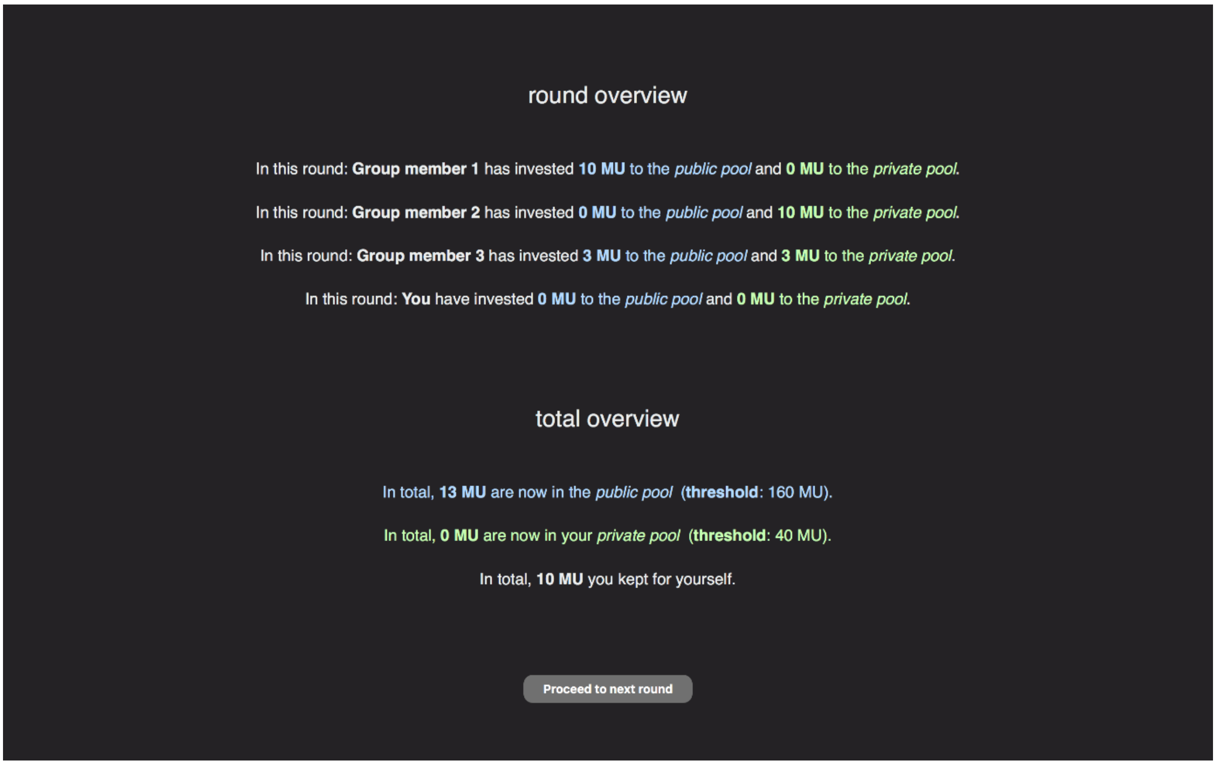


Fig. S13. Contribution feedback.

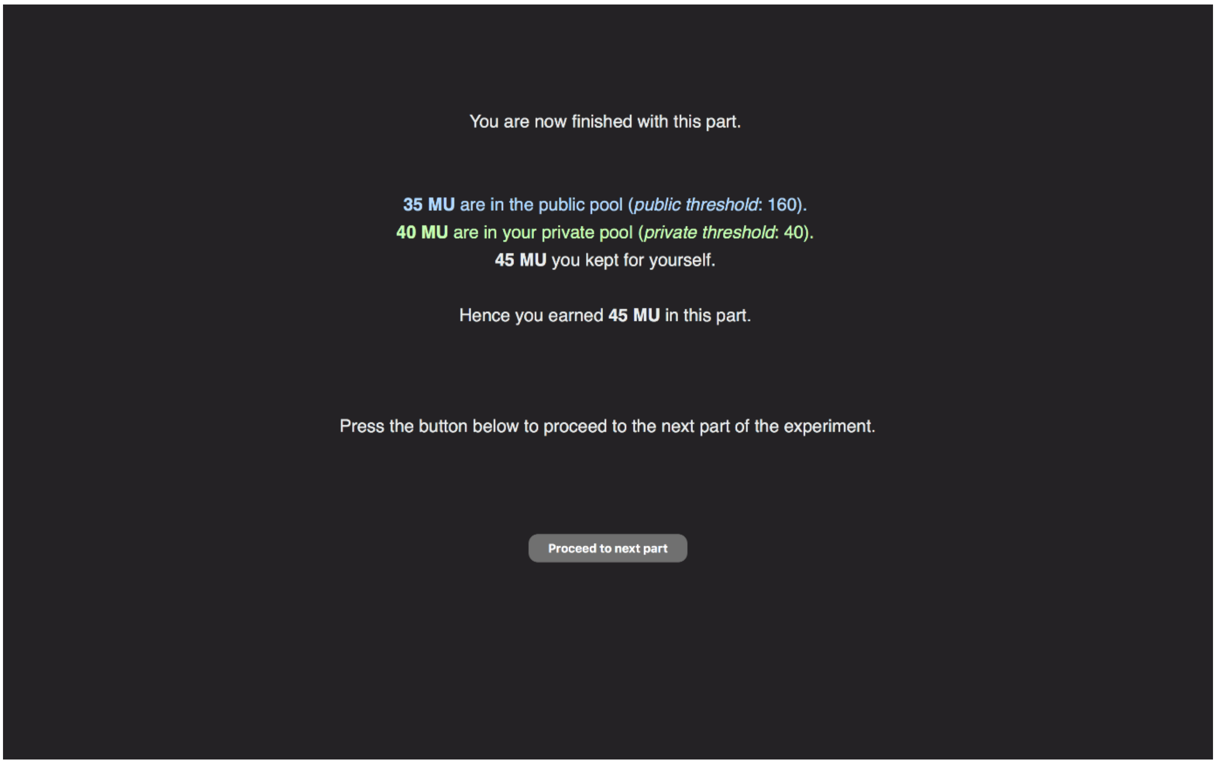


Fig. S14. Block feedback.

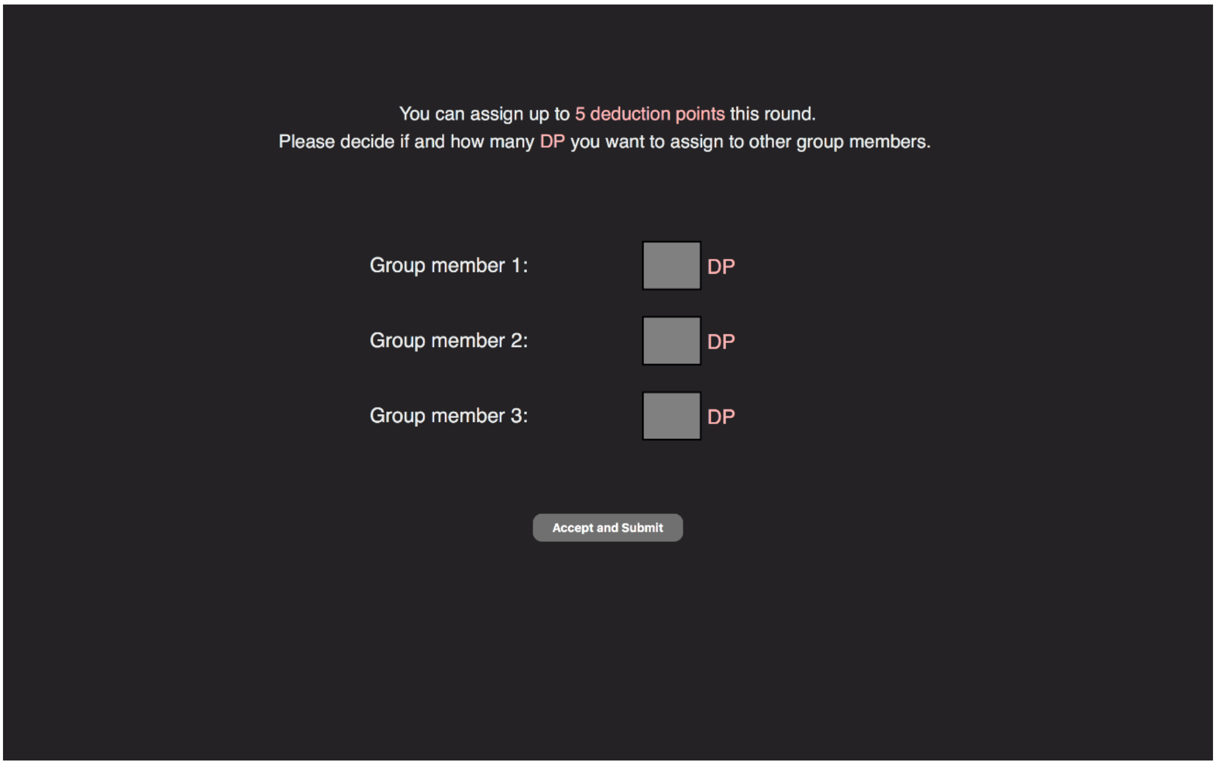


Fig. S15. Punishment stage.

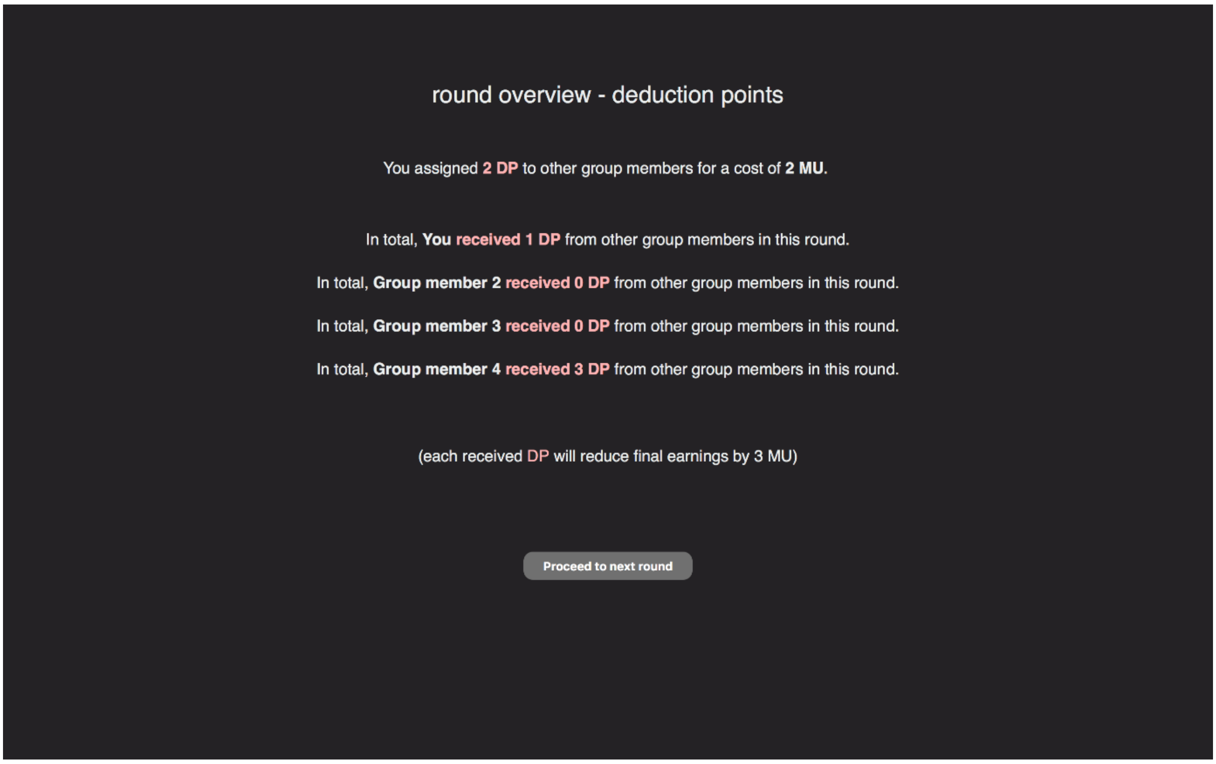


Fig. S16. Punishment feedback.

Statistical methods

Since data was clustered in groups and each participant made several decisions each block, data was treated as hierarchically structured and analyzed with random-effects regression models using the lme4 package in R and STAN.

