UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

WORKING PAPERS IN ECONOMICS

No 683

Cooperation under risk and ambiguity

Lisa Björk, Martin Kocher, Peter Martinsson, and Pham Nam Khanh

December 2016

ISSN 1403-2473 (print)
ISSN 1403-2465 (online)

Department of Economics
School of Business, Economics and Law at University of Gothenburg
Vasagatan 1, PO Box 640, SE 405 30 Göteborg, Sweden
+46 31 786 0000, +46 31 786 1326 (fax)
www.handels.gu.se   info@handels.gu.se

EFMD EQUIS ACCREDITED

Cooperation under risk and ambiguity*

Lisa Björk †1, Martin Kocher ‡1,2,3, Peter Martinsson §1,4 and Pham Nam Khanh ¶5

[1] *University of Gothenburg, Sweden*
[2] *Institute of Advanced Studies, Vienna, Austria*
[3] *LMU Munich, Germany*
[4] *Linköping University, Sweden*
[5] *Ho Chi Minh City University of Economics, Vietnam*

December 21, 2016

Abstract

The return from investments in public goods is almost always uncertain, in contrast to the most common setup in the existing empirical literature. We study the impact of natural uncertainty on cooperation in a social dilemma by conducting a public goods experiment in the laboratory in which the marginal return to contributions is either deterministic, risky (known probabilities) or ambiguous (unknown probabilities). Our design allows us to make inferences on differences in cooperative attitudes, beliefs, and one-shot as well as repeated contributions to the public good under the three regimes. Interestingly, we do not find that natural uncertainty has a significant impact on the inclination to cooperate, neither on the beliefs of others nor on actual contribution decisions. Our results support the generalizability of previous experimental results based on deterministic settings. From a behavioural point of view, it appears that strategic uncertainty overshadows natural uncertainty in social dilemmas.

JEL classification: C91, D64, D81, H41.

Keywords: Public good, conditional cooperation, experiment, uncertainty, risk, ambiguity

* **Acknowledgments**: Financial support from Formas through the Human Cooperation to Manage Natural Resources (COMMONS) programme is gratefully acknowledged. We kindly thank MELESSA of the University of Munich for providing laboratory resources. We would also like to thank Andreas Lange and seminar participants at the IAREP-SABE conference (Sibiu, 2015) and the 10th Nordic conference on behavioural and experimental economics (Tampere, 2015) for helpful comments and suggestions.

† Department of Economics, University of Gothenburg, Box 640, 405 30 Gothenburg, Sweden. Email: lisa.bjork@economics.gu.se

‡ Department of Economics, LMU Munich, Geschwister-Scholl-Platz 1, D-80539 Munich, Germany. E-mail: martin.kocher@lrz.uni-muenchen.de

§ Department of Economics, University of Gothenburg, Box 640, 405 30 Gothenburg, Sweden. E-mail: peter.martinsson@economics.gu.se

¶ School of Economics, Ho Chi Minh City University of Economics, Ho Chi Minh City, Viet Nam. E-mail: khanhnam@ueh.edu.vn

1 Introduction

Understanding cooperation in social dilemmas is a major research theme in the social sciences in recent decades. Social dilemmas are characterized by individual incentives to free ride on the cooperation of others at an efficiency cost to the whole group or society. In economics, this type of situation has been studied experimentally by applying variants of the prisoner's dilemma game and, more recently, the public goods game (Chaudhuri, 2011). Almost the entire experimental literature assumes that benefits from public goods, i.e. the return that cooperation yields to the group, are deterministic. Since the contributions of other group members are unknown in a simultaneous setting, returns from public goods are usually characterized by strategic uncertainty. However, the literature so far has neglected the uncertain nature of many public goods, i.e. even when total contributions of other group members are known, the individual and collective benefits from the public good may still be uncertain. In other words, the returns from investing in a public good could be risky or truly uncertain (ambiguous).

For example, when countries invest in CO2 emission reduction, they have only a vague idea about how their investment translates into the benefit of a more slowly rising temperature on Earth[1]. When a team member invests effort in joint production, the benefit of one extra hour of work for the whole team might be uncertain. When fishers limit their fishing activity to contribute to the replenishment of the stock in a lake, they do not know how exactly this contribution converts into stock protection. In short, although we know a lot about the strategic uncertainty in social dilemmas and how it affects the decision to contribute or not, we know almost nothing about how people contribute under natural uncertainty.

Does natural uncertainty of the benefits in the provision of a public good increase or decrease individual contributions? Does natural uncertainty interact with strategic uncertainty? How does it affect the efficiency of public good provision? We answer these questions by implementing a laboratory experiment that draws on the linear voluntary contribution mechanism (VCM). We implement a standard version of the simultaneous VCM that is very close to the one used in Fischbacher and Gächter (2010) and

[1]The Green Climate Fund was initiated at the 21st United Nations Climate Change Conference in Paris 2015. The goal is to raise USD 100 billion per year by 2020. The funds will be used to assist developing countries in mitigation and adaptation efforts to fight climate change (Green Climate Fund, 2014). Contributions to the fund are obviously characterized by a high degree of uncertainty; both strategic in terms of the contribution decisions of others, and natural as the impact of the monetary contributions on the intended purpose of combating climate change is truly uncertain.

that allows us to compare our results directly with a large body of existing literature. The experiment starts with a one-shot game that elicits unconditional and conditional contributions (e.g. Fischbacher et al., 2001, 2012; Kocher et al., 2008; Martinsson et al., 2015). This provides us with a characterization of cooperating types and enables a comparison of contributions in a situation that includes strategic uncertainty (i.e. the unconditional simultaneous contribution decision) to contributions in a situation that isolates strategic uncertainty (i.e. the conditional contribution schedule where others' contributions are fixed). After the one-shot game, participants in the experiment play a repeated game with a finite horizon, eliciting only unconditional contributions.

