Social Preferences, Beliefs, and the Dynamics of Free Riding in Public Good Experiments

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Abstract

We provide a test of the role of social preferences and beliefs in voluntary cooperation and its decline. We elicit individuals' cooperation preferences in one experiment and use them – as well as subjects' elicited beliefs – to explain contributions to a public good played repeatedly. We find substantial heterogeneity in people's preferences. With simulation methods based on this data, we show that the decline of cooperation can be driven by the fact that most people have a preference to contribute less than others, rather than by their changing beliefs of others' contribution over time. Universal free riding is very likely despite the fact that most people are not selfish.

JEL Code: C91, C72, H41, D64.

Keywords: public goods experiments, social preferences, conditional cooperation, free riding.

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In this paper we investigate the role of social preferences and beliefs for voluntary cooperation. This question is interesting because numerous public goods experiments have shown that many people contribute more to the public good than pure self-interest can easily explain. However, an equally important observation is that free riding increases in repeatedly played public good experiments across various parameters and participant pools.[1] The facts are clear, but their explanation is not.

An obvious candidate for explaining the decline of cooperation was learning the free rider strategy. However, Andreoni (1988) showed that cooperation resumed after a restart, which is inconsistent with a pure learning argument. In a subsequent paper he interpreted the decline in cooperation "to be due to frustrated attempts at kindness, rather than learning the free-riding incentives" (Andreoni (1995), p. 900). Several papers since argue that contributions that are not due to confusion might possibly be explained by other-regarding preferences (e.g., Palfrey and Prisbrey (1997); Brandts and Schram (2001); Goeree, Holt and Laury (2002); Ferraro and Vossler (2005); Kurzban and Houser (2005)). One type of social preference – long argued by social psychologists (e.g., Kelley and Stahelski (1970)) – is many people's propensity to cooperate provided others cooperate as well (e.g., Keser and van Winden (2000); Fischbacher, Gächter and Fehr (2001); Frey and Meier (2004); Croson (2007); Ashley, Ball and Eckel (2008); see Gächter (2007) for an overview). Such "conditional cooperation" is an interesting candidate for explaining the fragility of cooperation because this motivation depends directly on how others behave or are believed to behave. Conditional cooperators who observe (or

[1] See, for instance, Isaac, Walker and Thomas (1984); Andreoni (1988); Andreoni (1995); Weimann (1994); Laury, Walker and Williams (1995); Croson (1996); Burlando and Hey (1997); Gächter and Fehr (1999); Sonnemans, Schram and Offerman (1999); Keser and van Winden (2000); Fehr and Gächter (2000); Park (2000); Masclet, Noussair, Tucker and Villeval (2003); Carpenter (2007); Sefton, Shupp and Walker (2007); Egas and Riedl (2008); Herrmann, Thöni and Gächter (2008) and Neugebauer, Perote, Schmidt and Loos (forthcoming). The decline of cooperation has also been observed in prisoner's dilemma experiments. See, e.g., Selten and Stoecker (1986); Andreoni and Miller (1993) and Cooper, DeJong, Forsythe and Ross (1996).

believe) that others take a free ride, will reduce their contributions and thus contribute to the decline of cooperation.[2] It is unknown, however, to what extent conditional cooperation, and inter-individual differences in this regard, can explain (the decline of) cooperation. Our paper aims to shed empirical light on this question. For a related theoretical approach see Ambrus and Pathak (2007).

The novelty of our paper is to combine two observations from previous research: beliefs about other people's contributions matter and people differ in their cooperative preferences – some are free rider types, whereas others are conditional cooperators.[3] In our approach we measure people's cooperation preferences in a specially-designed public good game played in the strategy method (called the "P-experiment") and then observe the same people in a sequence of ten one-shot games (labeled the "C-experiment"), in which we also elicit their beliefs about others' contributions. This allows us to quantify how preference heterogeneity and beliefs interact in voluntary cooperation. Specifically, we can disentangle whether contributions decline because of cooperation preferences and/or because of the way people form (and change) their beliefs about how others will behave.

Our data from the P-experiment show that people differ strongly in their contribution preferences. This is consistent with previous evidence. The biggest groups of people are (i) conditional cooperators who cooperate if others cooperate, and (ii) free riders who never contribute anything, irrespective of how much others contribute. We push beyond this observation of preference heterogeneity by investigating how measured preferences and

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[2] Experiments on "assortative regrouping" of participants provide suggestive evidence for this explanation: in these experiments (e.g., Burlando and Guala (2005); Gächter and Thöni (2005); Page, Putterman and Unel (2005); Gunnthorsdottir, Houser and McCabe (2007)) contributors are matched up with contributors, and free riders with free riders. The results show that contributions are largely stabilized if free riders are moved out of the group.

[3] See, e.g., Fischbacher, et al. (2001); Burlando and Guala (2005); Kurzban and Houser (2005); Bardsley and Moffatt (2007); Kocher, Cherry, Kroll, Netzer and Sutter (2008); Herrmann and Thöni (forthcoming)).

beliefs are related to observed contribution behavior. We have therefore designed our experiments such that we can use the P-experiment to make a point prediction for each participant about his or her contribution in the C-experiment, given his or her beliefs.

Our approach allows us to answer the following three questions: how do people form their beliefs about others' contributions in a given period? What is the respective role of elicited contribution preferences and beliefs for determining contributions? How do beliefs and preference heterogeneity impact on the decline of cooperation?

Our results, which we detail in Section II, answer these questions as follows: first, belief formation can be described as a partial adjustment of one's belief into the direction of the observed contribution of others in the previous period. More specifically, beliefs in a given period are a weighted average of what others contributed in the previous period and one's own belief in the previous period. As we will show with the help of simulation methods, our estimated belief formation process implies that beliefs decline only if contributions decline, but not vice versa. Second, contributions are significantly positively influenced by predicted contributions, that is, the elicited preferences. In addition to their preferences, people's contributions also depend directly on their beliefs about others' contributions. This implies that the P-experiment underestimates the extent of conditional cooperation that occurs in the C-experiment. Third, contributions decline because on average people are "imperfect conditional cooperators" who only partly match others' contributions. The presence of free rider types is not necessary for this result; contributions also decline if everyone is an imperfect conditional cooperator.

I. Design and procedures

Our basic decision situation is a standard linear public good game. The participants are randomly assigned to groups of four people. Each participant is endowed with 20 tokens, which he or she can either keep or contribute to a "project", the public good. The payoff function is given as

$$\pi_i = 20 - g_i + 0.4\sum_{j=1}^{4} g_j \,, \qquad (1)$$

where the public good is equal to the sum of the contributions of all group members. Contributing a token to the public good yields a private marginal return of 0.4 and the social marginal benefit is 1.6. Standard assumptions therefore predict that all group members free ride completely, that is, $g_j = 0$ for all j. This leads to a socially inefficient outcome.

The instructions (see Appendix) explained the public good problem to the participants. Since we want to measure subjects' preferences as accurately as possible, we also took great care to ensure that the participants understood both the rules of the game and the incentives. Therefore, after participants had read the instructions, they had to answer ten control questions. The questions tested the subjects' understanding of the comparative statics properties of (1), to ensure that participants are aware of their selfish incentives and the dilemma situation. We did not proceed until all participants had answered all questions correctly. We can thus safely assume that the participants understood the game.