For group-level variables, e.g. whether the group reached their public threshold, data was aggregated across interdependence levels for each group. When data was analyzed on the subject level, it was aggregated across rounds (if not otherwise noted below) and contained one random intercept for each group and one random intercept for each subject;

$$y_i \sim N\left(\mu_y, \sigma_y^2\right), \text{ for } i = 1, \ldots, n$$
$$\mu_y = \alpha_{1j} + \alpha_{2k} + \beta_1 x_1 \ldots$$

$$\alpha_{1j} \sim N(\mu_{\alpha_1}, \sigma_{\alpha_1}^2), \text{ for } j = 1, \ldots, J$$
$$\alpha_{2k} \sim N(\mu_{\alpha_2}, \sigma_{\alpha_2}^2), \text{ for } k = 1, \ldots, K$$

where n = number of observations,

J = number of groups,

K = number of subjects

Logistic random-effects regression models were used when the dependent variable was binary (e.g. group's public threshold met). In this case, the link function respectively changed to;

$$\mathrm{P}(y_i = 1) \sim logit^{-1}\left(\mu_y\right), \text{ for } i = 1, \ldots, n$$

When looking at (aggregated) group level data, the model simplified to a one random intercept regression for each group;

$$y_i \sim N\left(\mu_y, \sigma_y^2\right), \text{ for } i = 1, \ldots, n$$
$$\mu_y = \alpha_{1j} + \beta_1 x_1 \ldots$$
$$\alpha_{1j} \sim N(\mu_{\alpha_1}, \sigma_{\alpha_1}^2), \text{ for } j = 1, \ldots, J$$

where n = number of observations,

J = number of groups

Extended results

Figure S17 shows four prototypical patterns from four of our experimental groups. Figure S17A exemplifies the classic free-rider problem underlying the tragedy of the commons. While three participants contributed resources to the public pool, one group member did not contribute any of her resources and free-rode on the contributions of the fellow group members. Figure S17B-D demonstrate how individual solutions to shared problems can change the face of the classic tragedy. Figure S17B shows a case of lack of group-solidarity; One group member tried to solve the problem collectively, while the other group members chose to solve the problem on their own. Figure S17C shows a case of coordination failure; Participants partly solved the problem independently, while the group also spent considerable resources on the public solution without reaching the public threshold. Finally, fig. S17D shows a case of persistent individualism; While three group members worked together and solved the problem collectively, one group member chose to be independent of the group and solved the problem individually. Figures S26-S35 in the 'Group Dynamics' section below, show the resource allocation results of all groups in the experiment.

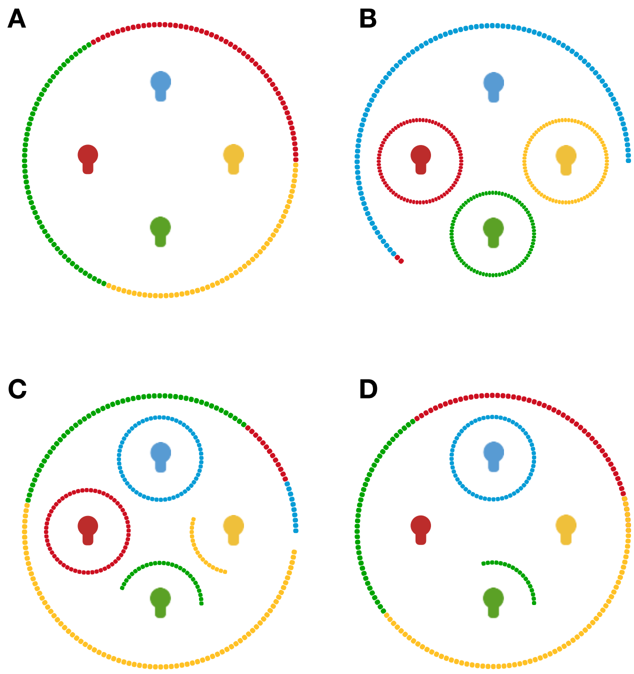


Fig. S17. Group dynamics. Prototypical resource allocation results in the experiment. Points around the stick-figure indicate resources invested to the individual pool. Points around the group indicate resources invested to the public pool. Colors indicate which participant contributed the resources. Exemplified is free-riding (**A**), lack of group support (**B**), coordination failure, due to investing resources in both the public and individual pool (**C**), and persistent individualism (**D**).

Collective vs. individual action. As predicted, the degree of interdependence *i* had a large influence on the allocation decisions of group members. In particular, individual solutions decreased significantly with increased costs for the individual solution c_i (table S1). Conversely, with higher interdependence, groups increasingly managed to coordinate collective action and solved the problem collectively (table S2).

Table S1. Individual action. Random-effects regression modeling the extent of individual action as a function of the cost for the individual solution.

	estimate	**SE**	**t**	**p**
intercept (c_i = 40)	1.71	0.13	12.88	< 0.001
cost c_i	-0.02	0.002	-10.20	< 0.001
random intercept variance	0.029			
error term y	0.086			

Table S2. Collective action. Random-effects logistic regression modeling the extent of collective action as a function of the cost for the individual solution.

	estimate	**SE**	**z**	**p**
intercept (c_i = 40)	-10.29	2.62	-3.92	< 0.001
cost c_i	0.18	0.04	4.05	< 0.001
random intercept variance	4.83			

Independence thresholds. Participants exhibited a strong preference for independence and were willing to pay a high premium to stay independent, even when the individual solution was much costlier compared to the collective solution. We calculated each individual's switching point (i.e. under which c_i a participant did not meet her individual target anymore) – shown in Fig. 2B in the main manuscript – and reported the average collective switching point of our experimental groups (i.e. under which c_i groups started to meet their public target). Figure S18 further shows each group's (left panel) and each subject's (right panel) pattern of collective vs. individual actions. Compared to the theoretical social optimum (switching to collective action when $i > 1$, lower panels), groups, on average, started to switch to collective action when $i > 1.7$. Subjects, on average, started to disengage from individual action when $i > 1.5$ (i.e. when individual actions were 50% more expensive than efficient collective action).

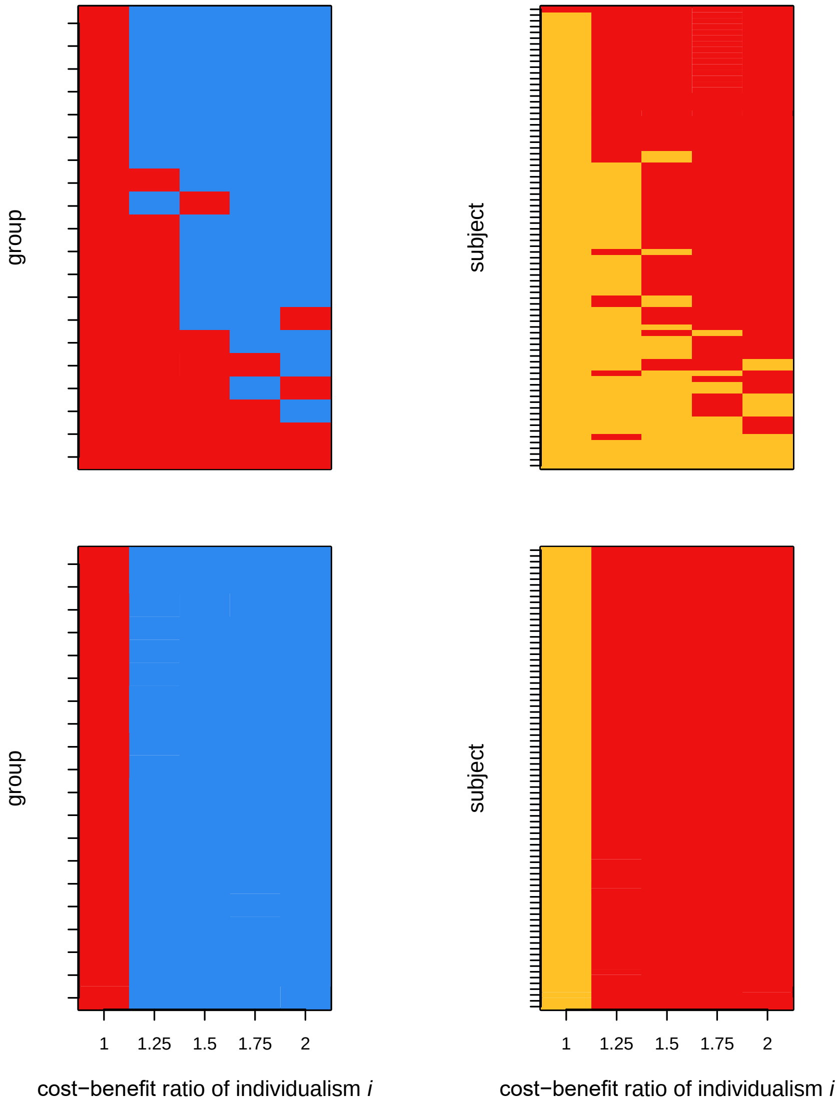


Fig. S18. Collective and individual action. Collective solutions and individual solutions observed empirically (upper panels) compared to the social optimum (lower panels). Each row represents one group (left panels) or subject (right panels). Blue (yellow) indicate whether a group (subject) reached their public (individual) threshold or not (red).

Group earnings. Providing individual solutions to shared problems not only give rise to individualism in social dilemmas but can also lead to coordination failure between collective and individual action and threaten social welfare (as exemplified in fig. S17C). As Fig. 2C in the main-manuscript and table S3 shows, group earnings and interdependence had a u-shape relationship. Groups efficiently coordinated on collective actions under high interdependence, when individual action was too costly ($i = 2$). When individual action was rather cheap ($i = 1$)

all of our participants preferred to solve the problem individually. However, when faced with intermediary dependence (e.g. i = 1.5), some group members engaged in individual action, while others attempted to solve the problem collectively, leading to lower group earnings (table S3).

Table S3. Earnings. Random-effects regression modeling earnings as a function of the cost for the individual solution and its second polynomial.

	estimate	**SE**	**t**	**p**
intercept (c_i = 40)	46.94	2.05	22.95	< 0.001
cost c_i	-16.94	15.31	-1.11	0.27
cost c_i × cost c_i	47.42	15.31	3.10	0.002
random intercept variance α_1	53.91			
random intercept variance α_2	72.18			
error term y	234.38			

Strategy compositions. Participants faced with the (in)dependence commons dilemma can follow different strategies. They can choose to be independent of the group and invest their resources in their individual pool, they can invest their fair share to the collective solution (160/n), or they can invest more than their fair-share if they are afraid that the group will not meet the public target. Further, they can attempt to free-ride on the cooperative efforts of others by investing less than the fair share and let others solve the problem for them. Accordingly, we labelled these strategies individualistic (meeting the own individual target), cooperative (contributing exactly 160/n to the public pool), altruistic (contributing more than 160/n to the public pool), and free-riding (contributing less than 160/n and simultaneously not meeting the own individual target). Note that these classifications are not exclusive. A participant is free to allocate her resources both to the individual and public pool and could, theoretically, meet her individual target and contribute to the public target, for example. In that case, she would be classified as an altruistic or cooperative individualist. In practice only two participants were classified as cooperative individualists and two participants as altruistic individualists (1% of all cases) and individual and public contributions were highly negatively correlated (r = -0.76).

The strategies of participants were strongly influenced by the level of co-dependence. To analyze how strategies shifted across the levels of co-dependence, we fitted a Bayesian multinomial logistic regression using STAN. We used 4 chains, 2000 iterations (discarding the first 1000 iterations), and non-informative gaussian priors (m=0, sd=8) for the predictors. The Gelman-Rubin statistic was 1.00 for all parameters, indicating good mixing of the chains and high convergence. We also compared a model including co-dependence as a predictor with a null-model that only included an intercept with the Bayes factor. The Bayes factor was > 100, indicating that the model that includes co-dependence as a predictor should be favored over the null-model that is omitting co-dependence to explain strategies.

Table S4 shows the results. As the base category, we chose the individualistic strategy. Hence, coefficients should be interpreted relative to the individualistic strategy (concretely, change in odds of the dependent variable being a particular strategy, given the odds of the dependent variable being the base-category). A more convenient way to interpret the relationship between the level of co-dependence and the likelihood for a given strategy is to visualize the predicted probabilities. As can be seen in fig. S19, individualistic strategies systematically increase with decreased co-dependence, while cooperative, altruistic, and free-riding strategies decrease with lower co-dependence.