By introducing three between-subject conditions, we address our research questions related to the impact of the natural uncertainty of the public good returns on contribution behaviour. Depending on the condition, the marginal per capita return (MPCR) from investment in the public good is either (i) deterministic (CONTROL condition), (ii) risky, with a 50% probability of being either low or high (RISK condition) or (iii) ambiguous, with an Ellsberg urn (Ellsberg, 1961) determining whether the return is high or low (AMBIGUITY condition)[2]. Regardless of the condition and the realization of the MPCR in conditions (ii) and (iii), the contribution decision remains a social dilemma, i.e. the MPCR is always set so that it is individually optimal to free ride (to contribute nothing to the public good) for a money-maximizing decision maker, regardless of risk/ambiguity attitude. For all conditions, it is ex-ante and ex-post socially optimal to cooperate (to contribute the entire endowment), regardless of risk- and ambiguity attitudes. In order to allow a direct comparison across conditions, the deterministic MPCR is set to the expected value of the MPCR in the risky condition and to the implied expectation in the ambiguous condition.

For what follows, it is helpful to clearly define terms: We use the term uncertainty as an umbrella term for risk (known probabilities) and ambiguity (unknown probabilities). Natural uncertainty refers to uncertainty implied by nature, whereas strategic uncertainty means uncertainty that originates from the choice of other decision makers[3]. Natural uncertainty can stem from for example the nature of the public good

[2]It is a well-established fact that, for (implied) probabilities around 50%, decision makers in lottery choices on average display an additional aversion against ambiguity, over and above the generally observed risk aversion (Kocher et al., 2015a).

[3]There is evidence that individuals dislike risk originating from strategic interactions more than risk that does not originate from deliberate (human) choices. In the literature, this disparity is referred to as betrayal aversion (see e.g. Bohnet and Zeckhauser, 2004; Bohnet et al., 2008, 2010 and the discussion in Section 2).

returns, from conflicting pieces of information, from limited experience with a certain phenomenon and from a lack of understanding of the interplay between variables affecting an outcome.

While the early literature on decision making under uncertainty focused almost exclusively on individual settings, there is a rapidly growing literature in behavioural and experimental economics on the effects of risk taking in settings that involve social interaction, such as social comparison and peer effects, and settings that involve risky decision making for others[4]. However, the existing literature examining the effects of natural uncertainty on cooperation in social dilemmas or closely related setups is very small (Berger and Hershey, 1994; Dickinson, 1998; Levati et al., 2009; Levati and Morone, 2013; Dannenberg et al., 2015; Köke et al., 2015). We discuss the results and experimental setups of these studies in detail in Section 2.

Our paper provides several innovations compared with the existing literature: First, our design and results are directly comparable to a large literature of VCM games with deterministic MPCRs. In contrast, however, most of the existing studies on natural uncertainty and cooperation deviate from the VCM in several dimensions (for instance by introducing thresholds, loss framing, etc.). Second, we can clearly distinguish between strategic uncertainty and natural uncertainty and, further, assess the effects of natural uncertainty in situations that do and do not involve strategic uncertainty. Third, we differentiate between risk and ambiguity concerning the MPCR in the VCM. This is an important distinction since ambiguity seems to better resemble the nature of the uncertainty related to benefits from investments in most of the above-mentioned examples of social dilemmas outside the laboratory (Boucher and Bramoullé, 2010; Millner et al., 2013). Fourth, we can compare contribution behaviour in a one-shot respectively a repeated setting using partner matching, which allows us to study the importance of reputation building.

Our decision environment - the standard VCM, altered by the introduction of risky or ambiguous benefits from the public good in the respective conditions - is set up such that theoretical predictions are as straightforward as possible. As already mentioned, free riders contribute nothing in all three conditions regardless of their risk/ambiguity attitudes (see also Kocher et al., 2015b). This is not true for decisions makers with social preferences as can be demonstrated by specifying a model with altruistic prefer-

[4] See e.g. Bolton and Ockenfels, 2010; Linde and Sonnemans, 2012; Brock et al., 2013; Cappelen et al., 2013; Gächter et al., 2013; Bursztyn et al., 2014; Lahno and Serra-Garcia, 2015; Krawczyk and Le Lec, 2016.

ences implemented in the most parsimonious way possible. We show that depending on the exact specification of risk preferences, reflected by the concavity of the utility function, such a model renders two predictions; one where natural uncertainty with respect to the benefits of contributions do not affect decisions of neither risk-averse nor ambiguity-averse decision makers, and one where risk- and ambiguity-averse decision makers have a stronger inclination to contribute to the public good under uncertain returns. These results follow from the linearity of our model; linear models of altruism provide a cut-off level of the altruism parameter that determines whether a decision maker contributes nothing or her entire endowment to the public good. For certain specifications, this cut-off level is lowered for risk- and ambiguity-averse decision makers under uncertain public good returns, which leads to higher average contributions. Evidently, the choice of model and specification is somewhat arbitrary which motivates empirical results.

