Cooperation Threshold among Conditional Cooperators

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1 Introduction

Achieving cooperation is paramount in our everyday life, particularly in the context of public goods. For example, Rustagi et al. (2010) find that groups with a higher share of conditional cooperators are better at managing forest commons in Ethiopia. Consequently, identifying components which promote cooperation is key towards designing environments that foster cooperation. Fehr and Gächter (2000) show that punishment can lead to efficient levels of cooperation, and Gürerk et al. (2006) find that people are even willing to choose sanctioning institutions. Without punishment, Gächter and Thöni (2005), Fischbacher and Gächter (2010), and de Oliveira et al. (2009) find a positive relationship between the degree of homogeneity of group composition and cooperation. In their lab experiments, only homogenous groups of conditional cooperators achieve cooperative outcomes, whereas a single free rider leads to a significant decrease in cooperation to very low levels. This suggests that the cooperation threshold, so the minimum share of conditional cooperators in a group required for cooperation among conditional cooperators, is at 100%. But this finding seems to not perfectly explain observations from everyday life, where high levels of cooperation can be observed even with some free riders in a group. Take for example the recent decision of the United States to withdraw from the Paris Climate Agreement, which has triggered renewed effort from the remaining members of the agreement to fight climate change during the 2017 Climate Conference COP23 in Bonn.[1] Furthermore, Hartig et al. (2014) find that the willingness to cooperate decreases in the degree of heterogeneity of group composition, but it does not completely disappear. This leads to the question whether there might exist a cooperation threshold which is strictly smaller than 100%.

This term paper proposes to address this question with a laboratory experiment at the Frankfurt Center for Economic Experiments (FLEX) with 360 participants. Based on simulated behavior, we find that when group composition is known and participants can observe other participants' giving decision in real time, conditional cooperators contribute 90% of their endowment even if there is one free rider in their group. There is a significant drop in contributions to 17% of the endowment in the presence of a second free rider. If participants get information on the group composition, but do not receive any real-time feedback about other participants' real-time contribution, we find a significant drop in contribution levels to 36% of the endowment already with one free rider.

This paper proceeds as follows. Section 2 reviews the related literature. Section 3 introduces a simple model to motivate our choice of hypotheses. The experimental design is presented in section 4. Section 5 contains our behavioral predictions. We report simulated results in section 6 and offer some concluding remarks in section 7.

[1]Steps agreed on include a 12-months assessment of the current situation and new financial commitments, see https://cop23.unfccc.int/news/bonn-climate-conference-becomes-launch-pad-for-higher-ambition.

2 Related Literature

This research proposal builds on the literature on how to achieve and sustain cooperation in groups.[2] In particular, it connects to the literature on the effect of heterogenous groups and information on the group composition on cooperation in linear public good experiments.
Gächter and Thöni (2005) sort like-minded participants into homogenous groups and find that homogeneity of contribution types boosts cooperation. The sorting is based on playing a one-shot linear public good game and ranking all contributions. The top three contributors are grouped together, followed by the next three highest contributors. Participants are shown the contribution of their group members in the ranking stage and then play a repeated linear public good game. Gächter and Thöni (2005) find that even without a punishment possibility cooperation reaches very high levels in homogenous groups of conditional cooperators already in the first stage. They show that a homogenous group composition significantly increases cooperation if participants are able to verify the group composition by observing past contribution decisions. This finding is in line with the results of Chaudhuri et al. (2005) and Chaudhuri and Paichayontvijit (2006), who find that information on the number of conditional cooperators in a group increases contributions of other conditional cooperators.
We are not aware of any experiment that explicitly tests for a cooperation threshold, but the experiments by Levati and Neugebauer (2004) and de Oliveira et al. (2009) are most closely related to our experimental set-up.
Levati and Neugebauer (2004) use an ascending English clock market mechanism in a repeated linear public good game and find that giving participants real-time feedback about the contribution decisions of their group members significantly increases contributions. Additionally, Levati and Neugebauer (2004) report that cooperation almost immediately breaks down if one of the group members stops contributing. This would suggest a cooperation threshold at 100%. But Levati and Neugebauer (2004) only look at heterogenous groups without any information on group composition in a repeated set-up with just 3 participants per group. With just 3 participants per group, it is not possible to identify any cooperation threshold between 66% and 100%. Furthermore, without any information on group composition, even with real-time feedback, conditional cooperators cannot distinguish between a fellow conditional cooperator and a free rider imitating the behavior of a conditional cooperator to drive up cooperation levels on which she can free-ride in later periods.
De Oliveira et al. (2009) elicit cooperative types and systematically vary the number of conditional cooperators in a repeated linear public good experiment. De Oliveira et al. (2009) also vary the available information on group composition. They report three major findings. Firstly, if information on group composition is available, homogenous groups of conditional cooperators are able to achieve efficiently high levels of cooperation. Secondly, if information is available, cooperation breaks down in the presence of one free rider. Thirdly, it is not enough to just give participants information on the cooperative type of their group members to achieve cooperative outcomes, but participants need to be able to verify this information during a learning period by observing real behavior. The results by de Oliveira et al. (2009) also suggest that the cooperation threshold is at 100%. But their experiment shares the same small group size of only 3 players. Furthermore, while giving participants information on the group composition mitigates the effect of strategic uncertainty about types, it is not possible to completely eliminate confounds due to the repeated nature of the experiment. The set-up by de Oliveira et al. (2009) does not allow participants to match the contribution of group members in previous periods to a certain member type. So the set-up does not allow to perfectly verify the type of a specific contributor. Consequently, in groups with one free rider there is still uncertainty left about whether a fellow contributor really is a conditional cooperator or a free rider who wants to drive up contribution