Table S4. Group-level transitions of strategies. Random-effects multinomial logistic regression modeling strategies as a function of the cost for the individual solution. Base category = individualistic strategy. Numbers in brackets show the 95% (Bayesian) confidence interval of the estimates.

	individualistic vs. altruistic	**individualistic vs. cooperative**	**individualistic vs. free-riding**
intercept ($c_i = 40$)	-11.73 [-15.05, -8.85]	-16.61 [-21.70, -12.21]	-15.74 [-19.86, -11.99]
cost c_i	0.19 [0.14, 0.24]	0.22 [0.16, 0.29]	0.23 [0.17, 0.29]
random intercept variance α_1	2.60	2.69	2.73
random intercept variance α_2	0.56	1.59	2.19

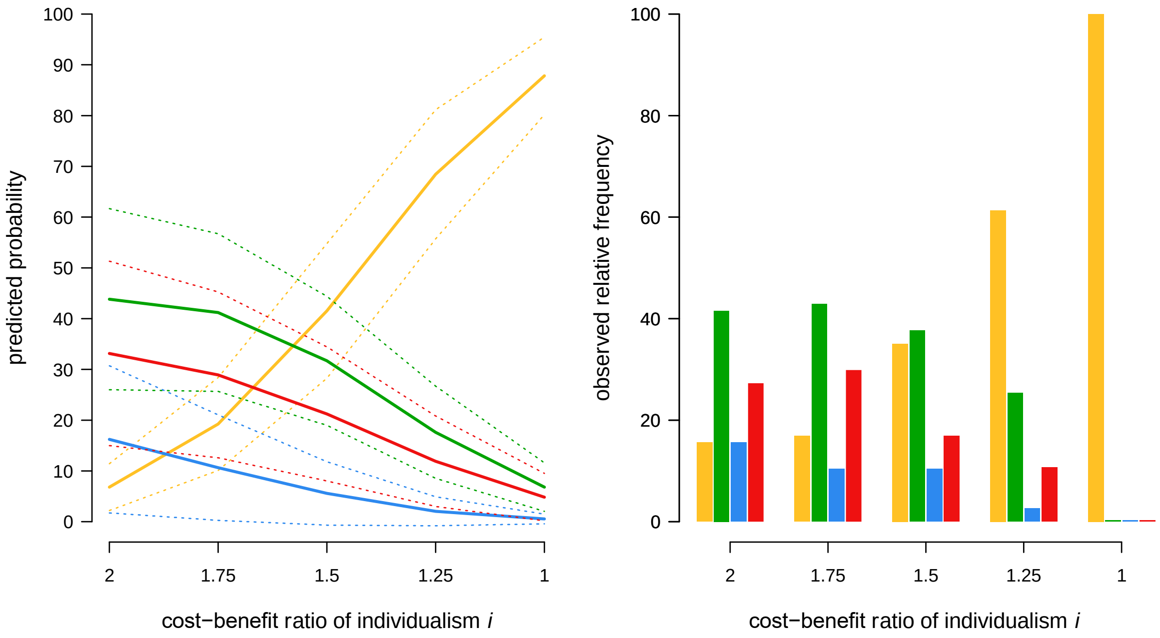


Fig. S19. Transitions of strategies. Predicted probability to follow a particular strategy (left) and observed relative frequencies in the experiment (right) across the cost-benefit ratio of individualism (yellow = individualistic strategy, green = altruistic strategy, blue = cooperative strategy, red = freeriding strategy). Bandwidth shows the estimated standard error.

Within-subject strategy shifts. In the cooperation literature, individualism has often been used synonymously with selfishness (*7, 35–37*). However, in classic social dilemmas, participants are forced to interact with each other and their payoff are dependent on their own actions as well as the actions of others. A notable exception is the literature on 'loners' (*15, 21, 38–47)*, in which agents or participants can choose to exit an interaction to receive a fixed payoff that is not influenced by the action of others. Our setup allows us to test how participants coordinate collective actions when faced with a shared problem that can be solved individually. Importantly, it also allows us to test if and when people who choose cooperative or free-riding strategies under high co-dependence (resembling the classic dilemma) switch to individualistic strategies when co-dependence decreases.

To analyze whether free-riders or cooperators differentially switch to individualistic strategies, we calculated the empirical Markov-chain transition probabilities of subjects when moving from high to low co-dependence. In the main manuscript, we show the transition probabilities for all binary transition states (from high to low *i*). Table S5 shows the average transition probabilities across all co-dependence levels. Note that we find fairly little free-riding across the independence levels (on average 20% of the contribution strategies were classified as free-riding strategies in the baseline treatment), which can be attributed to the fact that free-riding was risky in our game. While a free-riding strategy leads to the highest potential payoff (since by our definition, free-riding means contributing less than 40 to the public pool, which is lower than the fair share, needed to meet the public threshold, and lower than any of the individual thresholds) it can also lead to losing all remaining monetary units. Importantly, people who followed a cooperative compared to a free-riding strategy were not significantly more likely to switch to individualism ($t = 0.79$, $p = 0.43$). Likewise, people who followed an individualistic strategy were not significantly more likely to switch to cooperation vs. free-riding ($t = 1.73$, $p = 0.12$). Hence, it was not possible to predict whether a certain type under high co-dependence ('classic dilemma') would switch to individualism ('modern dilemma') and vice versa. These results suggest that individualism cannot simply be equated to selfishness but rather point to the possibility that individualism constitute a, so far largely neglected, social preference that transforms collective action and carries important implications for modern public goods problems and group welfare (as shown above).

Table S5. Within-subject transitions of strategies. Transition probabilities of individual strategies when going from high to low codependence based on Markov chain maximum likelihood estimations. Numbers in parenthesis show the 95% confidence interval.

	cooperation	**free-riding**	**individualism**
cooperation	0.50 [0.46,0.55]	0.15 [0.12,0.17]	0.35 [0.31,0.39]
free-riding	0.29 [0.25,0.34]	0.33 [0.28,0.38]	0.38 [0.33,0.43]
individualism	0.06 [0.04, 0.08]	0.09 [0.07, 0.11]	0.85 [0.78, 0.92]

Note. cooperative and altruistic strategies were collapsed which allows to compare the transition from individualism to cooperation and free-riding directly.

Peer punishment. Introducing peer punishment increased the propensity to solve problems collectively (table S6). At the same time, while peer punishment successfully decreases free-riding in classic public goods and collective action problems (*9, 12, 13, 48*), this was not true in the (in)dependence dilemma (table S7).

Table S6. Collective action under peer punishment. Random-effects logistic regression modeling the extent of collective action depending on the presence of peer punishment.

	estimate	SE	z	p
intercept (c_i = 40, baseline)	-10.35	1.89	-5.5	< 0.001
cost c_i	0.18	0.03	5.7	< 0.001
condition (1 = punishment)	1.60	0.78	2.1	0.04
random intercept variance	3.41			

Table S7. Free riding under peer punishment. Random-effects logistic regression modeling the extent of free riding depending on the presence of peer punishment.

	estimate	SE	z	p
intercept (c_i = 40, baseline)	-7.30	1.01	-7.2	< 0.001
cost c_i	0.08	0.01	5.6	< 0.001
condition (1 = punishment)	0.32	1.30	0.3	0.80
condition × cost c_i	-0.004	0.02	-0.19	0.85
random intercept variance α_1	< 0.01			
random intercept variance α_2	2.73			

To understand why, we analyzed at whom punishment was directed to. Figure S20 shows the average received punishment depending on the resource allocation strategy, defined above. As can be seen, individualists were punished the most, and significantly more than other types. Regressing the total received punishment on the resource allocation decisions of participants (average resource points invested into the individual pool, public pool, or kept for oneself), revealed that the more a participant invested resource points to their individual pool, the more punishment points they received from other group members. Importantly, keeping resource points for oneself was not significantly punished more than contributing resource points to the public pool (table S8).

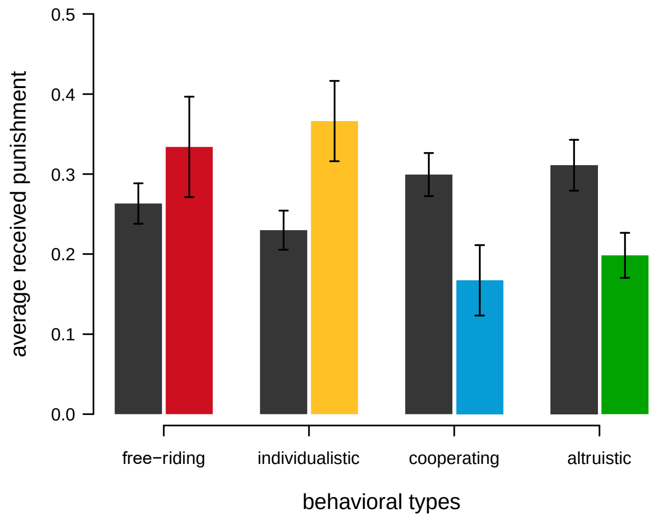


Fig. S20. Average received punishment. Average received punishment, depending on the resource allocation strategy. Grey bars indicate average punishment if *not* of this type (e.g. green bar = average punishment received by participants contributing more than the fair share, dark-grey bar = average punishment received by any other strategy type). Error bars indicate the standard error of the mean.

Table S8. Received punishment. Random-effects regression modeling received punishment as a function of the resource allocation decisions.

	estimate	**SE**	**t**	**p**
Intercept (public pool)	0.12	0.11	1.1	0.29
individual pool	0.04	0.01	3.8	< 0.001
kept units	0.02	0.02	0.9	0.38
random intercept variance α_1	0.06			
random intercept variance α_2	0.00			
error term y	0.16			

Punisher. Figure S21 shows the average punishment dealt in the (in)dependence dilemma (collapsed across dependence levels) depending on behavioral type. Altruists, those who contributed more than 160/n, punished the most, followed by individualists and free-riders. Interestingly, cooperators, those who contributed exactly 160/n, punished the least (the share of cooperators also significantly increased compared to baseline-groups without punishment opportunity, see Fig. 4B in the main manuscript).

More generally, the more a participant invested into either public or individual pool, the more the participant spent resources on punishment (table S9) – both individualists and collectivists were willing to punish.

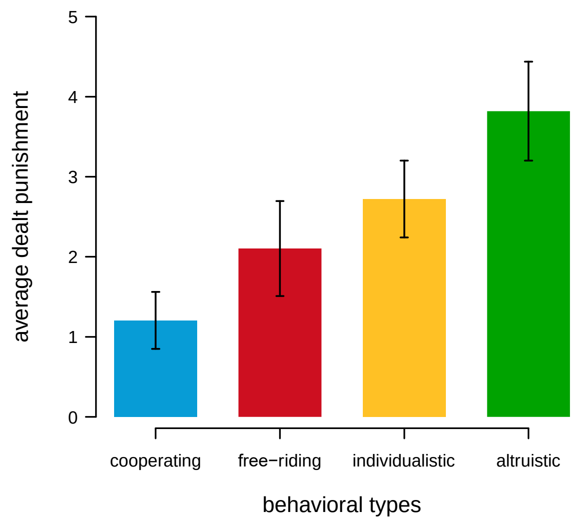


Fig. S21. Average dealt punishment. Average dealt punishment across the game depending on the resource allocation strategy (error bars indicate the SEM).

Table S9. Dealt punishment. Random-effects regression modeling dealt punishment as a function of the own resource allocation decisions.

	estimate	**SE**	**t**	**p**
Intercept (kept units)	-0.089	0.051	-1.8	0.08
own public pool contribution	0.036	0.010	3.5	< 0.001
own individual pool contribution	0.034	0.009	4.0	< 0.001
random intercept variance α_1	0.002			
random intercept variance α_2	0.006			
error term y	0.027			

Figure 4C in the main manuscript shows that the most punishment was dealt by altruists (those who contributed more than their fair share) aimed at individualists (those who chose individual action over collective action). Table S10 shows the dealt punishment pattern of altruists and individualists in more detail. In particular, the more a participant contributed to the public pool (compared to keeping the units), the less punishment they received from altruists (b = -0.03, n.s.). On the flipside, the more a participant contributed to her individual pool (compared to keeping the units), the more punishment they received from altruists (b = 0.05). Individualists, on the other hand, dealt significantly more punishment to participants who contributed to the public pool (compared to altruists, b = 0.05) and punished those participants who contributed to their individual pool significantly less (compared to altruist, b = -0.05).

Hence, altruists and individualists had contrary punishment patterns; They, not surprisingly, assigned less punishment to participants who acted like themselves. Instead, they aimed their punishment at those who invested in the opposite pool (altruists targeting individualists and vice versa). Importantly, the regression coefficients in table S10 should be interpreted relative to the resources that a participant kept for themselves; For example, for every resource point a participant assigned to the individual pool *instead of keeping the unit*, an altruist's average expenditure to punish such behavior increased by b = 0.05.

Table S10. Dealt punishment by altruists and individualists. Random-effects regression modeling dealt punishment by altruists and individualists based on the resource allocation decisions of the target.

	estimate	**SE**	**t**	**p**
Intercept (altruist, kept units)	0.18	0.09	1.9	0.05
public pool contribution of target	-0.03	0.02	-1.5	0.15
individual pool contribution of target	0.05	0.01	4.8	< 0.001
Individualist (kept units)	-0.13	0.13	-1.0	0.30
individualist × public pool	0.05	0.03	2.0	0.04
individualist × individual pool	-0.05	0.02	-2.4	0.02
random intercept variance α_1	0.002			
random intercept variance α_2	0.01			
error term y	0.03			

Punishment and group welfare. Compared to the baseline condition, punishment significantly decreased earnings of group members (fig. S22). Across dependence levels, subjects earned 9.2 points less compared to the baseline condition. There was no significant change in the pattern of earnings across dependence levels (table S11).