Within this basic setup we conducted two types of experiments. The first type of experiment (the "P-experiment") elicits people's contribution *preferences* in a linear one-shot public goods game. In the second type of experiment participants make *contribution choices* in a repeatedly played linear public goods environment (labeled "C-experiment"). The C-experiment consists of ten rounds in the random matching mode. We chose a random matching protocol to minimize strategic effects from repeated play. All participants play both types of experiments. For example, participants first go through the preference elicitation experiment in the P-C sessions before making their contribution choices in the C-experiment. Our C-P sessions counterbalance the order of experiments to control for possible sequence effects. The C-P sequence allows for a particularly strong test of measured preferences because people experience ten rounds of decisions in the C-experiment before their cooperation preferences are elicited in the P-experiment.

The rationale of the P-experiment is to elicit people's cooperation preferences: to what degree are people willing to cooperate given other people's degrees of cooperation?[4] Being able to observe contributions as a function of other group members' contributions without using deception requires the observation of contributions that can be contingent on others' contributions. Fischbacher, et al. (2001) (henceforth FGF) introduced an experimental design that accomplishes this task.[5] Since we use exactly the same method as FGF we refer the reader to FGF for all details.

The central idea of the P-experiment is to apply a variant of the so-called "strategy method" (Selten (1967)). The participants' main task in the experiment is to make two decisions, an "unconditional contribution" and a "conditional contribution". In the conditional contribution a subject has to indicate – in an incentive compatible way – how much he or she wants to contribute to the public good for each rounded average contribution level of other group members. Specifically, participants were shown a "contribution table" of the 21 possible values of the average contribution of the other group members (from 0 to 20) and were asked to state their corresponding contribution for *each* of the 21 possibilities. Since the FGF method elicits the contribution schedules in an incentive compatible way, free rider types have an incentive to enter a zero contribution for each of the 21 possible average contributions of other group members; conditional cooperators have an incentive to enter increasing

[4] Our approach does not require eliciting a utility function since we do not need a complete preference order for our purposes. It is sufficient to know subjects' best replies conditional on others' contributions.

[5] Ockenfels (1999) developed a similar design independently of FGF.

contributions, and unconditional cooperators have an incentive to enter their preferred contribution level.[6] The experiment was only played once, and the participants knew this. We wanted to elicit subjects' preferences, without intermingling preferences with strategic considerations.

Participants in the P-C sessions (C-P sessions) were only informed after finishing the P-experiment (C-experiment) that they would play another experiment. When we explained the C-experiment we emphasized that the groups of four would be randomly reshuffled in each period.[7] After each period, participants were informed about the sum of contributions in their group in that period. In addition to their contribution decisions, subjects also had to indicate their *beliefs* about the average contribution of the other three group members in the current period. In addition to their earnings from the public good experiment, we also paid participants based on the accuracy of their estimates.[8]

We elicited beliefs for two reasons. First, we can assess the correlation between beliefs and contributions, which we expect to differ between types of players. Second, by evaluating an elicited schedule at the elicited belief in a given period we can make a point prediction

[6] The P-experiment is incentive compatible because a random draw selects three group members for whom the unconditional contribution is payoff relevant and one group member for whom the conditional contribution, given the average unconditional contributions of the other three members, is payoff relevant. The payoffs are equal to (1). See FGF or Fischbacher and Gächter (2006) for further details.

[7] The likelihood in period 1 that a player would meet another player again once during the remaining nine periods was 72 percent. The likelihood that the *same* group of four players would meet was 2.58 percent. However, since the experiment was conducted anonymously, subjects were unable to recognize whether they were matched with a particular player in the past.

[8] Participants had a financial incentive for correct beliefs, but it was small to avoid hedging. If their estimation was exactly right, subjects received 3 experimental money units (≈ \$0.8) in addition to their other experimental earnings. They received 2 (1) additional money units if their estimation deviated by 1 (2) point(s) from the other group members' actual average contribution, and no additional money if their estimation was off the actual contribution by more than three points.

about an individual's contributions in the C-experiment: if an individual in the P-experiment indicates in his or her schedule that he or she will contribute *y* tokens if the others contribute *x* tokens on average, then the prediction for this individual in the C-experiment is to contribute *y* tokens if he or she believes that others contribute *x* tokens on average.

The sequence of experiments was reversed in the C-P sessions. The comparison of results from the P-experiments in the C-P sequence with those of the P-C sequence allows us to assess the relevance of experience with the public goods game for elicited cooperation preferences.

All experiments were computerized, using the software z-Tree (Fischbacher (2007)). The experiments were conducted in the computer lab of the University of Zurich. Our participants were undergraduates from various disciplines (except economics) from the University of Zurich and the Swiss Federal Institute of Technology (ETH) in Zurich. We conducted six sessions (three in the P-C sequence and three in the C-P sequence). In each of five sessions we had 24 participants and in one 20 participants. A post-experimental questionnaire confirmed that participants were largely unacquainted with one another. Our 140 participants were randomly allocated to the cubicles in each session, where they took their decisions in complete anonymity from the other subjects. On average, participants earned 35 Swiss Francs (roughly $30, including a show-up fee of 10 Swiss Francs).[9] Each session lasted roughly 90 minutes.

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[9] During the experiment subjects earned their payoffs in "points" (according to (1) and the earnings from correct belief estimates). At the end of the experiment, we exchanged the accumulated sum of points at an exchange rate of 1 point = CHF 0.35 for the points earned in the P-experiment and at a rate of 1 point = CHF 0.07 for the points earned in the C-experiment.

II. Results

We organize the discussion of our results as follows: In section A, we document the decline of cooperation. In section B, we present the extent of heterogeneity in people's cooperation preferences and actual contribution patterns. In the remaining sections, we analyze behavior in the C-experiment. We show how subjects form their beliefs (section C) and how their contribution decisions are related to the elicited preferences in the P-experiment (section D). We conclude in section E with a simulation study in which we assess how the belief process and subjects' preferences affect the decline of cooperation.

A. *The Decline of Cooperation*

Figure 1 sets the stage for our analysis, which aims to explain the decline of cooperation. The figure shows the temporal patterns of cooperation and beliefs for each of our six sessions separately.

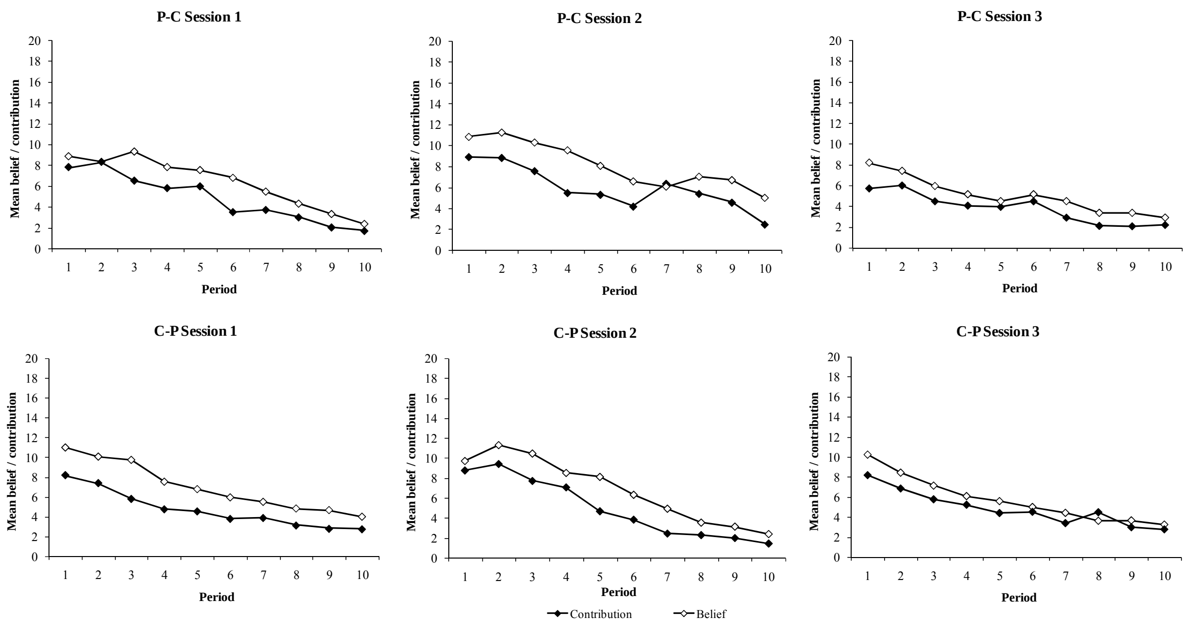


FIGURE 1. MEAN BELIEFS AND CONTRIBUTIONS OVER TIME.