[2]See Chaudhuri (2010) for a detailed overview on the different possibilities to achieve and sustain cooperation in lab experiments.

levels.

Summing up, firstly, the existing literature suggests that groups consisting of like-minded cooperators are able to achieve cooperative outcomes without punishment if credible information on group composition is available. Secondly, there is suggestive evidence that being able to verify the cooperative type of team members by observing real behavior is a necessary condition for achieving cooperation. But some confounds regarding group size and strategic uncertainty do not allow to make a definite conclusion on whether the cooperation threshold is at 100% or can be lower if conditional cooperators are able to perfectly verify information on the cooperative type of team members. We see our contribution to the literature in eliminating those confounds through our experimental design and explicitly testing whether a cooperation threshold smaller than 100% can exist.

3 Theoretical Intuition

The following model should be seen as further suggestive evidence that cooperation in linear public good games can be achieved even in the presence of free riders. But we will not explicitly test the model. We assume that there are only free riders (FR), who have standard preferences, and conditional cooperators (CC), who have social preferences based on Fehr and Schmidt (1999). Both types play a linear public good game and decide on their contribution g_i. Let S be the set of conditional cooperators, $S = \{i|type = CC\}$, and s the number of conditional cooperators, $s = |S|$. We assume that information on group composition is available, but not necessarily verifiable, such that players form individual, pessimistic expectations about s, $E_i(s) = \mu_i \leq s$.

$$
\begin{aligned}
&U_i^{FR} = x_i \\
&U_i^{CC} = x_i - \frac{\alpha_i}{n-1}\sum_j max(x_j - x_i, 0) - \frac{\beta_i}{n-1}\sum_j max(x_i - x_j, 0),\ \alpha_i > \beta_i > 0 \text{ and } \beta_i < 1 \\
&\text{with :} \\
&\quad x_i = \omega - g_i + \delta * \sum_j g_j,\ \delta < 1 < n\delta
\end{aligned}
$$

Since $\delta < 1$, free riders will choose $g_i^{FR} = 0$. For simplicity we assume that all conditional cooperators have the same preferences, so $\alpha_i = \alpha > 0\ \forall i \in S$ and $\beta_i = \beta > 0\ \forall i \in S$, and identical beliefs $\mu_i = \mu \leq s \forall i \in S$. Conditional cooperators anticipate that other conditional cooperators will perfectly match their individual contribution, which implies that

$$U_i^{CC} = \omega - g_i + \delta\mu g_i - \alpha\frac{n-\mu}{n-1}g_i$$

The optimal g_i^{CC} is given by:

$$
g_i^{CC} = \begin{cases} 0, & \frac{\partial U_i^{CC}}{\partial g_i} < 0 \\ \\ \omega, & \frac{\partial U_i^{CC}}{\partial g_i} \geq 0 \end{cases}
$$

Motivated by Blanco et al. (2011), we assume that $\alpha = 1$ and look at the experimental set-up of de Oliveira et al. (2009) and Levati and Neugebauer (2004) with $\delta = 0.5$ and $n = 3$.