The results from our laboratory experiment, on a large sample, show that risky and ambiguous benefits from the public good have only a very weak effect on average contribution levels. If anything, contributions are slightly lower under natural ambiguity than under natural risk or a deterministic setting. Furthermore, we do not find an interaction between strategic uncertainty and natural uncertainty. In summary, from a behavioural point of view, it appears that strategic uncertainty overshadows natural uncertainty in social dilemmas. We think that this is an informative and important null result. Our findings are highly relevant from a methodological perspective as they establish that results from experimental linear public goods with deterministic returns translate to more realistic setups with uncertain benefits. Thus, it seems that it is perfectly fine to abstract from uncertainty when studying social dilemmas as long as it does not change the nature (Köke et al., 2015) or perception (e.g. Dannenberg et al., 2015) of the game. We conclude that the usage of standard, more parsimonious experimental designs is justified. Our results also have implications for the design of mechanisms aimed at alleviating social dilemma situations outside the laboratory; since natural uncertainty seems to play a less important role in determining decision-making in social dilemmas that intuition would imply, we should probably direct efforts towards designing mechanisms that reduce strategic uncertainty. However, if possible, we should aim at designing more deterministic mechanisms of return to investment, since - if at all - there is a tendency of less cooperation under uncertainty.

The rest of the paper is organized as follows. Section 2 provides a very brief overview of the relevant literature. In Section 3, we introduce the details of our experimental design and derive theoretical predictions. Section 4 contains the empirical analysis and Section 5 concludes the paper.

2 Related literature

For reasons of succinctness, we focus solely on experimental papers in economics that deal with decision making under uncertainty in social interactions, with a particular focus on natural uncertainty and social dilemmas.

That individuals, on average, contribute a significant share of their endowment to an efficiency-enhancing public good despite the free-rider problem has become a stylized fact (Cox and Sadiraj, 2007). Many of the models that have emerged to explain the patterns of data involve other-regarding preferences such as inequity aversion (Fehr and Schmidt, 1999) and altruism (Anderson et al., 1998). The question of how natural uncertainty influences pro-sociality has received increasing attention in recent years, and the matter is far from resolved. Bohnet and Zeckhauser (2004) analyse the impact of natural and strategic uncertainty on individual willingness to take risk in trust and dictator games in which the outcome for the recipient is determined by a chance device. Their findings suggest that individuals are more likely to take risk in situations where the risk is attributable to 'nature' rather than to the behaviour of another player - a concept they refer to as betrayal aversion. Replicating the study in six different countries, Bohnet et al. (2008) conclude that betrayal aversion seems to be a robust finding across cultures. Building on these results, Bolton and Ockenfels (2010) design a dictator game to investigate whether and how social comparisons influence decisions in situations with natural risk. Their findings point in two directions: on the one hand, subjects are more willing to take risks when another certain option implies unequal payoffs, which is in line with previous findings of inequity aversion (Fehr and Schmidt, 1999); on the other hand, subjects are more prone to choose an outcome with a risky and socially unequal outcome than a certain outcome that implies an equal distribution of resources, which goes against inequity aversion. The authors argue that these contradictory findings could be a consequence of notions of procedural fairness. When the social inequality can be attributed to the chance mechanism, which is realized *after* the choice is made, it is less costly (in terms of utility) than when it is *directly* attributed to the decision. Brock et al. (2013) use dictator games in which the probabilities of outcomes for both the dictator and the recipient vary, to explicitly study whether decision makers care about the distribution of outcomes among players *ex ante* (in expected values) or *ex post* the resolution of uncertainty. Their results indicate that, on average, both considerations have positive weight in the decision function. However, for the category of pro-social subjects, ex-ante comparisons are more important, and the behaviour in standard dictator games is shown to be generalizable to risky dictator games. The reported results from risky dictator games indicate that the exact way in which ex ante and ex post concerns with respect to social equity enter the decision function in risky situations remains unsettled (Krawczyk and Le Lec, 2016).