Figure 1 conveys four unambiguous messages. First, contributions and beliefs decline in six out of six sessions. Second, behavior in the six sessions is very similar. Third, contributions are lower than beliefs in almost all instances. Finally, mean period contributions and beliefs are highly significantly positively correlated in all six sessions (Spearman rank correlation tests, p<0.007). This finding is consistent with previous observations in public goods games where beliefs were elicited (e.g., Weimann (1994); Croson (2007); Neugebauer, et al. (Forthcoming)).

B. *Heterogeneous Preferences and Contributions*

Recall that we have a complete contribution schedule from each participant that indicates how much he or she is prepared to contribute as a function of others' contribution. A simple way of characterizing heterogeneity is to look at the slope (of a linear regression) of the schedule and the mean contribution in the schedule. For instance, a free rider's schedule consists of zero contributions for all contribution levels of other group members. Therefore, his slope and mean contribution are zero. An unconditional cooperator, who contributes 20 tokens for all others' contribution levels, has a mean contribution of 20 and a slope of zero. A perfect conditional cooperator, who contributes exactly the amount others contribute, has a slope of one and a mean contribution of 10 tokens. Figure 2A depicts the results separately for the C-P and the P-C experiments. The *x*-axis shows the slope of the schedules and the *y*-axis the average contribution in the schedule. The dots in Figure 2A correspond to individual observations, and the size of a dot to the number of observations it represents.

Figure 2A shows two things. First, there is a large degree of heterogeneity.[10] Free riders (located at 0-0) and perfect conditional cooperators (at 1-10) are relatively the largest group of

[10] This evidence is consistent with other studies using different methods. See, e.g., Bardsley and Moffatt (2007); Kurzban and Houser (2005); Burlando and Guala (2005); Kocher, et al. (2008); Muller, Sefton, Steinberg and Vesterlund (2008); Duffy and Ochs (Forthcoming); and Herrmann and Thöni (forthcoming).

subjects. We also find a few participants who contribute an unconditional positive amount (along the *y*-axis, at *x*=0). A large number of participants has a positive mean contribution and a positive slope; a few participants have a negatively-sloped schedule (that is, they contribute more the less others contribute). Second, the distribution between the C-P and the P-C sessions is very similar. Mann-Whitney tests do not allow the rejection of the null hypotheses that both means and slopes are equally distributed between the treatments ($p>0.87$).[11] Thus, elicitation of preferences before subjects actually experienced contributions to the public good (in the P-C sessions) or after (in the C-P sessions) did not affect the elicited preferences. This is an important finding for our interpretation that the P-experiment elicits cooperation preferences. It shows that participants in the C-P sessions who have experienced actual contribution behavior do not express different cooperation preferences than do participants in the P-C sessions who are inexperienced in actual game playing when they express their preferences.[12]

[11] In Figure 2 we looked at the slope and mean contribution of a subject's schedule. However, qualitatively, we get very similar results if we look at Spearman rank order correlation coefficients, linear correlation coefficients, and slopes and intercepts of linear regressions. In all cases p-values of Mann-Whitney tests that compare the C-P and the P-C experiments yield $p>0.275$.

[12] The elicited contribution schedules in our study are also not significantly different from FGF ($\chi 2$-test, $p=0.729$). According to the FGF-classification, 55 percent are conditional cooperators, 23 percent are free riders, and the rest are unclassifiable or follow more complicated patterns. See an earlier version (Fischbacher and Gächter (2006)) for further details.

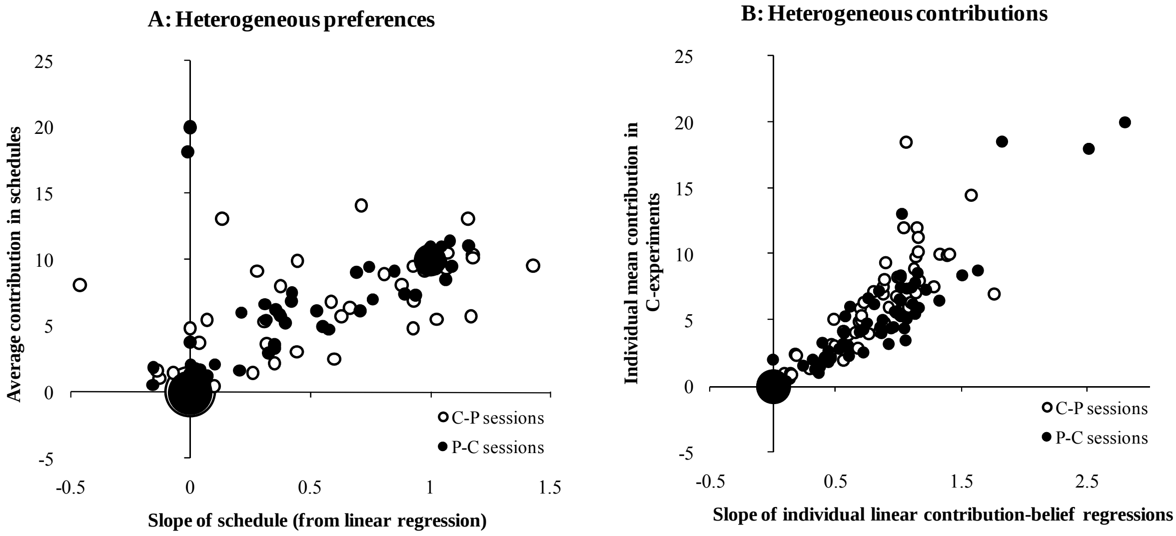


FIGURE 2. HETEROGENEOUS CONTRIBUTION PREFERENCES (PANEL A) AND ACTUAL CONTRIBUTIONS AS A FUNCTION OF BELIEFS (PANEL B).

Figure 2B shows a scatter plot of individual slopes of linear regressions (estimated without intercepts) of contributions on beliefs on the *x*-axis, and average contributions in the C-experiment on the *y*-axis. The dot size corresponds to the number of observations. Thus, the construction of Figure 2B is similar to Figure 2A. As in Figure 2A, we distinguish between the C-P and the P-C sessions. We find no sequence effect, neither with respect to average contributions nor with respect to slopes (Mann-Whitney tests, $p > 0.21$).[13]

Figure 2B reveals considerable heterogeneity in contribution behavior. Individual average contributions (depicted on the *y*-axis) vary between 0 and 20 tokens, although most participants contribute fewer than ten tokens on average. Fourteen percent of all participants contribute exactly zero in all ten periods. We find that the individual estimated slopes of the schedules from the P-experiment (Figure 2A) and the slopes of individual linear contribution-belief regressions in the C-experiments (Figure 2B) are highly significantly positively

[13] In Figure 2A the absolute number of [0-0]-combinations in the P-experiments was as follows: 18 in the C-P sessions and 14 in the P-C sessions. Six (seven) people are located at [1-1] in the C-P (P-C) sessions. In the C-experiments depicted in Figure 2B nine people are located at [0-0] in each of the C-P and the P-C sessions.

correlated (Spearman's ρ=0.39, p=0.0000). Average cooperation levels in the P-experiment and in the C-experiment are highly correlated as well (Spearman's ρ=0.40, p=0.0000). We interpret this as a first piece of evidence that expressed cooperation preferences and actual cooperation behavior are correlated at the individual level.