Firstly, suppose that perfect verification is possible, so $\mu = s$. The theoretical prediction is in line with the findings of Levati and Neugebauer (2004) and de Oliveira et al. (2009), which imply an identifiable cooperation threshold of 100%.

$$g_i^{CC} = \begin{cases} 0, & s < 2.5 \\ \omega, & s \geq 2.5 \end{cases}$$

But increasing the group size to $n = 4$, reveals that a cooperation threshold of $\frac{3}{4} = 75\%$ exists.

$$g_i^{CC} = \begin{cases} 0, & s < 2.8 \\ \omega, & s \geq 2.8 \end{cases}$$

Secondly, suppose that $s = 3$ and $\delta = 0.5$ and $n = 4$, but perfect verification is not possible, so $\mu \leq 2 < s$. Clearly, $g_i^{CC} = 0$.

Summing up, a very simple model of inequity aversion corroborates the suggestive evidence from the reviewed literature that a cooperation threshold smaller than 100% might exist, but could not have been identified due to a small group size and lack of perfect verification of information on the group composition.

4 Hypotheses and Experimental Design

Based on the reviewed literature and the model, we formulate two hypotheses.

Hypothesis 1 (Threshold existence)**.** *The cooperation threshold, so the required share of conditional cooperators in a group such that all conditional cooperators cooperate, can be smaller than 100%.*

Hypothesis 2 (Verification)**.** *The possibility to verify information on the group composition by observing past or present cooperation behavior is crucial for achieving cooperation. If conditional cooperators have the possibility to verify the group composition, the cooperation threshold is lower than if conditional cooperators do not have this possibility.*

We propose to test both hypotheses using a two-stage linear public goods game, which consists of an classification and a treatment stage. Both stages should be conducted in two different weeks.

In the classification stage, we plan to elicit the cooperative type of all participants based on Fischbacher et al. (2001). Participants play a one-shot normal linear public goods game and make an unconditional and a conditional contribution. For the conditional contribution decision, participants are asked to decide on a contribution for each possible average contribution of the rest of the team between 0 and 200 tokens with 10 tokens increments. In order to determine the earnings, participants are randomly grouped into groups of four. For three randomly picked team members the unconditional contribution decision is chosen to be payoff-relevant, for the last team member the conditional contribution is payoff-relevant. The average of the three unconditional contributions determines the contribution of the last team member based on the conditional contribution decision. Payoffs are payed out in a sealed envelope afterwards. The instructions are taken from Fischbacher et al. (2001) and just slightly adapted to our setting.

Using the Spearman rank correlation coefficient between the average level of contribution of the other team members and the participant's own conditional contribution, we plan to classify the participants' giving type as one of four types:

Type A (free rider): Type A's contribution is always close to zero.

Type B (conditional cooperator): Type B's contribution is a monotonically increasing function of the average contribution.

Type C (unconditional cooperator): Type C's contribution is always close to the full endowment.
Type D (other): Type D does not fit any of the three previous types.

In the treatment stage we plan to test our hypotheses by using a between-subject design by varying the number of conditional cooperators per group as well as the possibility to verify information on group composition. Only participants classified as "conditional cooperator" and "free rider" are invited to the second stage. Participants are aware of the existence of the second stage when signing up for the first stage. They are told that they can participate in up to two experiments and that this depends on their behavior in the first stage. But participants are not told that only conditional cooperators and free riders will be invited for the second stage to avoid strategic behavior in the first stage.

Participants in the second stage play a one-shot linear public good game using a slightly modified English clock market mechanism design like in Levati and Neugebauer (2004). The one-shot game consists of 20 consecutive rounds. The initial contribution of every group member is set to zero. In every round the contribution increases by 10 tokens and participants have to make a decision whether they want to exit the game or stay in the game. The final contribution of a participant is determined by the contribution level when she exits the game. If a participants exits the game, she can not make anymore decisions. There is no default option, so participants have to actively pick an option.

To test hypothesis 1, we systematically vary the number of conditional cooperators per group in a between-subject design. In treatment *4CC*, all group members are randomly picked from the pool of participants that were classified as "Type B". Similarly, in treatment *3CC*, three conditional cooperators are matched with one free rider. Finally, in treatment *2CC*, two conditional cooperators play the game together with two free riders. Before the game, we inform participants about the composition of their group by telling them how many players of type A and type B they are playing with. We plan to refer to conditional cooperators only as "Type B" and to free riders as "Type A". We describe the contribution behavior of both types, but without using the terms "cooperation" or "free-riding".[3]