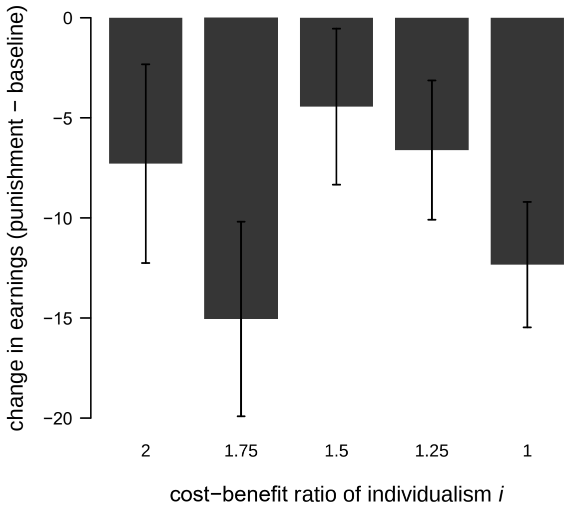


Fig. S22. Average change in earnings. Average change in earnings between punishment and baseline conditions across dependence levels (error bars indicate the SEM).

Table S11. Earnings across baseline and punishment. Random-effects regression modeling earnings as a function of the cost for the individual solution and its second polynomial in the baseline condition in comparison to the punishment condition.

	estimate	**SE**	**t**	**p**
intercept (baseline, $c_i = 40$)	46.94	3.03	15.51	< 0.001
cost c_i	-23.95	25.40	-0.94	0.35
cost c_i × cost c_i	67.06	25.40	2.64	0.008
punishment condition	-9.15	4.28	-2.14	0.039
punishment × cost c_i	6.65	35.92	0.19	0.85
punishment × cost c_i × cost c_i	-29.45	35.92	-0.82	0.41
random intercept variance α_1	160.14			
random intercept variance α_2	27.52			
error term y	322.48			

Additional results

Figure S23 shows the cumulative resource allocations for each treatment. As can be seen, higher interdependence increased contributions to the public pool and decreased contributions to the individual pool. Introducing punishment increased public contributions across dependence levels and decreased cumulative contributions to the individual pool.

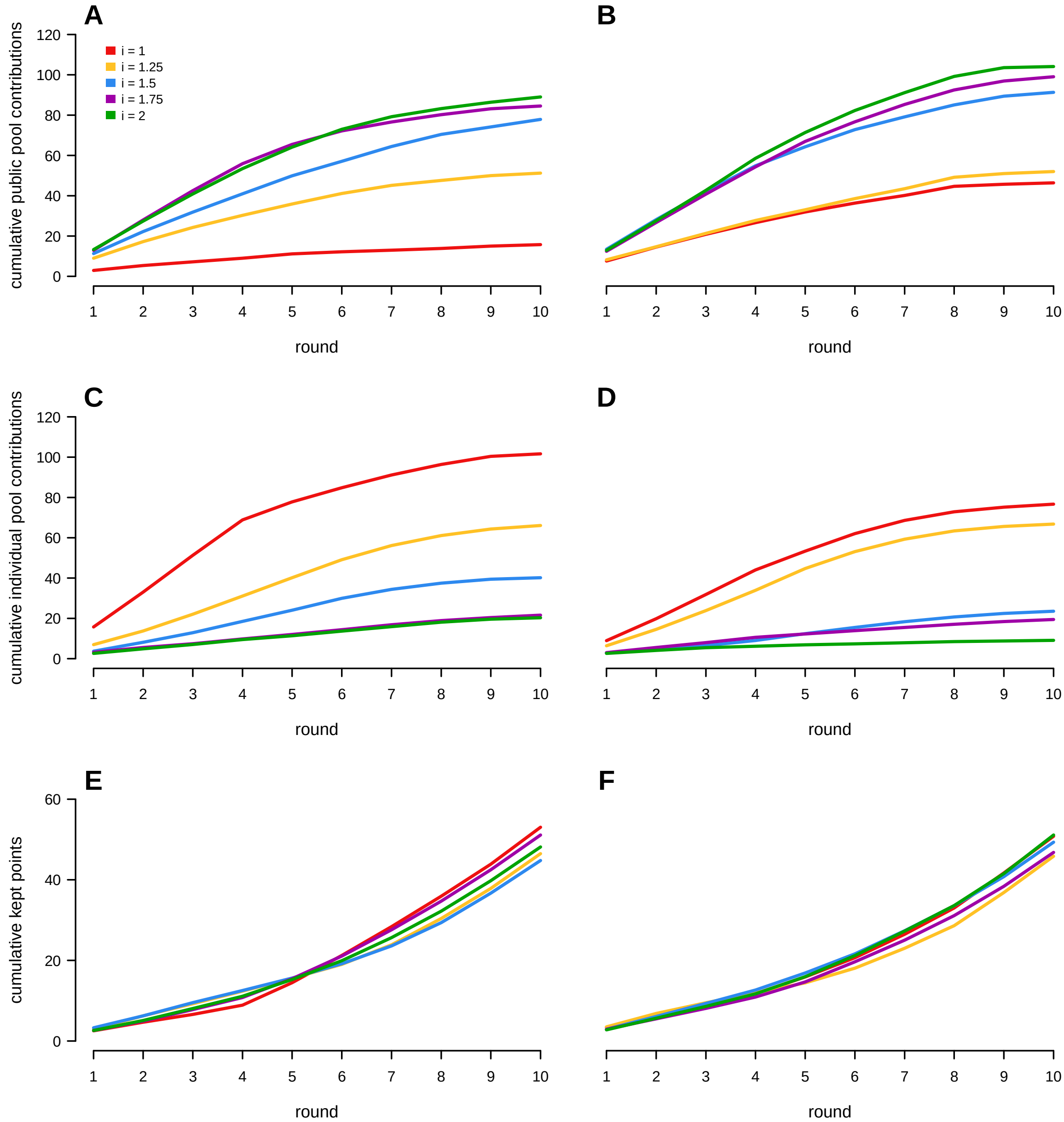


Fig. S23. Cumulative contributions across time. Average cumulated resources invested into the public pool (as a percentage of the public threshold) in the baseline treatment (**A**) and punishment treatment (**B**), average cumulated resources invested into the individual pool (as a percentage of the individual threshold) in the baseline treatment (**C**) and punishment treatment (**D**) and average kept units in the baseline treatment (**E**) and punishment treatment (**F**). Colors indicate the different dependence level.

Earning inequality. Peer punishment decreased the variance across dependence levels in the amount of points kept for oneself on the group level (fig. S23E-F). However, this was not true for within-group earnings. Across dependence levels, average group earnings varied by SD = 11.3 resource points in the baseline condition, while the manipulation of interdependence in the punishment condition led to earnings fluctuations of SD = 15.7 resource points across dependence levels (t-test, $t(32) = 2.1$, $p = 0.04$). The introduction of peer punishment also did not significantly decrease earnings inequality within groups (fig. S24 and table S12).

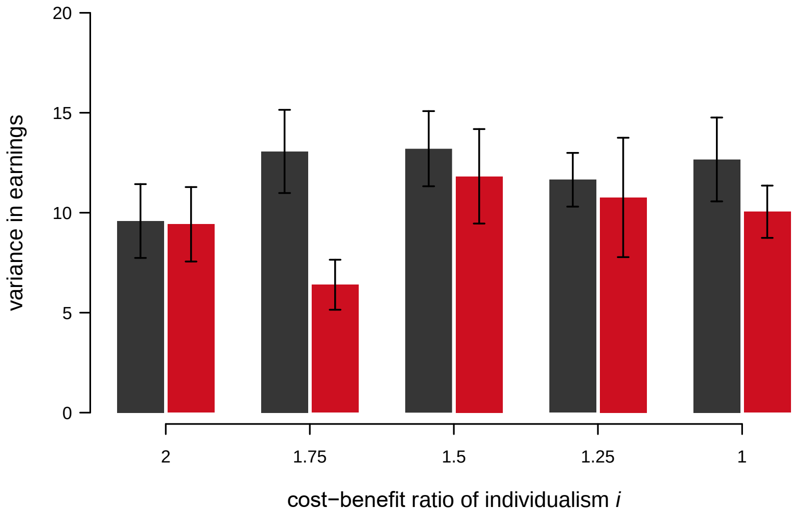


Fig. S24. Inequality in earnings. Inequality in earnings (measured by the within-group variance) across codependence levels and conditions (gray, baseline; red, punishment).

Table S12. Earnings inequality across baseline and punishment. Random-effects regression modeling within-group variance in earnings (earnings inequality) as a function of the cost for the individual solution in the baseline condition in comparison to the punishment condition.

	estimate	**SE**	**t**	**p**
intercept (baseline, $c_i = 40$)	9.19	3.43	2.7	0.01
cost c_i	-2.87	4.85	-0.6	0.55
punishment condition	0.05	0.05	0.9	0.37
punishment × cost c_i	0.01	0.07	0.1	0.91
random intercept variance α_1	21.37			
error term y	56.39			

Dynamics across rounds. To further understand how groups coordinated collective action or chose independent solutions, we fitted lagged random effects regressions to the unaggregated data in the baseline treatment before a participant or a group reached the individual or public target. Since data was clustered not only in groups and subjects, but also entailed repeated measures over time, we added a random slope for each subject across rounds to the model and one random intercept for each block. Since decisions of subjects across rounds (within one block) were correlated (mean $r_{public} = 0.67$; mean $r_{individual} = 0.74$), the assumption that the highest-order error-term ε_{yi} is independent across observations on the subject × round level is violated. We therefore allowed the error-term of round t to be correlated with the error-term of round t-r (where r refers to the number of rounds) for each subject (within one block), by estimating a random effects first-order autoregressive model (AR(1)), that models *y* at time t as a linear function of the value of *y* at time t-r, relaxing the assumption that the error-term ε_{it} is uncorrelated with ε_{it-1}. We further allowed the variance to differ across rounds to relax the assumption of variance homogeneity across rounds.

Resource allocation decisions were highly contingent on past behavior, and, unsurprisingly, also on the behavior of other group members. We first regressed the decision to contribute to the public pool on the decisions of other group members from round t-1 to t-6 to see how own contribution decisions were affected by the other group members. As can be seen in column 1 of table S13, the decision to contribute to the public pool was predicted by the public contributions of others in round t-1, t-2, and t-3. Participants contributed less to the public pool, the more others contributed to the public pool, revealing the free-riding dilemma of the public solution: The more others invested to the public pool, the lower the incentive of the decision maker to invest her resources into the public pool. Conversely, and as can be seen in column 1 of table S14, participants increased the contribution to their individual pool, the more other group members invested to their respective individual pools in round t-1, revealing that solving the problem individually was socially contagious to some degree.

In a second step, we controlled for the past decisions of the decision-maker in the regression. Public contributions in round t were predicted by public contributions in the previous rounds (table S13, column 2). Similarly, contributions to the individual pool in round t were predicted by the individual pool contributions in round t-1 (table S14, column 2). Hence, participants also showed some consistency in their investment decisions, independent of the decisions of other group-members.

In the last step, we wanted to know how social influence and own investment decisions in the past round interacted. For that, we introduced first-order interaction terms between the decisions of other group members and the own contribution decisions in round t-1 (table S13/S14, column 3) and round t-2 (table S13/S14, column 4).

Participants invested more to the public pool, the more other group members invested into their individual pool in round t-1 and the more the decision maker invested to the public pool in round t-1 (public t-1 × individual others t-1; table S13, column 3 and 4). Hence, participants willing to cooperate in round t-1 increased their cooperation when other group members went for their individual solution.

Conversely, participants invested more to their individual pool, the more other group members invested to the public pool and the more the decision maker invested to her individual pool in round t-1 (individual t-1 × public others t-1; table S14, column 3 and 4).

Taken together, these patterns resonate with the notion of two opposing and conflicting strategies; ‘Collectivists’ increase their public contributions as a response to individual-pool allocations of others, willing to compensate for others’ ‘individualism’, while ‘individualists’ increase their contributions to their individual pool, even when others contribute to the public pool.

Table S13. Public pool contributions based on past round behavior. Lagged random-effects regressions modeling the decision to contribute to the public pool based on past round behavior of oneself and other group members in the baseline condition (SEs in parentheses).