Before we investigate the link between beliefs, preferences, and contributions, we look at how people form beliefs in the C-experiment. Understanding belief formation is important because previous evidence, and our own, suggests that beliefs have an influence on contributions (see section II.D). It is therefore possible that belief formation contributes to the decay of cooperation if beliefs decline *per se*, that is, independently of contributions. In section E we will address this possibility and a competing hypothesis suggested by our findings on contribution preferences (Fig. 2A) – contributions decline because people are imperfect conditional cooperators.

C. *The Formation of Beliefs*

With the help of three econometric models, we investigate the question of how people form their beliefs about their group members' contribution in a given period. The estimation method is OLS with robust standard errors clustered on sessions as the independent units of observation.[14]

Model 1, which only includes "Period", simply confirms the impression from Figure 1 that beliefs decline significantly over time. However, this model cannot explain *why* there is a downward trend. Model 2 presents our model of belief formation. We argue that people form their beliefs in period t on the basis of their beliefs in period t-1 and the observation of others' contributions in period t-1. To see this, take periods 1 and 2. In period 1 a subject can only

[14] We estimated all models with random and fixed effects specifications, as well as with Tobit, with very similar results. For instance, the correlation coefficient of predicted values of the Tobit estimation and the OLS is 0.9995. Since the estimation results are very similar, we only report the OLS results for ease of interpretation.

rely on his or her intuitive ("home-grown") beliefs about others' contributions. In period 2, he or she also makes an observation about others' actual contribution in period 1. A subject may therefore update his or her period 2 belief on the basis of his or her period 1 belief and the observed period 1 contributions by others. A similar logic might hold in all remaining periods.

Model 2 presents the estimates of this belief formation model. We find that both "Belief (t-1)" and "Others' contribution (t-1)" are highly significantly positive; "Period" is insignificant, an order of magnitude smaller than in Model 1, and not significantly different from zero. We also estimated Model 2 separately for periods 1 to 5 and periods 6 to 10. The estimated coefficients are very similar in both halves of the experiment (Chow-test, $p>0.1$).[15] In other words, the way people form beliefs does not change over time.

Model 3 is the same as Model 2 except that we drop the insignificant variable "Period". The sum of coefficients of "Belief (t-1)" and "Others' contribution (t-1)" is insignificantly different from 1 ($F(1,5) = 0.41$, $p=0.549$).[16] We will use this model in our simulations below.

[15] We also applied an Arellano-Bond linear, dynamic panel-data estimation method (Arellano and Bond (1991)). However, there is still significant second order correlation ($p<0.05$, Arellano-Bond test) in the residuals implying that its estimates are inconsistent (Arellano and Bond (1991), pp. 281-282). Moreover, in simulations similar to those which we discuss in Section II.E it turned out that the Arellano-Bond estimates cannot explain the data patterns at all, whereas Model 3 can. As a further robustness check of Model 2 we also included up to three lags for the variable "Others' contributions". Only the first lag is significant; the higher lags are very small and insignificant.

[16] The period coefficient in Model 2 is insignificantly different from zero but highly significantly different from -0.761, the value of the period coefficient in Model 1. For reasons of comparability with Model 2 we estimated Model 1 for periods 2-10 only. The period coefficient in Model 1 for all periods is -0.753.

TABLE 1—FORMING BELIEFS.

	Dependent variable: Belief about other group members' contribution		
Model	1	2	3
Period	-0.761***	-0.079	
	(0.090)	(0.042)	
Others' contrib. (t-1)		0.394***	0.415***
		(0.023)	(0.020)
Belief (t-1)		0.549***	0.569***
		(0.037)	(0.036)
Constant	10.711***	0.835*	0.118
	(0.864)	(0.398)	(0.148)
Observations	1260	1260	1260
R-squared	0.26	0.64	0.64

Notes: OLS regressions with data from period 2 to 10. Robust standard errors (clustered on sessions) in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Given these results, we can summarize the belief formation process as follows: a subject's belief in a given period is a weighted average of what he or she *believed* about others in the previous period and his or her *observation* of the others' contribution in the previous period. We will use this result when we investigate the role of belief formation for explaining the dynamics of voluntary cooperation in section II.E.

D. *Explaining Contributions*

In this section we investigate determinants of people's contributions econometrically. We have three explanatory variables – "Period", "Predicted Contribution", and "Belief". We estimated three basic models which we document in Table 2. The estimation method is OLS with robust standard errors clustered on sessions as the independent units of observation.[17]

[17] As with belief formation, we estimated all models with random and fixed effects specifications, as well as with Tobit. Since the estimation results are very similar, we only report the OLS results.

TABLE 2—EXPLAINING CONTRIBUTIONS

	Dependent variable: Contribution					
Model	1	2	3	4a	4b	4c
Periods used	1-10	1-10	1-10	1-10	1-5	6-10
Subjects excluded+	no	no	no	yes	yes	yes
Period	-0.639	-0.060				
	(0.071)***	(0.056)				
Predicted		0.242	0.242	0.443	0.385	0.614
Contribution		(0.069)**	(0.069)**	(0.073)***	(0.074)***	(0.082)***
Belief		0.644	0.666	0.545	0.582	0.376
		(0.071)***	(0.059)***	(0.065)***	(0.065)***	(0.116)**
Constant	8.343	0.005	-0.473	-0.318	-0.204	-0.116
	(0.545)***	(0.569)	(0.244)	(0.312)	(0.541)	(0.378)
Observations	1400	1400	1400	1260	630	630
R-squared	0.10	0.34	0.34	0.38	0.33	0.33

Robust standard errors in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%.

+ Models 4a to 4c exclude (confused) subjects who, on the basis of the P-experiment could not be classified according to the FGF classification as either a "free rider", "conditional cooperator", or a "triangle contributor".

Model 1, which only includes "Period", confirms the impression from Figure 1 that contributions decline significantly over time. Model 2 adds the variables "Predicted Contribution" and "Belief". We find that both variables matter significantly. In other words, in the C-experiments, there is conditional cooperation on top of contribution preferences, but there is no significant decline in cooperation that is not explained by "Predicted Contribution" and "Belief" ("Period" is an order of magnitude smaller than in Model 1 and not significantly different from zero). Model 3 is the same as Model 2 but drops the insignificant variable "Period".[18]

The observations from models 2 and 3 raise two related questions: (i) Why is the coefficient on "Predicted Contribution" surprisingly low (it should be one if the elicited preferences would predict perfectly)? (ii) Why do people condition their contribution decision based not only on their preferences according to their predicted contribution but also on their

[18] One might worry about multi-collinearity in models 2 and 3 because beliefs enter the calculation of Predicted Contributions. Although Belief and Predicted Contribution are correlated (rho = 0.395), the variance inflation factor as an indicator of multi-collinearity is 1.22, which is below the critical value of 5.

beliefs? Regression models 4a to 4c shed light on the first question. These models are the same as model 3 but exclude "confused" subjects (10 percent) who, according to the classification proposed by FGF, could not be classified as either a free rider, a conditional cooperator, or as a triangle contributor. Excluding confused subjects seems justified because there is no reason why their unsystematic preferences in the P-experiment should predict behavior in the C-experiment. Model 4 shows that the coefficient on "Predicted Contributions" increases substantially once the confused subjects are excluded. Regression models 4b and 4c reveal that there is also a time trend in the relative importance of "Predicted Contributions" and "Beliefs". "Beliefs" seem to be more important for conditional cooperation in the first half than in the second half of the experiment (see also Figure B1). In the second half the coefficient on "Predicted Contributions" is substantially higher than in the first half and also exceeds the coefficient on "Beliefs".