Table 1: Experimental Set-Up Second Stage

# independent observations		Hypothesis 2	
		Feedback	No Feedback
Hypothesis 1	2CC	10	10
	3CC	10	10
	4CC	10	10

To test hypothesis 2, we also vary the possibility to verify the information on group composition in a between-subject design. In treatment *FEEDBACK*, participants get real-time feedback about the contribution of their group members. For this, we provide participants with an overview table containing every group members' type together with her real-time contribution determined by the decision to stay or exit. In addition, at the beginning of each round we provide participants with a overlay notification whenever a group member chooses to exit the game. In the treatment *NO FEEDBACK*, participants do not get any information on the contribution decisions of their group members during the game. Participants are only informed about the contribution of every team member after the last round. Consequently, in the *NO FEEDBACK* treatment, participants are not able to verify the information we give them on

[3]The instructions are in the respective HTML template in our submitted oTree code.

group composition. Table 1 summarizes our experimental set-up in the second stage.
The endowment in both stages is 200 tokens and participants are payed at a conversion rate of 20 tokens to 1EUR. The MPCR of the linear public good game is 0.5. In both stages, we provide participants with an on-screen calculator to compute how combinations of own contribution and average contribution of the rest of the team translate into payoffs. Furthermore, before participants can start the actual experiment, they have to correctly answer several control questions in both stages, reflecting their understanding of the game. We plan to frame the public goods game as an allocation game between a private account and an investment in a common project to avoid framing effects of the term contribution. The experiment is planned to be conducted at the Frankfurter Laboratory for Experimental Economic Research (FLEX) and is programmed using oTree (Chen et al., 2016).

5 Behavioral Predictions and Power Analysis

We expect high levels of contributions if the actual share of conditional cooperators in the group is higher than the conjectured cooperation threshold. Given our hypotheses, we assume this cooperation threshold to be lower if verification of information on group composition is possible. Based on the results of Levati and Neugebauer (2004) and de Oliveira et al. (2009), we expect the cooperation threshold to be at 100%, or 4 conditional cooperators out of 4 group members, in the *NO FEEDBACK* treatments. In the *FEEDBACK* treatments we conjecture a cooperation threshold of 75%, or 3 conditional cooperators and one free rider.

Hypothesis 1 (Threshold existence). *In the FEEDBACK treatment, the average contribution among conditional cooperators for 3CC is significantly higher than for 2CC, but there is no significant difference between 3CC and 4CC.*
Hypothesis 2 (Verification). *The average contribution among conditional cooperators in the 3CC treatment is significantly higher for FEEDBACK than for NO FEEDBACK, but is identical in the 4CC treatment.*

We conducted a power analysis for the second stage using the results reported by de Oliveira et al. (2009) for average contributions among conditional cooperators. We choose de Oliveira et al. (2009) and not Levati and Neugebauer (2004), since only de Oliveira et al. (2009) systematically vary and communicate the group composition. In Levati and Neugebauer (2004), participants are randomly allocated to groups and group composition is not known, so individual beliefs are not fixed. Table 2 summarizes the assumptions for our power analysis based on de Oliveira et al. (2009).[4] We also compare our assumptions with the values reported in figure 1 of Gächter and Thöni (2005) for sorted groups without the possibility to punish and the first period of their

[4] All values are taken from table 2 column "Known Distribution & After" of de Oliveira et al. (2009) and rescaled to our endowment. For groups above our conjectured cooperative threshold, we take the results reported for the groups with only conditional cooperators. For groups below the respective cooperative threshold, we take the results reported for groups with at least one free rider. For the standard deviation, we take the results reported for groups with only conditional cooperators for all our treatment groups. The reason is that de Oliveira et al. (2009) report only time-averages of their repeated set-up, but state that the variation across time was very high. Since we only have a one-shot game, we should not have this variation over time. Furthermore, de Oliveira et al. (2009) report standard deviations based on contributions of both conditional cooperators and free riders, whereas we focus only on the contributions of conditional cooperators. Consequently, we take the smallest reported standard deviation from de Oliveira et al. (2009).
It could also be that providing feedback on the dropping out decision of free riders leads to a strong reciprocal reaction of conditional cooperators in the 2CC treatment. This would decrease the average contribution if conditional cooperators had optimistic beliefs about the contribution of free riders. On the other hand, even without providing feedback, conditional cooperators might already expect free riders to always contribute zero, given that players classified as free riders exhibited close to zero contributions in the first stage. In this case, providing feedback on its own should not have an additional effect. We assume the latter case to be more likely.

repeated set-up. The values are very similar to the values we assume and further strengthen the validity of our assumptions.
Simulating the experiment 1000 times using draws from a normal distribution based on the values from table 2 and using the Wilcoxon-Mann-Whitney test with 10 independent observations, we achieve a statistical power of 81% for hypothesis 1. For hypothesis 2 we also find a statistical power of 81%.