The impact of uncertainty on pro-social behaviour in settings that combine natural and strategic uncertainty is discussed in a small but emerging literature on voluntary contributions to public goods or to reduce risk. The few available studies do not give a conclusive picture of the effects of uncertainty on contributions or the potential mechanisms that are driving the differences in contributions. One issue that complicates the reading is the variation in experimental design. The two most evident differences are whether contributions involve a binary or a more continuous choice set, and whether the uncertainty of the payoffs is conditioned on a threshold being reached (or avoided) or on a chance mechanism that could either be independent of *or* positively related to the sum of contributions to the public good. Since binary contributions might frame a decision-making situation differently than a more continuous choice set, and threshold-structured public goods games change the set of Nash equilibria, it is difficult to distinguish a general conclusion from the previous studies. In an attempt to sort the literature, we begin by discussing studies looking at contributions as a device to reduce or prevent risk, and then discuss studies of prisoner's dilemma/public goods contributions under uncertainty. Berger and Hershey (1994) investigate insurance behaviour in a repeated public goods game. Each player is exposed to a risk of incurring a private loss of probability 1/n. In each round, players can decide to invest a fixed amount in a collective insurance pool from which all losses, irrespective of whether the player has contributed, are refunded. If the sum of losses exceeds the value of the insurance pool, subjects need to divide the additional cost among them. Compared with a situation of certain losses, investment in the insurance pool was significantly lower under risky losses. The authors reason that a combination of increased risk-seeking preferences under stochastic returns and a feeling of less responsibility to cooperate when losses can be attributed to 'bad luck' explain the results. A similar effect on risk taking in the loss domain is found in a study by Suleiman et al. (1996), who conduct a sequential common pool resource game where the uncertainty regarding the resource size is determined by a draw from one of three different uniform distributions of common knowledge to the subjects. They find that subjects tend to increase their withdrawal of resources as the level of uncertainty regarding the size of the common pool increases. The authors explain this result as a consequence of wishful thinking, i.e. subjects base their estimate of the unknown resource on a weighted average of the interval end points with a biased towards the larger value[5].

In a recent study, Köke et al. (2015) examine protective and preventive behaviour in an infinite horizon public goods game in which subjects face a binary decision of whether to cooperate or defect to reduce the magnitude of a loss, or the probability of losing the entire endowment. They find that subjects are more likely to cooperate and to sustain cooperation when they can reduce the probability of experiencing a full loss rather than marginally reduce the magnitude of the loss. Rather than risk aversion, the authors attribute the results to a combination of anticipated regret aversion and learning dynamics. They argue that subjects learn to defect more slowly when the probability of a loss is reduced - a finding that has an optimistic flavour from the point of view of sustained preventive actions to counter climate change.

Motivated by environmental problems and the 'tipping-point' properties of many ecosystems, Dannenberg et al. (2015) study a ten-period repeated sequential threshold public good game in groups of six players. Uncertainty is introduced on the threshold level of contributions that has to be reached to avoid a catastrophic event that destroys 90% of the remaining individual endowment of each player. Players are informed about 13 potential threshold levels with either equal or unknown probability of realization, depending on the treatment. Compared with a control treatment with a known threshold level, risk and ambiguity have a negative effect on the ability of groups to reach the threshold. The result is largely driven by individual cooperative preferences. Conditional cooperators are able to coordinate to reach the unknown threshold when enough group members signal their willingness to contribute early on. Hence, the authors conclude that one mechanism to increase the level of cooperation under uncertainty is to find ways to incentivize high initial contributions.

The relevance of loss aversion in explaining lower contributions in situations involv-

[5] In relation to this, it is interesting to note that Hsee and Weber (1997) find that individuals base their predictions about others' risk preferences on a weighted average of own risk preferences and risk neutrality.

ing uncertainty is examined by Levati and others in two studies. In the first, Levati et al. (2009) implement a repeated prisoner's dilemma game with either low or high risky marginal returns to contributions. The game is calibrated such that full contributions are not socially beneficial when the low marginal return is realized. Compared with a situation with certain marginal returns, the risky treatment significantly reduced average contributions. This result is completely driven by lower initial contributions as the time trends of the contributions over the rest of the periods are similar in the two treatments. Revisiting the setup, Levati and Morone (2013) modify the 2009 study by calibrating marginal returns such that full contributions are socially efficient for both realizations. They also add a treatment with ambiguous marginal returns. Now they find no significant differences in contribution behaviour in situations involving risky, ambiguous or deterministic marginal returns of investment. The authors attribute their previous findings of lower contributions under risk to loss aversion rather than risk aversion[6].

Lastly, Gangadharan and Nemes (2009) study a repeated linear public goods game in a within-subject design and let groups of five players participate in seven treatments in which the probability distributions of the private and public investments are either certain, probabilistic or endogenously determined by the level of contributions. In the control treatment, the MPCR is set to 0.3 and the private return to 1. The risky realizations of the investment returns are determined by a known Bernoulli distribution with expected values of 0.3 for public investments and 1 for private investments. In the ambiguity treatments, the probability distribution of the realizations of the returns to private and public investments is unknown. However, the authors allow participants the choice to forgo 1/5 of their endowment to find out about the probability distribution in the ambiguity treatments[7]. This design makes it hard to determine the pure effect of ambiguity on contributions, since group members either know the probability distribution or might suspect that other group members know it, which could affect

[6] Similarly, Dickinson (1998) finds null results in a repeated public goods game with uncertainty on the level of the MPCR. He employs a within-subject design, repeated public goods game in groups of five to study how uncertainty regarding the MPCR influences contributions. The MPCR is known in the first seven periods. In the subsequent seven periods, the returns are risky with a mean-preserving spread resolved with the help of a bingo cage. In the last seven periods, the MPCR is set to zero with a probability negatively correlated with the level of contributions to the group account. The order of these two last conditions is altered between sessions. Dickinson finds no difference in contribution levels across the three within-subject treatments.