Why do beliefs matter on top of contribution preferences? First, note that in the regressions 4a to 4c, the constant is not significantly different from 0, and the sum of the coefficients for "Predicted Contribution" and "Belief" add up to a number not significantly different from 1 (e.g., in regression 4a the sum equals 0.998; $F(1,5) = 0.08$, $p=0.7863$). Hence, according to these regressions, subjects contribute a weighted average of "Predicted Contribution" and "Belief". A contribution that matches the belief is by definition perfectly conditionally cooperative. Thus, subjects behave according to a contribution pattern that is inbetween their elicited contribution schedule and perfect conditional cooperation. Since most people's elicited contribution preferences lie below the diagonal, that is, below the schedule of perfect conditional cooperators, this intermediate contribution pattern lies above the predicted cooperation. This means that subjects are more cooperative in the C-experiment than predicted from their decisions in the P-experiment. Regressions 4b and 4c show that this is in particular the case in earlier periods; in later periods "Predicted Contribution" becomes more important than "Beliefs".

There are two potential explanations for why beliefs matter on top of "Predicted Contribution". First, subjects could have additional reasons for contributing in the C-experiment that were particularly important in the first periods and are not captured by the P-experiment. One obvious candidate reason is subjects' willingness to invest in cooperation in order to induce high beliefs and contributions in the population. Such a behavior could be motivated by selfishness (although this would not be rational because subjects are rematched after each round), or it could be motivated by altruism. Second, due to some form of "self-deception", reported beliefs could be lower than the beliefs people actually hold, for example in order to avoid disappointment. Admittedly, however, these are speculations, and our experiment is not designed to address them. Our experiment is designed to observe the role of beliefs and contribution preferences for the decline of cooperation, which we will discuss in detail in the next section.

E. *Why Do Contributions Decline?*

Because both beliefs and contribution preferences matter for determining contributions, the question arises as to how they each contribute to explaining the decline of cooperation. In this section we use simulation methods to understand two fundamental issues: do contributions decline because of contribution preferences and/or because of the way people form their beliefs? What is the role of preference heterogeneity? We use simulation methods because they allow us to use counter-factual assumptions which are helpful in disentangling the role of preferences and beliefs.

The simulations are based on a two-stage process. In the first stage, the simulated players form a belief about the other players' contributions. Then, players decide on a contribution, which they (partially) base on their beliefs. Before we address our two main questions, we make the following basic observations on the conditions under which such a two-stage process can explain the decline of cooperation. Contributions will not decline if contributions or beliefs are independent of experience and time, that is, if people are *unconditionally cooperative* or if they have *unconditional beliefs*. Thus, to explain the decline of cooperation both beliefs and contributions need to be *conditional*. Of course, this is only a necessary condition. Suppose, for instance, that belief updating is naïve (that is, beliefs are equal to the average contribution in the previous period) and contributions match beliefs. In this case cooperation will be stable. Thus, cooperation will only decline if either beliefs are lower than naïve beliefs or if people are imperfect conditional cooperators. Our simulations will shed light on the relative importance of these two possibilities.

To be able to disentangle in our simulations the roles of beliefs and contributions for the decay of cooperation we make (counterfactual) assumptions about cooperation behavior and belief formation. With regard to cooperation behavior we will assume that the simulated players (i) contribute according to preferences we have observed in the P-experiment or (ii) they (counterfactually) are all perfect conditional cooperators. The second dimension concerns belief updating. Here we assume that players either (i) update according to the weighted-average model outlined above (Model 3 of Table 1) or (ii) they (counterfactually) form their beliefs naïvely. Thus, we have 2×2 combinations of assumptions about cooperation behavior and belief formation. Starting from the benchmark of perfect conditional cooperation and naïve beliefs we can hold one dimension constant and change the other one to see whether belief formation or contributions are responsible for the decay of cooperation.

The simulations use the exact matching structure that was in place in each period of a given session.[19] As starting values we use the actual contributions and beliefs in period 1. The details of our 2×2-methodology are as follows:

1. In our benchmark model, the *pCC_N-model*, we assume that all players are perfect conditional cooperators, that is, players match their beliefs exactly: *Contribution*(t) =

[19] That is, in simulation models 3 and 4 described below we replace each human participant by his or her contribution schedule and observe how contributions evolve given our assumptions about belief updating.

Belief(t). Beliefs are formed naïvely (denoted by sub-index N), that is, *Belief*(t) = *Others' Contribution*(t-1). Under these assumptions contributions are obviously stable at the initial level of contributions.

2. The pCC_A-*model* keeps the assumption of perfect conditional cooperation but assumes that beliefs are formed according to the actual beliefs estimated in Model 3 in Table 1 (denoted by sub-index A). In this model, contributions will only drop if beliefs *per se* become inherently pessimistic.[20] Thus, this model reveals the extent to which the belief formation process itself is responsible for the decay of cooperation.
3. The aCC_A-*model* keeps the actual beliefs assumption but replaces perfect conditional cooperation by actual conditional cooperation as elicited in the P-experiment (denoted aCC). The weights on contribution preferences and beliefs correspond to the estimated parameters of Model 3 in Table 2. This simulation model shows the combined predicted effects of actual belief updating and actual contribution preferences for the decline of cooperation.
4. Finally, in the aCC_N-*model* the simulated players determine their contributions according to the actual conditional contribution schedules but beliefs are updated naïvely. By assuming naïve beliefs, this model reveals the extent to which the cooperation preferences themselves contribute to the decline of cooperation.

We address the second question of this section, concerning the role of heterogeneity for the decline of cooperation, with two counter-factual models in which we remove heterogeneity from the contribution process. By comparing these models with the actual contributions we can assess the role of heterogeneity. The models differ only in their assumptions of the belief formation process:

[20] "Virtual learning" (Weber (2003)), that is learning with no feedback by just thinking about the problem for several periods is a possible reason for this "pessimism".

5. In the *iCC_N-model* players are assumed to be identical conditional cooperators (iCC). As a schedule, we use an *average* linear one: *Contribution* = α + *k***Contribution of others*. The estimates from the data of our P-experiment return α=0.956 and *k*=0.425. Therefore, in this model *Contribution* = 0.956 + 0.425**Contribution of others*. The iCC_N-model assumes that belief formation is naïve. Thus, in comparison to the aCC-models, the iCC_N-model informs us about the role of preference heterogeneity of players under naïve belief formation.
6. Finally, the *iCC_A-model* is the same as the iCC_N-model but assumes actual belief formation.

Figure 3 depicts the simulation results. We compare the simulation results to the actual average contributions ("data"). Panel A illustrates the implications of our simulation models. For this purpose we use the average over all six sessions. Panel B depicts the predictive success of the aCC_A-model at the session level. We illustrate the results of the aCC_A-model because it is the only simulation model that does not use counter-factual assumptions.