Table 2: Average contribution levels among conditional cooperators by grouping and treatment

	Feedback	No Feedback
2CC	90	90
	(50)	(50)
3CC	160	90
	(50)	(50)
4CC	160	160
	(50)	(50)

Standard errors in parentheses

6 Simulated Results

We simulate the behavior in both stages and present results to highlight our approach to evaluate the experiment. For the simulation of the classification stage, we take the distribution of types from Fischbacher et al. (2001) and simulate the conditional giving decision for 360 "participants". For free-riders, the simulated decision is a random draw from a uniform distribution between 0 and 30 tokens. For conditional cooperators, the simulated decision is a random draw from a uniform distribution around the respective value of the average contribution level of the rest of the group. For unconditional cooperators, the simulated decision is a random draw from a uniform distribution between 170 and 200 tokens. Lastly, for "other", the simulated decision is a random draw from a uniform distribution between 0 and 200 tokens. Figure 1 summarizes the results of the simulations using classification based on the Spearman rank correlation coefficient between the average level of contribution of the other team members and the participant's own conditional contribution.

We simulate the treatment stage by choosing one draw from the 1000 simulations for the power analysis from section 5. Table 3 summarizes our findings for the simulated second stage and also includes our test results for the Wilcoxon-Mann-Whitney test.
Regarding the threshold existence, we find that in the *FEEDBACK* treatment the average contribution among conditional cooperators in the $3CC$ groups is significantly higher than the average contribution in the $2CC$ groups. Furthermore, we cannot reject that the average contribution among conditional cooperators is the same in the $3CC$ and $4CC$ treatment. Conditional cooperators can achieve almost efficiently high levels of cooperation even with one free rider in the group. Consequently, given the simulated data, our econometric approach can correctly identify that the cooperation threshold can be lower than 100% if conditional cooperators can verify that other conditional cooperators in the group cooperate even in the presence of a free rider.
Regarding the verification hypothesis, looking at the *NO FEEDBACK* treatment, we find that the average contribution among conditional cooperators is significantly higher in the $4CC$ groups than in the $3CC$ groups. Furthermore, we cannot reject that the average contribution among

Figure 1: First stage results (Diagonal = perfect conditional)