	(1)	(2)	(3)	(4)
intercept (c_i = 40)	**-10.133****	2.104	2.582	2.338
	(3.581)	(2.475)	(2.367)	(2.340)
public contr. – others t-1	**-0.125****	**-0.059****	**-0.077****	**-0.079****
	(0.013)	**(0.013)**	**(0.015)**	**(0.015)**
public contr. – others t-2	**-0.072****	0.014	0.017	0.028
	(0.012)	(0.013)	(0.013)	(0.016)
public contr. – others t-3	**-0.042****	-0.001	-0.004	-0.014
	(0.012)	(0.013)	(0.012)	(0.012)
public contr. – others t-4	-0.001	**0.027***	0.022	0.024
	(0.012)	**(0.013)**	(0.013)	(0.013)
public contr. – others t-5	**-0.060****	**-0.055****	**-0.059****	**-0.061****
	(0.013)	**(0.014)**	**(0.014)**	**(0.014)**
public contr. – others t-6	-0.015	-0.019	-0.030	**-0.039****
	(0.014)	(0.015)	(0.014)	**(0.014)**
individual contr. – others t-1	0.009	0.001	-0.025	-0.015
	(0.013)	(0.012)	(0.015)	(0.015)
individual contr. – others t-2	0.017	0.015	0.014	-0.021
	(0.012)	(0.013)	(0.013)	(0.017)
individual contr. – others t-3	0.006	-0.006	-0.012	-0.010
	(0.011)	(0.012)	(0.012)	(0.012)
individual contr. – others t-4	0.006	-0.004	-0.008	-0.007
	(0.011)	(0.012)	(0.012)	(0.012)
individual contr. – others t-5	-0.003	-0.010	-0.013	-0.016
	(0.010)	(0.012)	(0.012)	(0.012)
individual contr. – others t-6	0.020	-0.007	**-0.027***	**-0.036****
	(0.013)	(0.013)	**(0.012)**	**(0.012)**
public contr. t-1		**0.421****	**0.309****	**0.327****
		(0.023)	**(0.038)**	**(0.039)**
public contr. t-2		**0.092****	**0.056***	0.045
		(0.023)	**(0.022)**	(0.038)
public contr. t-3		0.031	0.037	0.033
		(0.022)	(0.022)	(0.021)
public contr. t-4		-0.013	-0.021	-0.022
		(0.022)	(0.022)	(0.022)
public contr. t-5		0.031	0.028	0.026
		(0.022)	(0.022)	(0.022)
public contr. t-6		**-0.067****	**-0.078****	**-0.087****
		(0.020)	**(0.020)**	**(0.020)**
individual contr. t-1		-0.027	0.016	0.024
		(0.019)	(0.031)	(0.033)
individual contr. t-2		-0.004	0.003	-0.041
		(0.021)	(0.021)	(0.037)
individual contr. t-3		-0.019	-0.024	-0.018
		(0.020)	(0.020)	(0.020)
individual contr. t-4		-0.004	0.000	-0.002
		(0.020)	(0.020)	(0.020)
individual contr. t-5		-0.020	-0.014	-0.012
		(0.020)	(0.020)	(0.020)
individual contr. t-6		**-0.040***	**-0.037***	**-0.041***
		(0.019)	**(0.018)**	**(0.018)**
public t-1 × public others t-1			**0.008***	**0.008***
			(0.003)	**(0.003)**
public t-1 × individual others t-1			**0.019****	**0.009****
			(0.002)	**(0.003)**
individual t-1 × public others t-1			0.001	0.000
			(0.002)	(0.003)
individual t-1 × individual others t-1			-0.002	-0.003
			(0.002)	(0.002)
public others t-1 × individual others t-1			**0.006****	**0.004***
			(0.002)	**(0.002)**
public t-2 × public others t-2				-0.005
				(0.003)
public t-2 × individual others t-2				**0.014****
				(0.003)
individual t-2 × public others t-2				0.002
				(0.003)
individual t-2 × individual others t-2				0.004
				(0.002)
public others t-2 × individual others t-2				0.003
				(0.002)
round	**0.830***	-0.140	-0.130	-0.054
	(0.338)	(0.272)	(0.265)	(0.264)
c_i	**0.320****	0.022	0.035	0.053
	(0.055)	(0.039)	(0.038)	(0.038)
c_i × round	**-0.026****	-0.001	-0.002	-0.004
	(0.005)	(0.004)	(0.004)	(0.004)

* $p < 0.05$, ** $p < 0.01$

Table S14. Individual pool contributions based on past round behavior. Lagged random-effects regressions modeling the decision to contribute to the own individual pool based on past round behavior of oneself and other group members in the baseline condition (SEs in parentheses).

	(1)	(2)	(3)	(4)
intercept (c_i = 40)	**7.246***	**4.877***	**5.168***	**5.197***
	(3.234)	**(2.055)**	**(2.035)**	**(2.030)**
public contr. – others t-1	-0.009	-0.006	-0.014	-0.015
	(0.013)	(0.013)	(0.017)	(0.018)
public contr. – others t-2	-0.024	-0.007	-0.010	-0.023
	(0.013)	(0.015)	(0.015)	(0.018)
public contr. – others t-3	-0.001	0.005	0.005	0.004
	(0.013)	(0.014)	(0.014)	(0.014)
public contr. – others t-4	0.003	0.005	0.006	0.005
	(0.014)	(0.015)	(0.015)	(0.015)
public contr. – others t-5	0.001	0.003	0.002	0.002
	(0.014)	(0.016)	(0.016)	(0.016)
public contr. – others t-6	-0.019	-0.017	-0.021	-0.022
	(0.016)	(0.014)	(0.014)	(0.014)
individual contr. – others t-1	**0.056****	**0.055****	**0.045****	**0.038***
	(0.013)	**(0.010)**	**(0.016)**	**(0.017)**
individual contr. – others t-2	0.011	-0.018	-0.017	-0.005
	(0.013)	(0.015)	(0.015)	(0.019)
individual contr. – others t-3	0.013	0.005	0.006	0.006
	(0.011)	(0.014)	(0.013)	(0.014)
individual contr. – others t-4	0.012	0.007	0.010	0.008
	(0.012)	(0.014)	(0.014)	(0.014)
individual contr. – others t-5	0.008	0.006	0.007	0.008
	(0.012)	(0.014)	(0.014)	(0.014)
individual contr. – others t-6	0.019	0.022	0.021	0.021
	(0.014)	(0.012)	(0.012)	(0.012)
public contr. t-1		-0.016	0.006	-0.005
		(0.028)	(0.047)	(0.049)
public contr. t-2		-0.036	-0.033	-0.017
		(0.028)	(0.028)	(0.046)
public contr. t-3		0.016	0.013	0.011
		(0.027)	(0.027)	(0.027)
public contr. t-4		-0.008	-0.007	-0.007
		(0.027)	(0.027)	(0.027)
public contr. t-5		**-0.057***	**-0.058***	**-0.055***
		(0.027)	**(0.027)**	**(0.027)**
public contr. t-6		-0.010	-0.015	-0.020
		(0.024)	(0.024)	(0.024)
individual contr. t-1		**0.606****	**0.522****	**0.520****
		(0.023)	**(0.035)**	**(0.039)**
individual contr. t-2		-0.040	-0.032	-0.033
		(0.026)	(0.026)	(0.044)
individual contr. t-3		**0.056***	**0.052***	**0.053***
		(0.024)	**(0.024)**	**(0.024)**
individual contr. t-4		**-0.108****	**-0.106****	**-0.109****
		(0.025)	**(0.025)**	**(0.025)**
individual contr. t-5		**-0.072****	-0.079	**-0.084****
		(0.026)	(0.025)	**(0.026)**
individual contr. t-6		**-0.051***	**-0.062****	**-0.070****
		(0.022)	**(0.022)**	**(0.023)**
public t-1 × public others t-1			-0.001	0.000
			(0.004)	(0.004)
public t-1 × individual others t-1			-0.001	0.000
			(0.003)	(0.003)
individual t-1 × public others t-1			**0.008****	**0.005***
			(0.003)	**(0.002)**
individual t-1 × individual others t-1			**0.004***	0.001
			(0.002)	(0.004)
public others t-1 × individual others t-1			-0.001	-0.002
			(0.002)	(0.002)
public t-2 × public others t-2				0.000
				(0.004)
public t-2 × individual others t-2				-0.002
				(0.003)
individual t-2 × public others t-2				**0.009****
				(0.004)
individual t-2 × individual others t-2				-0.002
				(0.002)
public others t-2 × individual others t-2				0.001
				(0.002)
round	**-0.854***	**-0.533***	**-0.528***	**-0.529***
	(0.338)	**(0.231)**	**(0.227)**	**(0.228)**
c_i	-0.028	-0.025	-0.026	-0.022
	(0.051)	(0.032)	(0.032)	(0.032)
c_i × round	0.005	0.004	0.004	0.003
	(0.005)	(0.004)	(0.004)	(0.004)

* $p < 0.05$, ** $p < 0.01$

The coordination on collective or individual actions was highly contingent on the co-dependence level of groups (as shown in the main manuscript / tables S1-S2). Under low co-dependence (i = 1), individual action dominates, while under high co-dependence (i = 2), groups more readily coordinate on collective action. Hence, very low or high levels of co-dependence serve as a strong situational coordination device for groups.

However, under intermediary co-dependence, we see the most coordination failure and variance in outcomes across groups indicating that subjects are closer to an indifference point between collective and individual action. With i = 1.5, 13 out of 20 groups successfully coordinated collective actions, while 27 out of 80 participants reached their individual threshold. Hence, what action to take is the most ambiguous for groups and group dynamics should play a larger role under intermediary co-dependence. We therefore focused on this intermediary co-dependence level to understand what led some groups to move towards individual action, while other groups successfully coordinated collective action.

Figure S25 shows whether groups reached a collective solution depending on their first-round public and individual investments. Both, first-round public and first-round individual investments, were predictive of whether a group solved the problem collectively or not. Every point that groups contributed to the public pool in the first round *increased* the odds to solve the problem collectively by 36% (logistic regression, $b = 0.31$, $z = 2.1$, $p < 0.05$). Likewise, every point that groups contributed to their individual pools in the first round *decreased* the odds to solve the problem collectively by 33% (logistic regression, $b = 0.26$, $z = -2.0$, $p < 0.05$).

Whether subjects opted for individual action was also predicted by first round behavior. Every point a subject contributed to their individual pool in the first round increased the odds to reach her individual threshold by 79% (logistic random effects regression, $b = 0.58$, $z = 2.7$, $p = 0.01$) and every point other group members contributed to their individual pool in the first round increased the odds to solve the problem individually by 37% (logistic random effects regression, $b = 0.32$, $z = 2.0$, $p < 0.05$).

Hence, group outcomes were highly path dependent when situational incentives were not clear enough. Already investments of the first round significantly predicted whether groups would successfully coordinate collective action or opt for individual solutions.

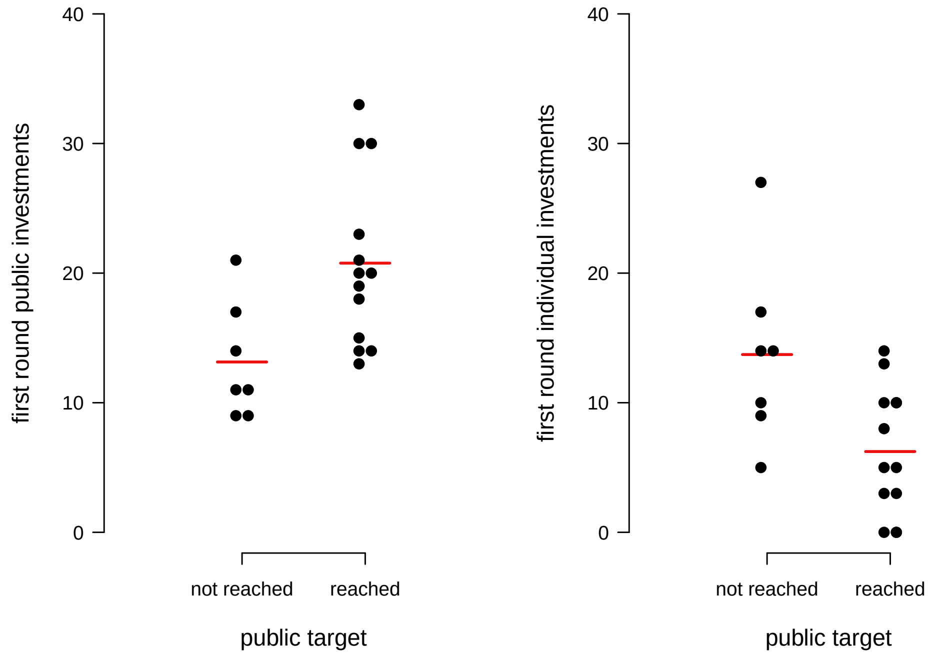


Fig. S25. First round behavior predicting group outcome. Public target reached as a function of first round public (left) and individual investments (right) under intermediary co-dependence (i = 1.5). Each dot represents one group. Red line represents the average.

While the ability to punish increased successful collective action from 65% to 85% under i = 1.5 this was not attributable to actual punishment. The amount of punishment in a group did not predict whether a group would reach a collective solution or not (logistic random effects regression, b = -0.48, z = -0.30, p = 0.76) and the amount of punishment was uncorrelated with punishment-adjusted earnings (i.e. earnings that did not include the costs of punishment and earning-losses due to received punishment; r = -0.21, t(18) = -0.92, p = 0.37). This suggests that the mere presence and possibility of punishment, rather than the actual use of the punishment device, increased collective action.