Since the average initial contribution is 8 tokens, the pCC_N-benchmark implies that contributions are stable at the initial level. The pCC_A-model predicts that contributions will decline to the extent beliefs decline. The simulation results return stable contributions. To understand this finding recall that according to our model of actual belief formation (Model 3 of Table 1) *Belief*(t) = 0.415**Others' contribution*(t-1) + 0.569**Belief*(t-1) + 0.118. By assumption of perfect conditional cooperation *Contribution*(t-1) = *Belief*(t-1) for all players and therefore *Belief*(t) = (0.415 + 0.569)**Belief*(t-1). The sum of the two coefficients (0.415 and 0.569) equals 0.984, which is insignificantly different from 1 (F-test, p=0.549). This observation implies that, under perfect conditional cooperation, beliefs remain constant. Hence, we conclude that the belief formation process *per se* does not contribute to the decline of cooperation.[21] Put differently, beliefs decline because contributions decline and not because people become inherently more pessimistic over time, irrespective of contribution behavior.

The aCC_A-model and the aCC_N-models replace the assumption of perfect conditional cooperation with people's actual contribution preferences as elicited in the P-experiment. Both simulation models predict a decline of cooperation. Since beliefs *per se* are not responsible for the unraveling of cooperation we conclude that the decline is triggered by people's contribution preferences. The aCC_N-model predicts a much faster decline than we actually observe in the data. By contrast, the aCC_A-model tracks the actual data quite well. To evaluate this model statistically, we regress the actual contributions on the predicted contributions (using OLS). We find that the model coefficient (robust s.e.)) equals 1.002 (0.030), which is not significantly different from 1. The model constant (robust s.e.) equals –0.036 (0.188), which is not significantly different from 0. Thus, on average, the aCC_A-model predicts the data very well. This is also apparent from Figure 3B, which compares the session averages with the predictions from the aCC_A-model applied to the respective session.

Finally, we can assess the importance of preference heterogeneity by comparing the aCC-models with the iCC-models (under both naïve and actual belief updating). By construction, the iCC-models eliminate preference heterogeneity by replacing the individual preference schedules by the average preference schedule, whereas the aCC-models use the individual preference schedules. The comparison shows that preference heterogeneity is surprisingly unimportant in explaining the decay of cooperation because the aCC-models and the iCC-models match each other closely under both naïve and actual belief updating. Heterogeneity matters only towards the end of the experiment. In the iCC-models contributions stop

[21] If we disregard the constant and take the coefficient of 0.984 literally, the belief formation process *per se* can account for a decline of cooperation of at most 14 percent (i.e., $1-(1-0.984)^9=0.135$) over the nine remaining periods after period 1.

declining towards the end while the models with heterogeneous preferences correctly predict the decline also in the last periods. Due to more realistic belief updating, the iCC_A-model matches the data better than the iCC_N-model.

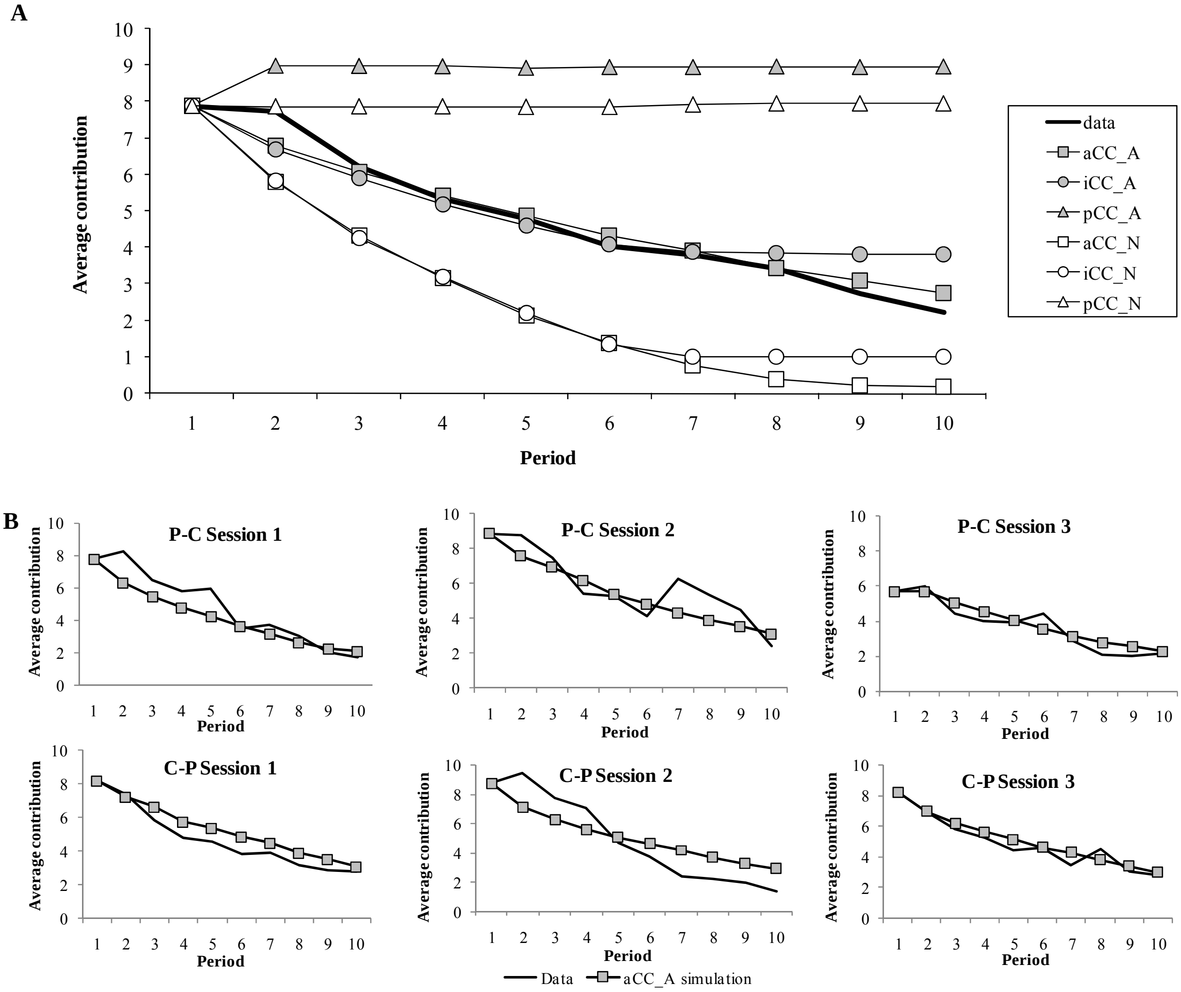


FIGURE 3. EXPLAINING THE DECLINE OF COOPERATION – SIMULATION RESULTS. PANEL A: DISENTANGLING THE SOURCES OF DECLINE. PANEL B: PREDICTING THE DECLINE FOR EACH OF THE SIX SESSIONS, USING THE aCC_A-MODEL.

III. Summary

Our goal in this study was to investigate the role of social preferences and beliefs about others' contributions for the dynamics of free riding in public goods experiments. We achieved this by eliciting preferences in one specially-designed game (the "P-experiment") and observing contributions and beliefs in ten one-shot standard public goods games with random matching (the “C-experiments”).