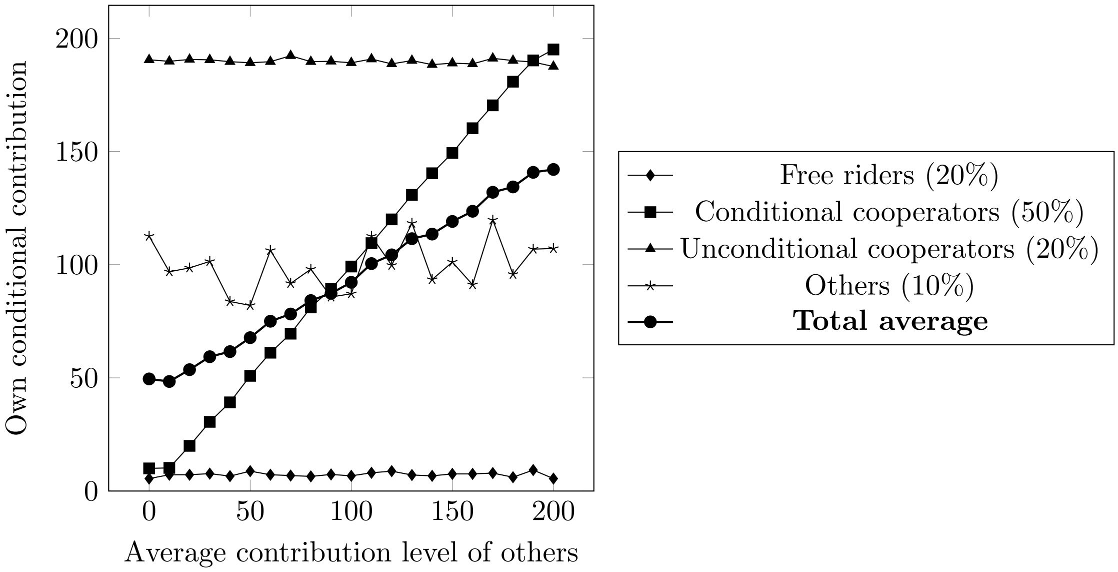

Table 3: Average contributions in the second stage among conditional cooperators

	Average contribution[a]		Difference in average contribution[b]		
	Feedback	No Feedback	Feedback−No Feedback	Feedback[c]	No Feedback[c]
2CC	34.864	53.057	−18.913	-	-
	(24.615)	(49.705)	(0.684)	-	-
3CC	180.734	72.775	107.959***	145.870***	19.718
	(27.792)	(54.809)	(0.000)	(0.000)	(0.361)
4CC	182.340	184.224	−1.884	1.606	111.449***
	(16.443)	(16.216)	(0.850)	(0.741)	(0.000)

[a]Standard errors in parentheses, values are averages among conditional cooperators without free riders.
[b]p-values of a two-sided Wilcoxon rank sum test in parentheses, * denotes significance at 10%, ** at 5%, and *** at 1%
[c]Differences between CC-treatments, (n)CC − $(n-1)$CC

conditional cooperators is the same in the $2CC$ and $3CC$ groups. This points to a cooperation threshold at 100%, which is higher than the cooperation threshold in the *FEEDBACK* treatment. This is also reflected in the result that the average contribution among conditional cooperators for $3CC$ groups is significantly higher in the *FEEDBACK* treatment than the average contribution in the *NO FEEDBACK* treatment, but we cannot reject that it is the same for $2CC$ and $4CC$ groups. Consequently, given the simulated data, our econometric approach can identify a higher cooperation threshold in the *NO FEEDBACK* treatment. Finally, even though the average contribution in the $2CC$ treatment is lower with feedback than without feedback, the difference is not statistically significant.
As a robustness check, we plan to also conduct linear regressions of the following form.

$$AC_g = \beta_0 + \beta_1 * 3CC_g + \beta_2 * 4CC_g + \beta_3 * F_g + \beta_4 * 3CC_g * F_g + \beta_5 * 4CC_g * F_g + u_g$$

AC_g denotes the average contribution among conditional cooperators in group g. $3CC_g$, $4CC_g$, and F_g are dummies for the number of conditional cooperators and the *FEEDBACK* treatment.

Table 4 reports the results of a normal linear regression and a Tobit I corner regression. The results of both models are in line with the results of the non-parametric tests. $3CC$ does not have a significant effect if there is no feedback, only $4CC$ significantly increases the average contribution among conditional cooperators in the *NO FEEDBACK* treatment. This suggests a cooperation threshold at 100% in the *NO FEEDBACK* treatment. But in the *FEEDBACK* treatment, the interaction term between $3CC$ and feedback is highly significant, whereas the interaction term between $4CC$ and feedback is not significantly different from zero. Consequently, only in the $3CC$ treatment, giving feedback significantly increases the average contribution among conditional cooperators.

Table 4: OLS and Tobit I regressions

	OLS	Tobit I
3CC	19.72	24.35
	(15.69)	(19.18)
4CC	131.17***	150.57***
	(15.69)	(20.04)
Feedback	-18.19	-11.83
	(15.69)	(19.13)
3CC× Feedback	126.15***	137.78***
	(22.19)	(27.59)
4CC × Feedback	16.31	6.108
	(22.19)	(27.73)
_cons	53.06***	46.69***
	(11.10)	(13.74)
sigma		42.08
		(4.725)
N	60	60

Standard errors in parentheses, clustered at group level
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

7 Conclusion

Previous findings in the literature on how to achieve cooperation in teams suggest that cooperation among conditional cooperators breaks down in the presence of free riders. In this term paper, we suggest to use exogenous sorting of cooperative types into groups to show that conditional cooperators can be willing to cooperate in a one-shot public good game even if there is a free rider in their group. We conjecture that the willingness to cooperate crucially depends on having a strong mechanism to verify information on the group composition by observing the cooperative behavior of other conditional cooperators in real time.
We see our contribution in showing for the first time that cooperation might be achieved in the lab in the presence of free riders. In the field, in many environments it is possible for team members to observe real time cooperative behavior of other team members. Examples include

students or employees working together on group projects or countries implementing public policies to fight climate change. Consequently, we believe that our set-up is not completely different from environments in the field and that our findings should not be an artefact of a specific lab experiment. Nevertheless, additional experiments are required to further strengthen our hypothesis. Additional experiments in the lab could increase the group size even further and see whether the required share of conditional cooperators to achieve cooperation decreases in larger teams.

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