[7] This option is used by 43 % and 17 % of the subjects to find out about the probability distribution of the returns to the private and public investments, respectively.

their beliefs of others' behaviour. The authors find that subjects invest less in the account subject to uncertainty, regardless of whether it is private or public. However, when the uncertainty is related to the public good, the combination of strategic and natural uncertainty has an additional negative impact on contributions.

Of the existing studies, the experiments in Levati and Morone (2013) and Gangadharan and Nemes (2009) are closest to ours, although there are several differences. Most importantly, in addition to the repeated game, we implement a one-shot decision, which is more likely to detect potential differences between deterministic and stochastic MPCRs. In the repeated setting, reputation concerns are known to dominate other behavioural motivations, and thus our design allows us to clearly distinguish between strategic uncertainty and natural uncertainty. Further, we are able to see how uncertainty of returns affects the contribution decisions of different types of players, since the contribution schedules from the preference elicitation in our experiment allows for classification of behavioural types in terms of contribution patterns. We also measure individual attitudes to risk and ambiguity. Finally, the relationship between strategic and natural risk can be directly addressed in our experiment.

3 Experimental design and predictions

3.1 Predictions

We assume that decision makers have cooperative attitudes (preferences) determining contribution strategies. In combination with the beliefs about the decisions of others these strategies translate into actual contribution decisions. The conceptual framework for this idea is based on Fosgaard et al. (2014). According to the framework, the nature of the MPCR (deterministic versus uncertain) could affect both individual cooperative attitudes (a_i) and individual beliefs about others' contributions (b_i). Contribution strategies in the one-shot preference elicitation task are only influenced by attitudes, whereas the unconditional contribution decision ci is influenced by both attitudes and beliefs, i.e. $c_i = c_i(a_i, b_i)$ with $a_i, b_i = a_i, b_i\{D, R, A\}$, where D stands for a deterministic MPCR, R for a risky MPCR and A for an ambiguous MPCR.

The conceptual framework does not provide us with directions of possible effects of uncertainty in the MPCR. Thus, we develop the following toy model, based on the most parsimonious way of introducing pro-sociality and uncertainty in a utility model. We assume a potentially non-linear utility function and incorporate a parameter capturing unconditional altruism or warm glow, i.e. the utility derived from giving to others, as a linear component of the utility function (Anderson et al., 1998). The objective function V of a risk-neutral player in the linear VCM can then be written as:

$$V(c_{i,RN}) := (\pi_i + \alpha_i \sum_{i \neq j}^{n} \pi_j) = w - c_i + m \sum_{j=1}^{n} c_j + \alpha_i (\sum_{i \neq j}^{n} w - c_j + m \sum_{k=1}^{n} c_k), \qquad (1)$$

where $\alpha_i \geq 0$ is an individual parameter determining the level of utility derived from the sum of others' profits and the subscript RN denotes risk neutrality of the individual. Further, $\pi_k = \pi_k\{i,j\}$ denotes the profit of player k; w the endowment; m the MPCR, and n the number of group members. The maximization problem results in the usual bang-bang solution following from the linearity of the problem:

$$c_{i,RN} = \begin{cases} full, & \text{if } \alpha_i \geq \frac{1-m}{m(n-1)} \\ zero, & \text{if } \alpha_i \leq \frac{1-m}{m(n-1)} \end{cases} \qquad (2)$$

which has the following interpretation. For full contribution, the warm-glow parameter needs to be larger than the ratio of the individual marginal return to contributions $(1-m)$ and the marginal value to all other players $(m(n-1))$; otherwise the contribution is zero. Such cut-off results of course represent a simplification. However, as can be seen below, the obtained results can still be useful to get an impression of the direction of potential effects. An important issue to keep in mind is the effect of uncertainty with respect to the MPCR on beliefs. While this is irrelevant for free riders, beliefs are important for conditional cooperators. For them, introducing uncertainty could have an additional effect on beliefs, on top of the potential effect on cooperative attitudes. Our toy model cannot capture such positive influences on the beliefs (Chaudhuri, 2011; Smith, 2012)[8] , since the pro-social motive is assumed to be belief independent. We also abstract from decision errors (McKelvey and Palfrey, 1998) and loss aversion in order to keep the model tractable. Other potential extensions to the model include non-linearity, a motivation to match the contribution of others, additional deviations from the homo oeconomicus assumptions such as a specific form of bounded rationality.