We find substantial heterogeneity in elicited cooperation preferences as well as in actual contribution behavior. Belief formation is best described as a weighted average of own beliefs and others’ contributions in the previous period. Contributions are determined significantly by people’s contribution preferences and their beliefs, which matter on top of contribution preferences. Surprisingly, people in the C-experiment are more conditionally cooperative than suggested by the elicited preferences of the P-experiment.

These observations imply that for understanding the dynamics of free riding behavior one needs to understand both the role of contribution preferences and beliefs. Our findings show that contributions decline (in randomly composed groups) because the majority of people are imperfect conditional cooperators. Beliefs decline because contributions decline, and not vice versa. After some time all types *behave* like income-maximizing free riders, even though only a minority is motivated by pure income-maximization alone.

APPENDIX: INSTRUCTIONS FOR THE EXPERIMENT

This is a translation of the original German version. We present the instructions of the P-C experiments here; those of the C-P experiments were adapted accordingly. They are available upon request.

Instructions for the P-Experiment

You are now taking part in an economics experiment financed by the Swiss Science Foundation. If you read the following instructions carefully, you can – depending on your decisions – earn some more money in addition to the 10 Francs, which you can keep in any case. The entire amount of money which you earned with your decisions will be added up and paid to you in cash at the end of the experiment. These instructions are solely for your private information. **You are not allowed to communicate during the experiment.** If you have any questions, please ask us. Violation of this rule will lead to the exclusion from the experiment and all payments. If you have questions, please raise your hand. A member of the experimenter team will come to you and answer them in private.

We will not speak of Francs during the experiment, but rather of points. Your whole income will first be calculated in points. At the end of the experiment, the total amount of points you earned will be converted to Francs at the following rate:

1 point = 35 centimes.

All participants will be divided in groups of four members. **Except for us - the experimenters - no one knows who is in which group.**

We describe the exact experiment process below.

<u>The decision situation</u>

You will learn how the experiment will be conducted later. We first introduce you to the basic decision situation. You will find control questions at the end of the description of the decision situation that help you to understand the decision situation.

You will be a member of a group consisting of **4 people**. Each group member has to decide on the allocation of 20 points. You can put these 20 points into your **private account** or you can invest them **fully or partially** into a project. Each point you do not invest into the project, will automatically remain in your private account.

<u>Your income from the private account:</u>

You will earn one point for each point you put into your private account. For example, if you put 20 points into your private account (and therefore do not invest into the project) your income will amount to exactly 20 points out of your private account. If you put 6 points into your private account, your income from this account will be 6 points. **No one except you earns something from your private account.**

<u>Your income from the project</u>

Each group member will profit equally from the amount you invest into the project. On the other hand, you will also get a payoff from the other group members' investments. The income for each group member will be determined as follows:

Income from the project *= sum of all contributions × 0.4*

If, for example, the sum of all contributions to the project is 60 points, then you and the other members of your group each earn 60 × 0.4 = 24 points out of the project. If four members of the group contribute a total of 10 points to the project, you and the other members of your group each earn 10 × 0.4 = 4 points.

<u>Total income:</u>

Your total income is the sum of your income from your private account and that from the project:

Income from your private account (= 20 – contribution to the project) *+ Income from the project (= 0.4 × sum of all contributions to the project)*
Total income

Control questions:

Please answer the following control questions. They will help you to gain an understanding of the calculation of your income, which varies with your decision about how you distribute your 20 points. *Please answer all the questions and write down your calculations.*

1. Each group member has 20 points. Assume that none of the four group members (including you) contributes anything to the project.
   What will *your* total income be? ___________
   What will the total income of the *other* group members be? ___________
2. Each group member has 20 points. You invest 20 points in the project. Each of the other three members of the group also contributes 20 points to the project.
   What will *your* total income be? ___________
   What will the total income of the *other* group members be? ___________

3. Each group member has 20 points. The other 3 members contribute a total of 30 points to the project.

   a) What will *your* total income be, if you – in addition to the 30 points – invest 0 points into the project?
   ***Your* Income** ___________
   b) What will *your* total income be, if you – in addition to the 30 points – invest 8 points into the project?
   ***Your* Income** ___________
   c) What will *your* total income be, if you – in addition to the 30 points – invest 15 points into the project?
   ***Your* Income** ___________

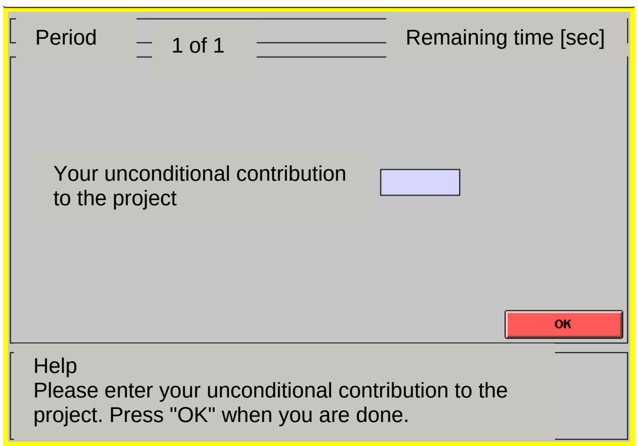
4. Each group member has 20 points at his or her disposal. Assume that you invest 8 points to the project.

   a) What is your total income if the other group members – in addition to your 8 points – contribute another 7 points to the project?
   ***Your* Income** ___________
   b) What is your total income if the other group members – in addition to your 8 points – contribute another 12 points to the project?
   ***Your* Income** ___________
   c) What is your income if the other group members – in addition to your 8 points – contribute another 22 points to the project?
   ***Your* Income** ___________

The Experiment

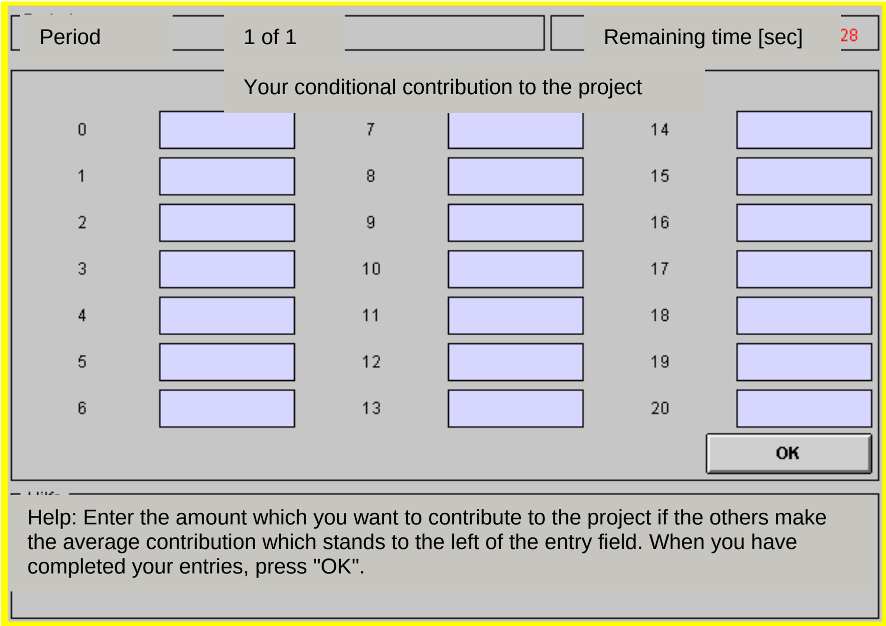
The experiment includes the decision situation just described to you. You will be paid at the end of the experiment based on the decisions you make in this experiment. The experiment will only be conducted **once**. As you know, you will have 20 points at your disposal. You can put them into a private account or you can invest them into a project. Each subject has to make **two types** of decisions in this experiment, which we will refer to below as the **"unconditional contribution"** and **"contribution table"**.