Individual group outcomes

Figures S26-S35 show the outcome of all group interactions separated by baseline and punishment condition and individual threshold. Each figure shows the final allocation of resources for each subject (indicated by color) to their individual pool (circle around subject) and the shared public pool (circle around group). A complete circle around the individual (group) indicates that the individual (public) threshold was reached.

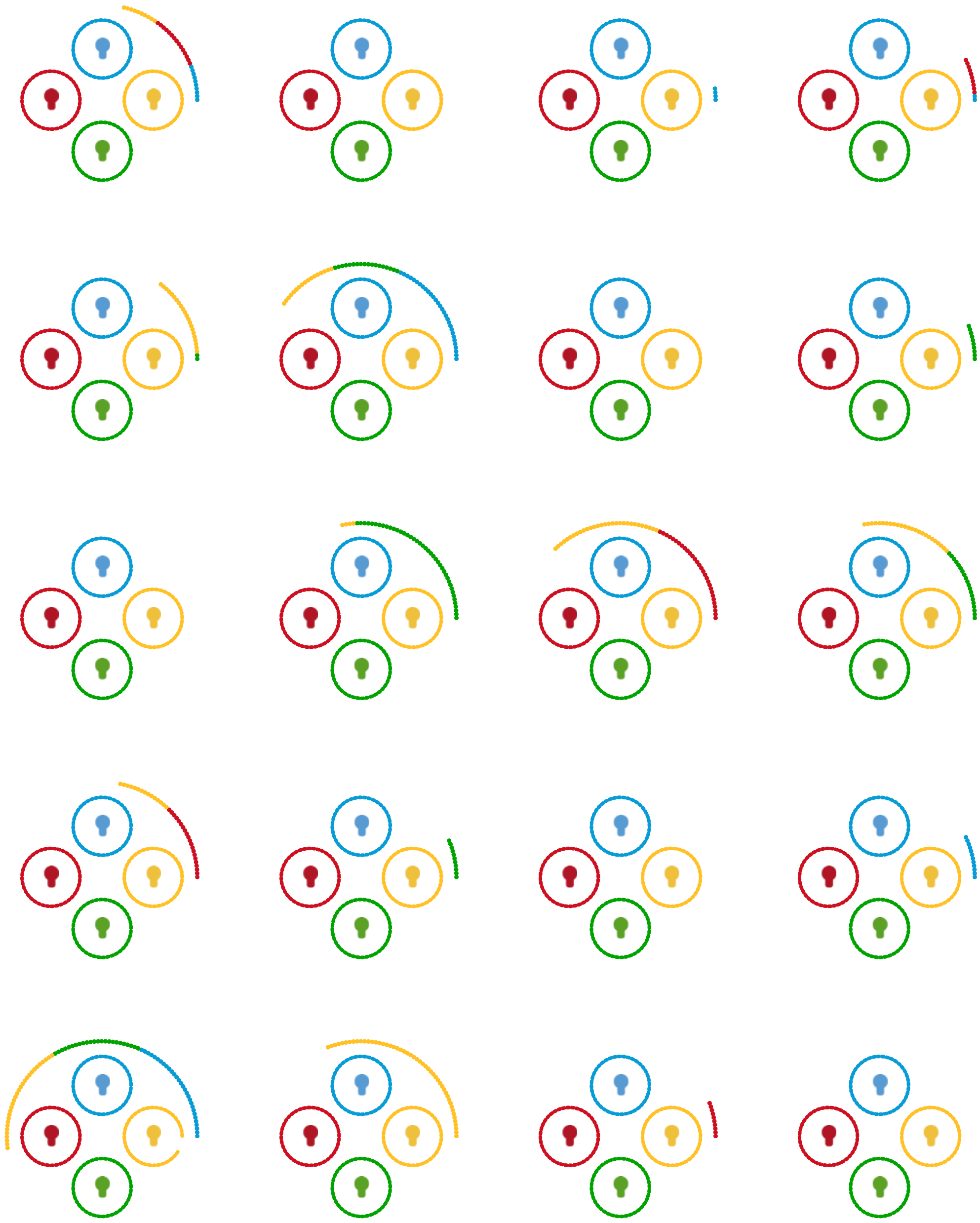


Fig. S26. Baseline condition, c_i = 40.

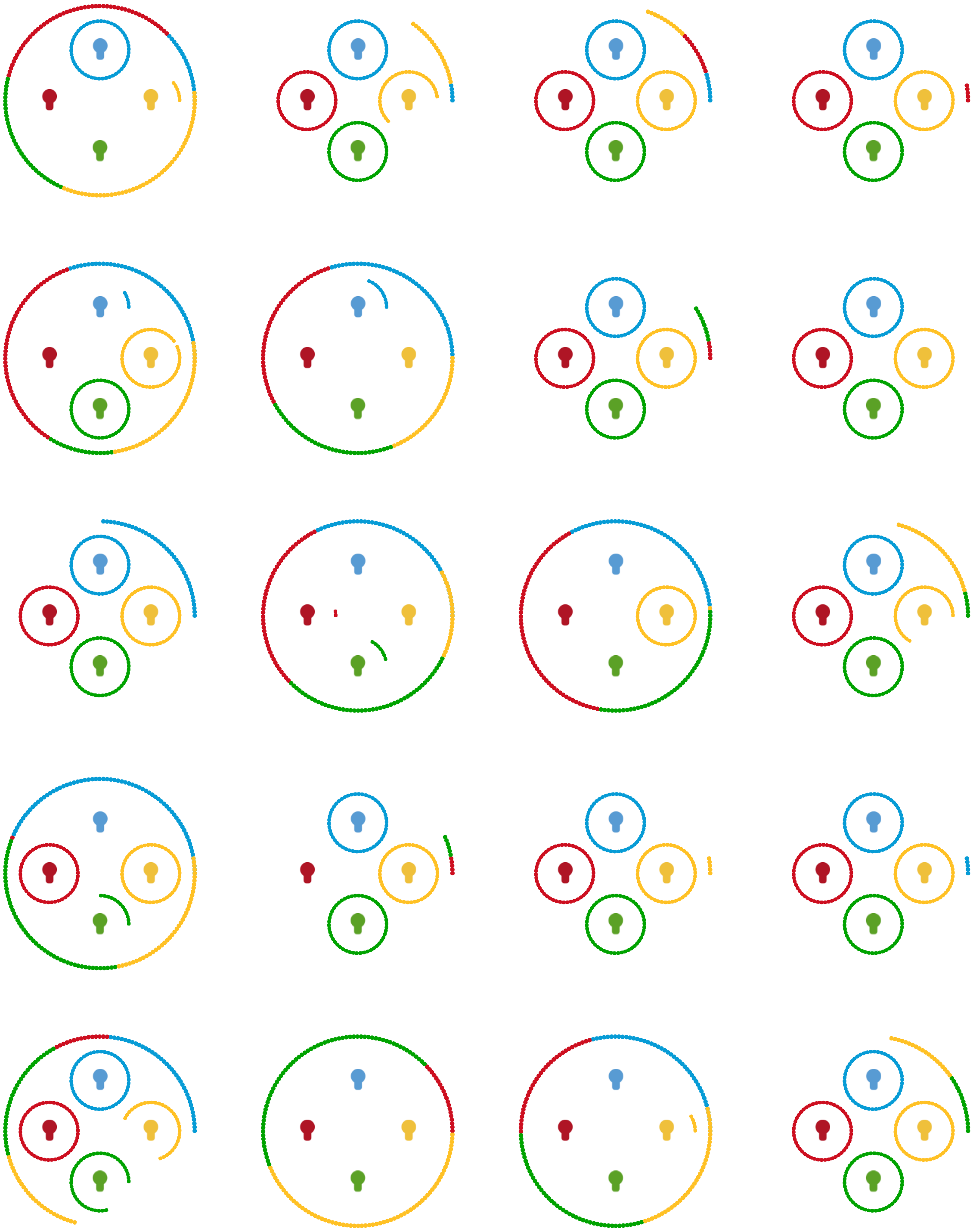


Fig. S27. Baseline condition, c_i = 50.

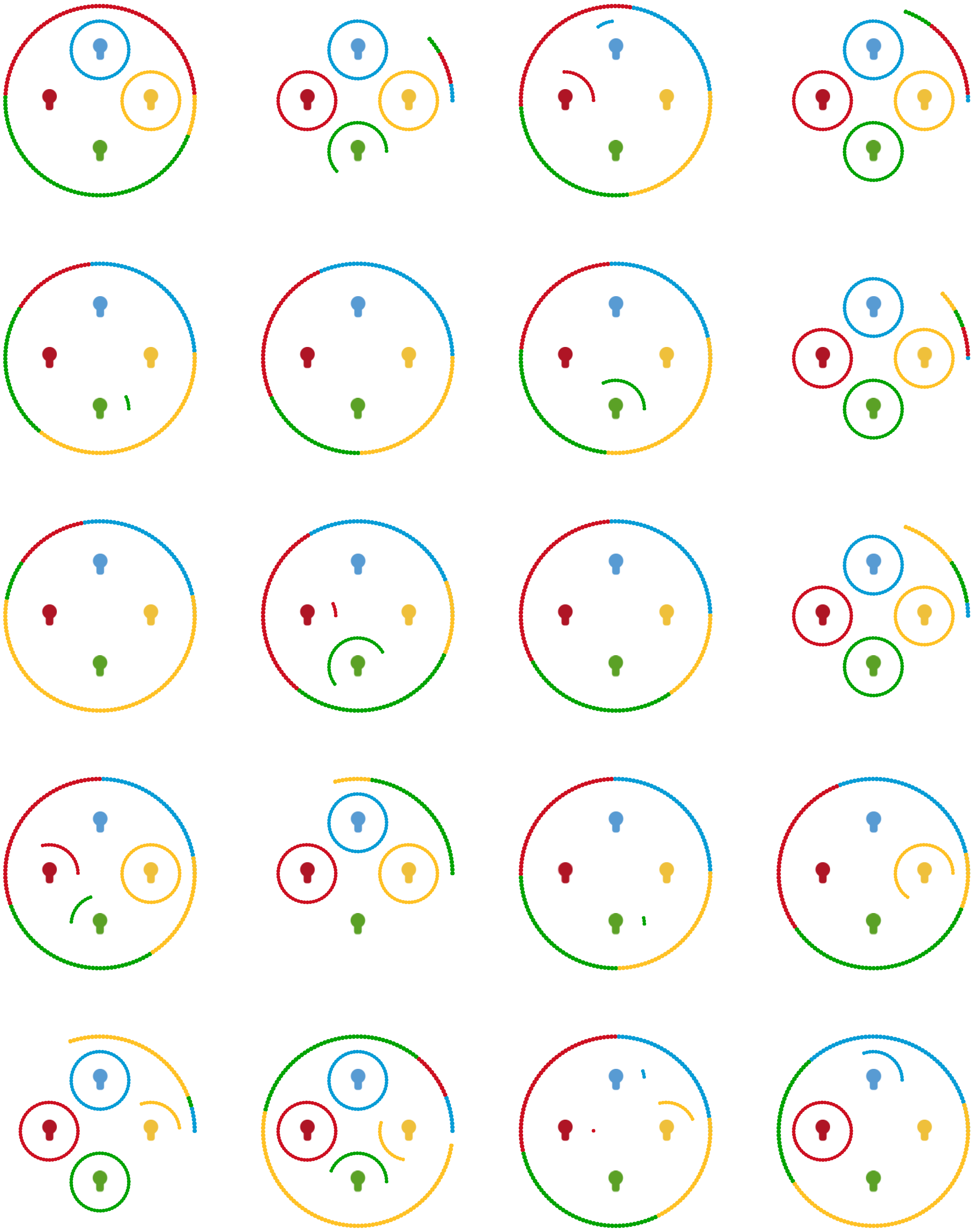


Fig. S28. Baseline condition, c_i = 60.