To fix things, let us first assume that individuals exhibit constant relative risk

[8] For a discussion about how beliefs seem to be game dependent through their connection to preferences about reciprocity and guilt, see Fosgaard et al. (2014).

aversion (CRRA) and that risk aversion applies only to utility derived from own profits and not to utility from other-regarding concerns. Then, equation (1) becomes:

$$V(c_{i,RA1}) := \frac{1}{1-r_i}(\pi_i)^{1-r_i} + \alpha_i \sum_{i \neq j}^{n} \pi_j \tag{3}$$

Now the threshold level of the warm-glow parameter for full contributions is strictly smaller than that of a risk-neutral individual whenever $ri < 1$:

$$c_{i,RA1} = \begin{cases} full, & \text{if } \alpha_i \geq \frac{1-m}{\pi_i^{r_i} m(n-1)} \\ zero, & \text{if } \alpha_i \leq \frac{1-m}{\pi_i^{r_i} m(n-1)} \end{cases} \tag{4}$$

That is, as the utility from own monetary payoffs is discounted for risk-averse individuals, the relative weight of the other-regarding component becomes larger. Hence, the cut-off level of the warm-glow parameter for contributions is lower than that for a risk-neutral individual. This implies that average contribution levels to the public good increase, ceteris paribus, the more risk averse individuals are. As an aside, note that the belief regarding the level of risk attitudes of other group members should affect unconditional contributions, but not conditional contributions. A straightforward extension of the model shows that if a risk-averse, conditionally cooperative player assumes that another player is risk neutral, she should adjust the belief and contribute less than when facing another risk-averse player in her group. The second option is to consider risk aversion over the entire utility function, i.e.:

$$V(c_{i,RA2}) := \frac{1}{1-r_i}(\pi_i + \alpha_i \sum_{i \neq j}^{n} \pi_j)^{1-r_i} \tag{5}$$

The solution shows that the threshold level for α_i coincides with that for a risk-neutral individual for any level of risk attitude (as the parentheses $(\pi_i + \alpha_i \sum_{i \neq j}^{n} \pi_j)^{-r_i}$ cancel out). Hence, risk attitudes do not change the cut-off value.

To summarize, cooperative attitudes of risk-averse individuals in a social dilemma, with other-regarding preferences entering linearly into their utility functions, are either unaffected or reinforced by uncertainty depending on the way in which risk aversion enters their utility functions. A very similar logic applies to ambiguity attitudes if we assume that ambiguity aversion can be represented by a smooth function (Klibanoff et al., 2005). Ambiguity aversion will in this case add additional concavity to the utility function and, thus, intensify the effect of risk aversion whenever there is an effect on the cut-off level for cooperation.

We formulate our hypotheses in relation to the conceptual model (Figure 1). Given the theoretical results, and bearing in mind that the model choice is somewhat arbitrary and that empirical assessments seem desirable in order to establish stylized facts, our hypotheses stipulate null effects. All hypotheses are formulated as a comparison to a case with deterministic MPCR and assume that the MPCR remains in the range that implies a social dilemma.

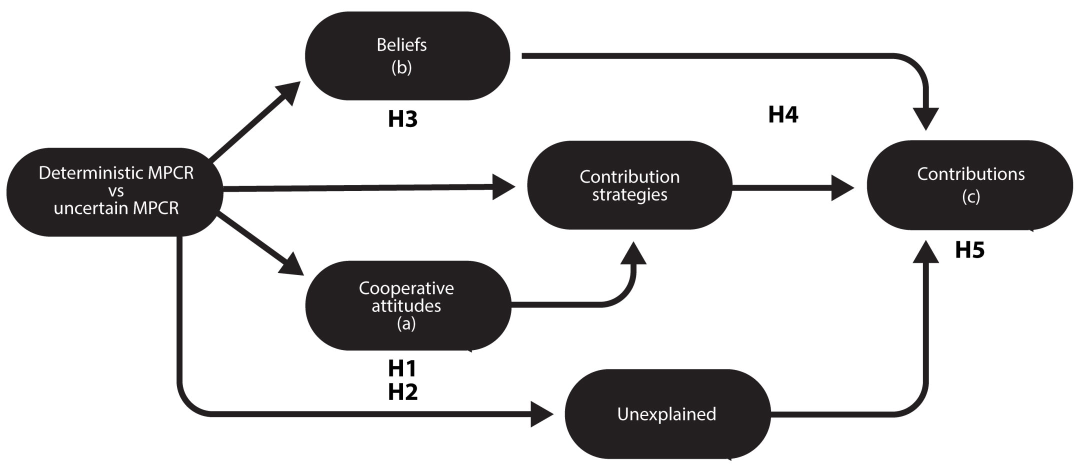


Figure 1: Conceptual framework. The abbreviations H1 - H5 represent our testable hypotheses.

HYPOTHESIS 1: Cooperative attitudes are not affected by natural uncertainty over the MPCR.

HYPOTHESIS 2: The distribution of contribution types remains unaffected by natural uncertainty over the MPCR.

HYPOTHESIS 3: Beliefs about other group members' mean contribution levels are not different under natural uncertainty over the MPCR.

HYPOTHESIS 4: The relative impact of attitudes and beliefs about contributions is unaffected by natural uncertainty over the MPCR.

HYPOTHESIS 5: Contribution behaviour is not different under natural uncertainty over the MPCR.

3.2 Experimental design

Our experiment implements three conditions in a between-subject design: CONTROL, RISK and AMBIGUITY. Each session was divided into three parts as summarized in Table 1. Our basic experimental setting is a public goods game with a linear payoff function (i.e. a VCM) played in groups of four. All players played two versions of this game: a one-shot game (Part 1) in order to elicit cooperative attitudes, beliefs and unconditional contributions, followed by a 10-period repeated game (Part 2) in order to elicit cooperative behaviour in a repeated setting. Participants were informed in the initial instructions that the experiment consisted of three parts. The instructions for each part were distributed and read out loud prior to the start of the respective part (see Appendix II).