- You decide how many of the 20 points you want to invest into the project in the **unconditional** contribution. Please indicate your contribution in the following computer screen:



After you have determined your unconditional contribution, please click "OK".

- Your second task is to fill in a "contribution table" where you indicate how many tokens **<u>you</u> want to contribute** to the project **for each possible average contribution of the <u>other</u> group members** (rounded to the next integer). You can condition your contribution on that of the other group members. This will be immediately clear to you if you take a look at the following table. This table will be presented to you in the experiment:



The numbers are the possible (rounded) average contributions of the **other** group members to the project. You simply have to insert how many tokens you will contribute to the project into each input box – conditional on the indicated average contribution. **You have to make an entry into each input box**. For example, you will have to indicate how much you contribute to the project if the others contribute 0 tokens to the project, how much you contribute if the others contribute 1, 2, or 3 tokens, etc. You can insert **any integer numbers from 0 to 20** in each input box. Once you have made an entry in each input box, click "OK".

After all participants of the experiment have made an unconditional contribution and have filled in their contribution table, a random mechanism will select a group member from every group. Only **the contribution table will be the payoff-relevant decision for the randomly determined subject**. Only the **unconditional contribution** will be the payoff-relevant decision for the **other three group members** not selected by the random mechanism. You obviously do not know whether the random mechanism will select you when you make your unconditional contribution and when you fill in the contribution table. You will therefore have to think carefully about both types of decisions because both can become relevant for you. Two examples should make this clear.

<u>EXAMPLE 1</u>: Assume that **the random mechanism selects you. This implies that your relevant decision will be your contribution table**. The unconditional contribution is the relevant decision for the other three group members. Assume they made unconditional contributions of 0, 2, and 4 tokens. The average contribution of these three group members, therefore, is 2 tokens. If you indicated in your contribution table that you will contribute 1 token if the others contribute 2 tokens on average, then the total contribution to the project is given by 0+2+4+1=7 tokens. All group members, therefore, earn 0.4×7=2.8 points from the project plus their respective income from the private account. If, instead, you indicated in your contribution table that you would contribute 19 tokens if the others contribute two tokens on average, then the total contribution of the group to the project is given by 0+2+4+19=25. All group members therefore earn 0.4×25=10 points from the project plus their respective income from the private account.

<u>EXAMPLE 2:</u> Assume **that the random mechanism did not select you,** implying that **the unconditional contribution is taken as the payoff-relevant decision** for you and two other group members. Assume your unconditional contribution is 16 tokens and those of the other two group members are 18 and 20 tokens. Your average unconditional contribution and that of the two other group members, therefore, is 18 tokens. If the group member whom the random mechanism selected indicates in her contribution table that she will contribute 1 token if the other three group members contribute on average 18 tokens, then the total contribution of the group to the project is given by 16+18+20+1=55 tokens. All group members will therefore earn 0.4×55=22 points from the project plus their respective income from the private account. If, instead, the randomly selected group member indicates in her contribution table that she contributes 19 if the others contribute on average 18 tokens, then the total contribution of that group to the project is 16+18+20+19=73 tokens. All group members will therefore earn 0.4×73=29.2 points from the project plus their respective income from the private account.

The random selection of the participants will be implemented as follows. Each group member is assigned a number between 1 and 4. As you remember, a participant, namely the one with the number 11, was randomly selected at the very beginning of the experiment. This participant will throw a 4-sided die **after** all participants have made their unconditional contribution and have filled out their contribution table. The resulting number will be entered into the computer. If participant 11 throws the membership number that was assigned to you, then your contribution table will be relevant for you and the unconditional contribution will be the payoff-relevant decision for the other group members. Otherwise, your unconditional contribution is the relevant decision.

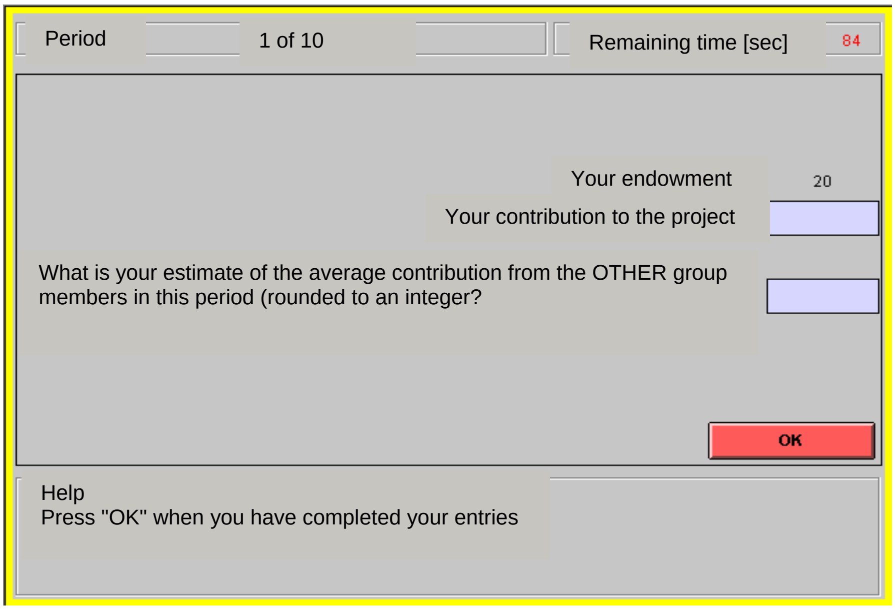
Instructions for the C-Experiment

We will now conduct another experiment. This experiment lasts **10 periods**, in which you and the other group members have to make decisions. As in the other experiment, every group consists of **4 people**. The formation of the group changes at random after every period. **So your group consists of <u>different</u> people in all 10 periods.** The whole experiment is finished after these 10 periods,.

The decision situation is the same as that described on page 2 of the instructions of the previous experiment. Each member of the group has to decide about the usage of the 20 points. You can put these 20 points into your private account or you can invest them fully or partially into a project. Each point you do not invest into the project is automatically placed into your private account. Your income will be determined in the same way as before. Reminder:

Income from your private account (= *20 – contribution to the project*)
+ *Income from the project* (= *0.4* × *sum of all contributions to the project*)
Total income
1 point = 7 centimes!

The decision screen, which you will see in every period, looks like this:



As you can see, you have to make two inputs:

1. First you have to **decide on your contribution to the project**, that is, you have to decide how many of the 20 points you want to contribute to the project, and how many points you want to put into your private account. This decision is the same as the unconditional contribution of the previous experiment. You only make unconditional decisions in this experiment. There is **no contribution table**.

2. Afterwards you have to estimate the average contribution to the project (rounded to an integer) of the other three group members of this period. You will be paid for the accuracy of your estimate:

    - If your estimate is exactly right (that is, if your estimate is **exactly** the same as the actual average contribution of the other group members), you will get **3 points** in addition to your other income from the experiment.
    - If your estimate deviates by one point from the correct result, you will get 2 additional points.
    - A deviation by 2 points still earns you 1 additional point.
    - If your estimate deviates by 3 or more points from the correct result, you will not get any additional points.

After these 10 periods are over, the whole experiment is finished and you will receive:

\+ your income from the first experiment
\+ your income from the second experiment (including your income from your correct estimates)
= total income from both experiments
\+ 10 Francs show up fee !

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