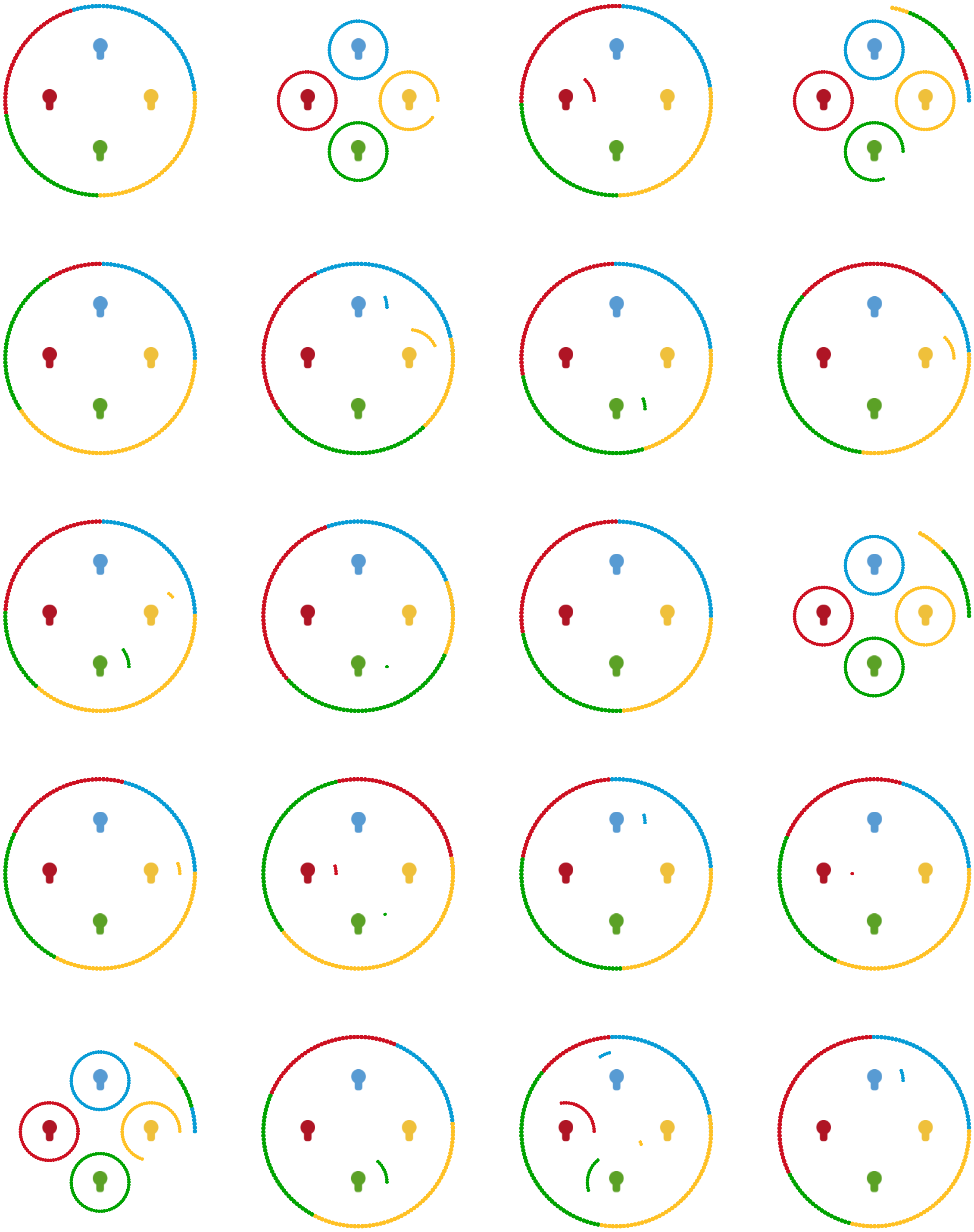


Fig. S29. Baseline condition, c_i = 70.

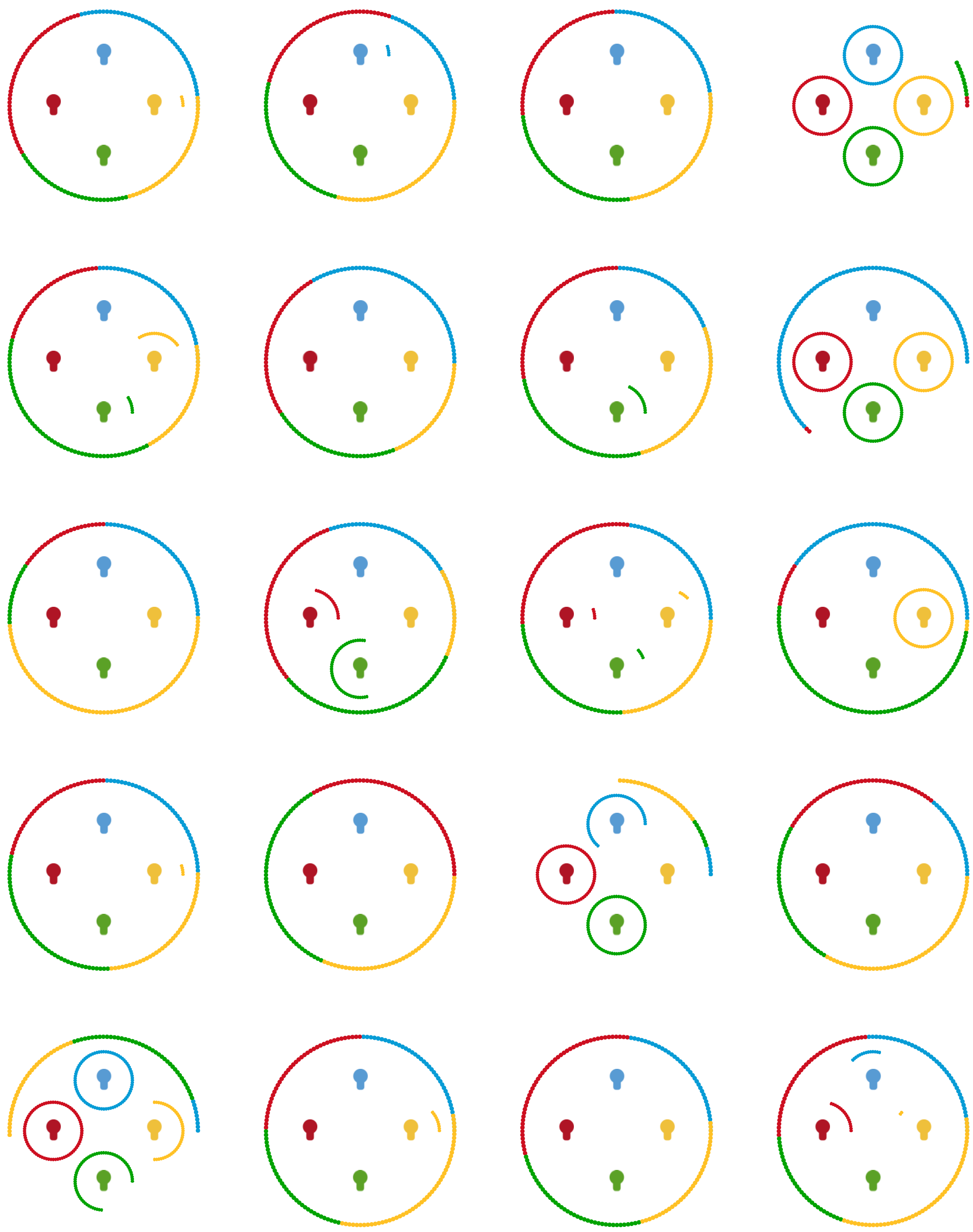


Fig. S30. Baseline condition, c_i = 80.

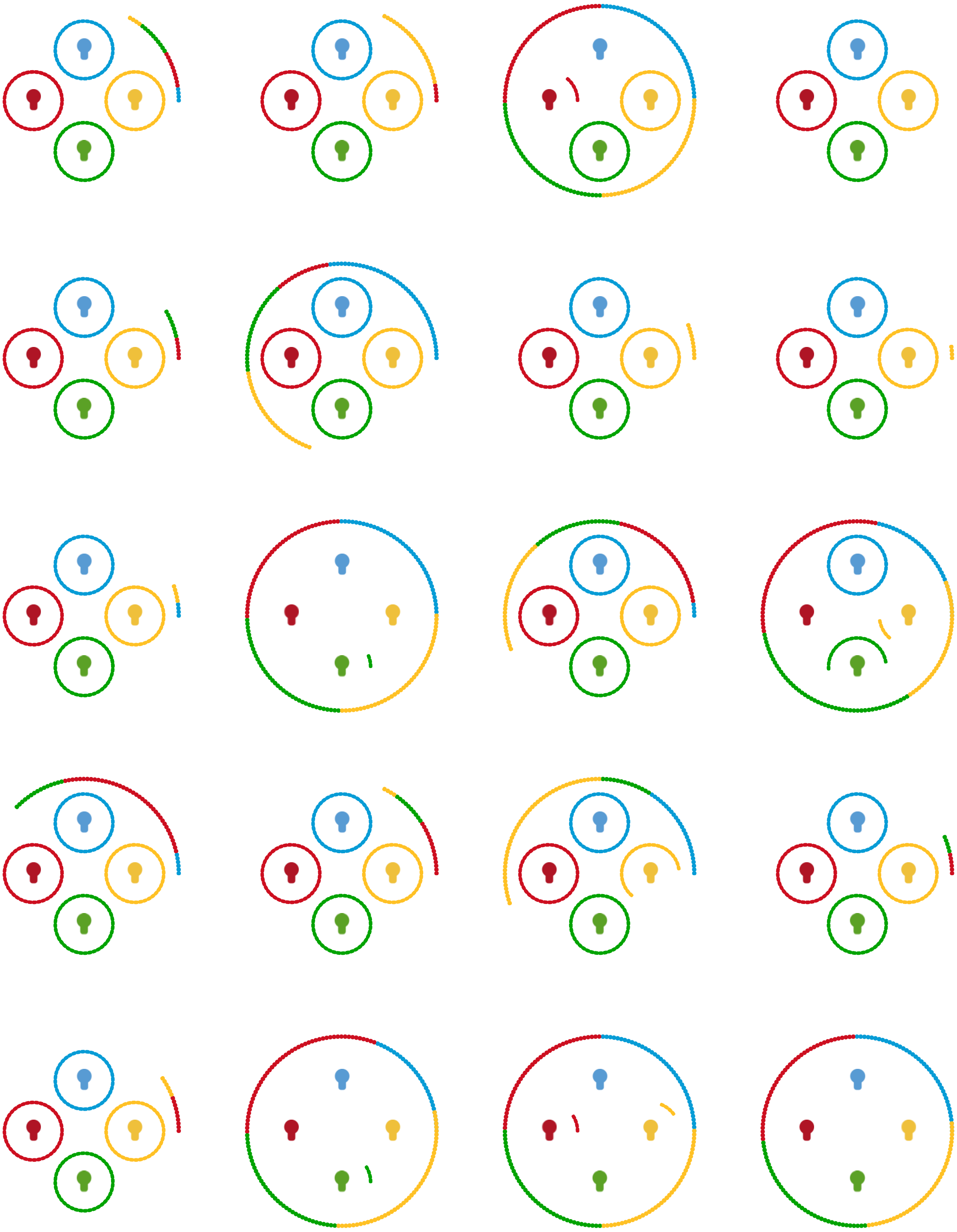


Fig. S31. Punishment condition, c_i = 40.

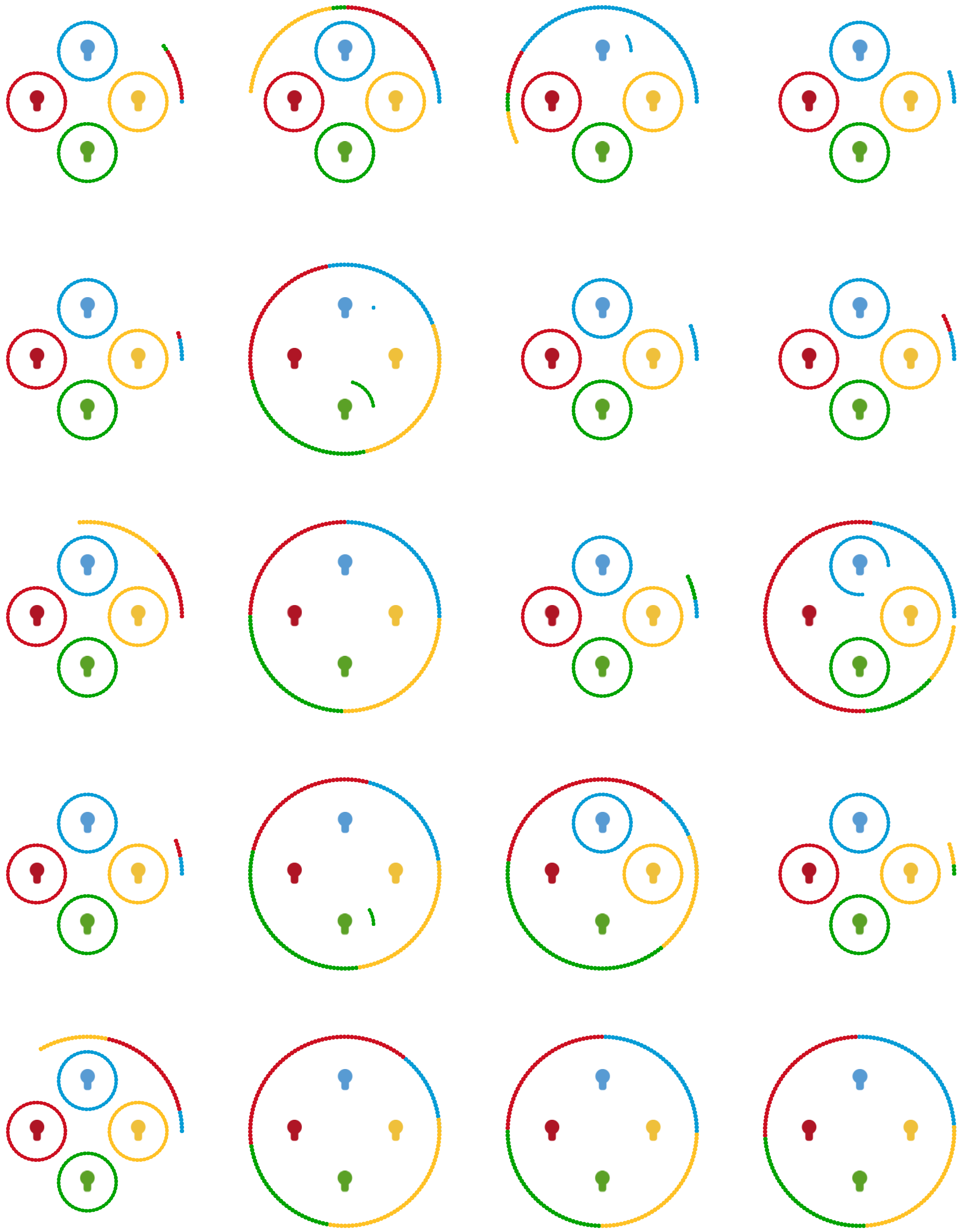


Fig. S32. Punishment condition, c_i = 50.