In Part 1, we followed the design by Fischbacher et al. (2001) and conducted a one-shot public goods game with elicitation of an unconditional contribution and a vector of conditional contributions (aka a contribution table). At the end of Part 1, without any knowledge of the outcomes, subjects were asked for their beliefs regarding the average contribution of their group members in the one-shot game. They were incentivized as in Gächter and Renner (2010)[9]. All contribution decisions were incentivized as described in Fischbacher et al. (2001) and clearly described to the participants, using a random mechanism that made the conditional contribution payoff-relevant for one group member and the unconditional contribution payoff-relevant for the remaining group member. The amounts were denoted in experimental currency units (ECU), where 1 ECU = €0.10 in Part 1. The final payoffs for Part 1 were not announced until the end of Part 3. Thus, the participants did not know how much the other group members had contributed to the public good in Part 1.

In Part 2, participants were randomly assigned to a new group of four members with whom they had previously not interacted, and played a repeated linear public goods game for ten periods in fixed groups. After each period, players received feedback on the contributions of the other group members, the total contribution to the public good and the payoff of each group member including themselves. Subjects were informed that all ten periods were payoff-relevant, and the exchange rate was set to 1 ECU=

[9]If the guess was within 0.5 points of the actual average contribution, the subjects earned an amount equal to half of the endowment. If the guess was further off than 0.5 points, they earned a fourth of the endowment divided by the (absolute) distance between the guess and the actual average contribution. This task was not included in the instructions, i.e. it came as a surprise to the participants. A screenshot of the belief elicitation is included in Appendix I, Figure 6

€0.04.

Both in Part 1 and in each period in Part 2, each subject was endowed with 20 tokens and could choose how much of the endowment to contribute, c_i, to the public good while keeping the rest in an individual account[10]. Thus, the individual profit from the decision in every round was determined by:

$$\pi_i = (20 - c_i) + m_T \sum_{j=1}^{4} c_j \tag{6}$$

where the public good is represented by the sum of all four group members' contributions; $\sum_{j=1}^{4} c_j$. The MPCR, m_T, was fixed at $m_T = 0.6$ in CONTROL and either high ($m_T = 0.9$) or low ($m_T = 0.3$) in the RISK and AMBIGUITY conditions, respectively. Each subject experienced only one of the three conditions. The MPCR in the two uncertainty conditions was realized at the end of each period with the condition-specific distribution of probabilities. By setting the probability of the high and the low MPCR to 50%, the expected MPCR in the risk condition equals 0.6, which is exactly the same as in CONTROL. The levels of m_T were calibrated such that the social dilemma structure of the game was kept, i.e. $m_T < 1$ and $nm_T > 1$, while at the same time maximizing the distance between the high and low realizations. In effect, this calibration ensures a Nash equilibrium of zero contributions for a (monetary) payoff-maximizing individual, since $m_T < 1$. Also, the social optimum of contributing the entire endowment remains unaltered across conditions because $nm_T > 1$. The marginal returns were determined through a 'chips-drawing' procedure introduced to the participants at the beginning of the first public goods game.

In the RISK condition, one opaque bag was filled with 100 chips (50 yellow and 50 white) in front of the participants at the beginning of Part 1. The realization of m_R was implemented by randomly selecting one participant who publicly drew one coloured chip, with replacement, for each group in the sessions. If the colour of the drawn chip matched the colour picked by the experimenters prior to the session and written down on a piece of paper placed in a closed envelope, m_R was set to 0.9 for that group. If the colours did not match, m_R was set to 0.3. At the beginning of Part 2, ten bags were filled in front of the subjects (one for each period of the game), and

[10] Fischbacher and Gächter (2010) did not find evidence of order effects in an experimental setup very similar to ours. Hence, since no feedback was provided between Parts 1 and 2, we do not expect any order effects between these parts.

the realization of m_R took place at the end of each period in the same way as in Part 1. Hence, during Part 2 participants knew the realizations after each period.

In the AMBIGUITY condition, prior to Part 1, subjects were asked to choose a 'decision colour', either yellow or white. The realization of m_A was implemented in a similar manner as described for the RISK condition. Instead of filling the bags in front of the participants, they were instructed that the bags had been filled beforehand with 100 chips from a large pool of chips containing an unknown distribution of yellow and white chips (we followed the procedure of Kocher et al., 2015; reasons for the specific setup are discussed there). If the colour of the drawn chip matched the colour chosen by a majority[11] of the group, m_A was set to 0.9 for that group; otherwise m_A was set to 0.3. In Part 2, subjects were shuffled into new groups and the majority colour was determined anew, based on the group members' initial choice of decision colour and the majority of the group. In both uncertainty conditions, subjects were invited to inspect the content of the bags at the end of the experiment.