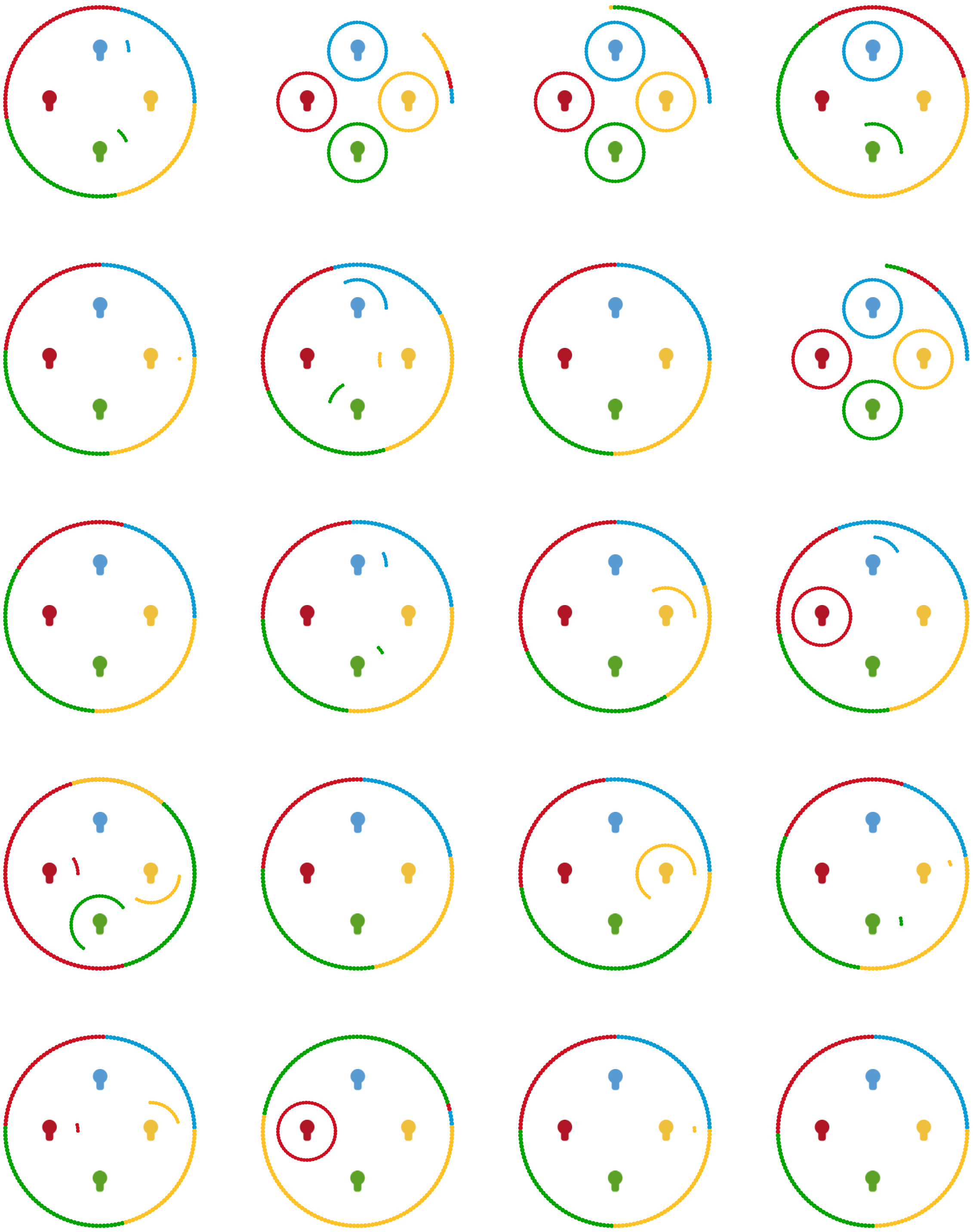


Fig. S33. Punishment condition, c_i = 60.

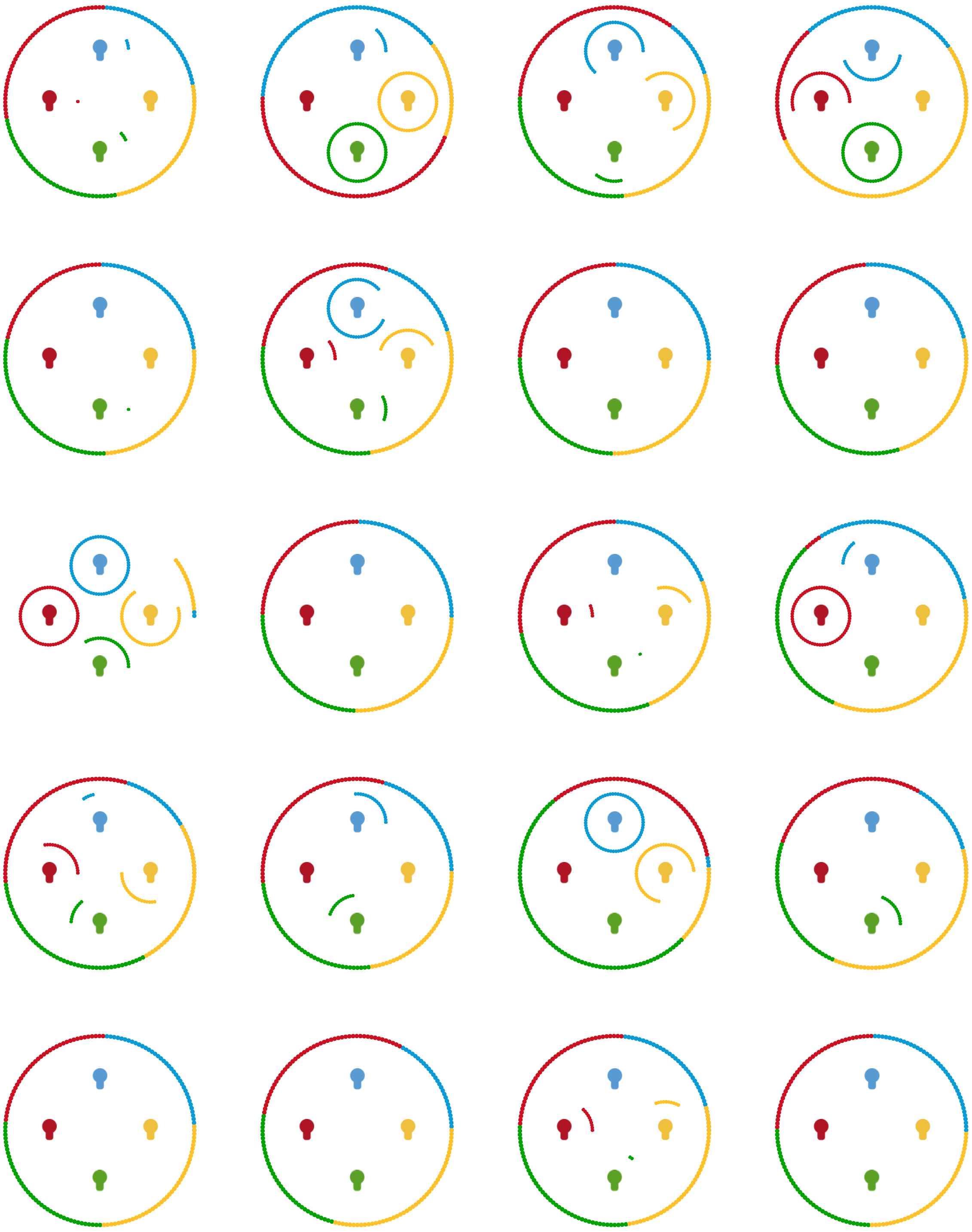


Fig. S34. Punishment condition, c_i = 70.

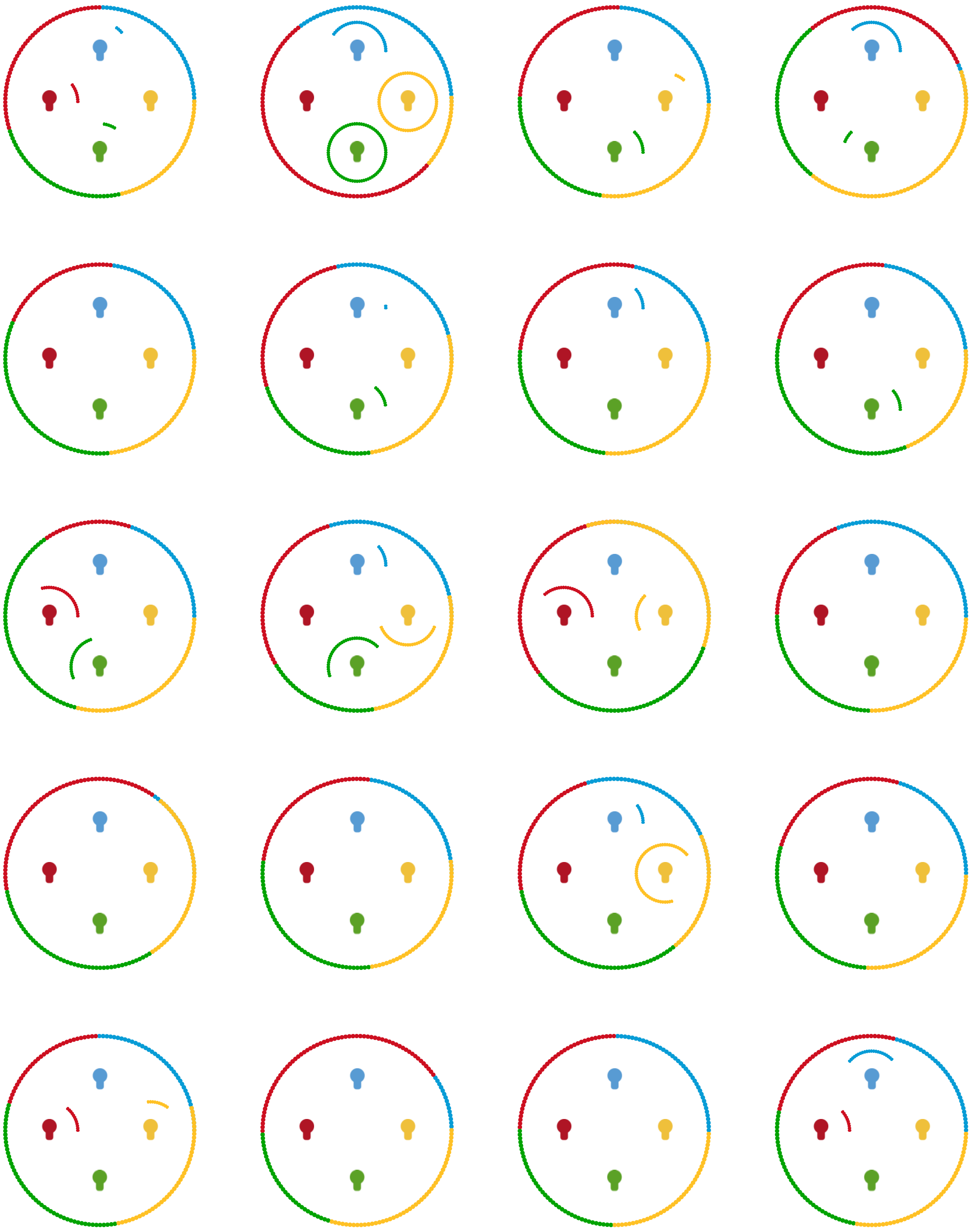


Fig. S35. Punishment condition, c_i = 80.