Table 1: Overview of the experimental design

	Condition		
	CONTROL	RISK	AMBIGUITY
Part I: Public goods game - One shot • Unconditional contrib. • Conditional contrib. • Beliefs	$m_{CONTROL} = 0.6$ $n * m_{CONTROL} = 2.4$	$m_{RISK} = 0.3$; $p = 50\%$ $m_{RISK} = 0.9$; $p = 50\%$ $n * m_{RISK} = 1.2$; $p = 50\%$ $n * m_{RISK} = 3.6$; $p = 50\%$	$m_{AMBIGUITY} = 0.3$; *unknown p* $m_{AMBIGUITY} = 0.9$; *unknown p* $1.2 \leq n * m_{AMBIGUITY} \leq 3.6$
Part II: Public goods game - Ten periods • Unconditional contrib.	$m_{CONTROL} = 0.6$ $n * m_{CONTROL} = 2.4$	$m_{RISK} = 0.3$; $p = 50\%$ $m_{RISK} = 0.9$; $p = 50\%$ $n * m_{RISK} = 1.2$; $p = 50\%$ $n * m_{RISK} = 3.6$; $p = 50\%$	$m_{AMBIGUITY} = 0.3$; *unknown p* $m_{AMBIGUITY} = 0.9$; *unknown p* $1.2 \leq n * m_{AMBIGUITY} \leq 3.6$
Part III: Lottery			
Risk attitudes	50 red, 50 blue chips	50 red, 50 blue chips	50 red, 50 blue chips
Ambiguity attitudes	100 chips; red or blue	100 chips; red or blue	100 chips; red or blue
Number of observations	60	60	60

[11] In the case of a tie, the majority colour was determined by a random draw.

Part 3 consisted of multiple choice lists to elicit attitudes to risk and ambiguity, following the design by Sutter et al. (2010). All amounts were expressed in euros (see Appendix II for an example of the lists). Participants completed a series of ordered choices on whether to take a safe or an uncertain payoff. In the first 20 choice problems, attitudes to risk were elicited. The safe payoff was increased in increments of €0.5 from 0 to €10 and the risky payoff was either €10 or 0, each with a probability of 50%. The second set of 20 decisions focused on attitudes to ambiguity. The safe payoff was identical to the first 20 choices, and the ambiguous payoff was either €10 or 0, each with an unknown probability. The payoff-relevant choice was determined by letting one randomly chosen participant draw a card form a deck of 40 cards, which represented the 40 decisions made. If the number of the card corresponded to a risky choice (1-20), the participant drew one chip from a bag filled with 50 red and 50 blue chips in front of all participants. If the number of the card corresponded to an ambiguous choice (21-40), the participant drew a chip from a bag with an unknown distribution of red and blue chips, filled as the bags in Parts 1 and 2 described for the AMBIGUITY treatment. The payoff from the risky/ambiguous choice was set to €10 if the colour drawn matched the colour chosen by the participant prior to Part 3, and to €0 otherwise. For participants who had chosen the safe amount in the choice problem determined by the card, the safe amount was paid out regardless of the colour drawn. It should be noted that we cannot exclude order effects from Part 2 to Part 3 due to the feedback information, in particular on profits in Part 2. Thus, the elicitation of uncertainty attitudes in Part 3 provides auxiliary data that do not affect our condition comparisons. Given this, our test of equality in uncertainty attitudes across conditions is a demanding test of successful randomization.

4 Empirical analysis and results

The experiment was carried out in the MELESSA laboratory at the University of Munich, Germany, and programmed using the z-tree software (Fischbacher, 2007). One hundred eighty participants were recruited with ORSEE (Greiner, 2015) from the laboratory's subject pool. In total, nine experimental sessions were run with 20 participants in each session. The sample was similar in socio-economic characteristics such as gender (Fisher's exact test, p=0.80) and academic field (χ^2 test, p=0.10) when comparing across the three treatments [12]. The experiment lasted 1.5 - 2 hours, depending on the condition. The average payoff was €24 (€23.4 in CONTROL, €24 in RISK and €24.4 in AMBIGUITY). The earnings were paid privately in cash at the end of the session together with a show-up fee of €4.

The risk attitude elicitation task in Part 3 of our experiment allows us to determine individual attitudes to risk and ambiguity. We find no significant differences across conditions when looking at the number of risky and ambiguous choices in a Mann-Whitney test (risk attitudes in Part 3: CONTROL=RISK: p=0.136; CONTROL=AMBIGUITY: p=0.679; RISK=AMBIGUITY: p=0.299; ambiguity attitudes in Part 3: CONTROL=RISK: p=0.530; CONTROL=AMBIGUITY: p=0.920; RISK= AMBIGUITY: p=0.679)[13], which we take as evidence that our randomization worked.

4.1 Cooperative attitudes

The conditional contribution schedules from Part 1 allow us to elicit cooperative attitudes. By conditioning decisions on other group members' average contributions, the decision becomes (from a game-theoretic perspective) sequential and does not exhibit any strategic uncertainty. Do contribution schedules differ across our three treatments, which feature different types of natural uncertainty? A quick glance on figure 2 indicates that there are very small differences between the treatments.

[12] All tests throughout the paper are two-sided.

[13] We find similar results when using the switching point as a proxy for risk and ambiguity attitudes, respectively. The great majority of our subjects are consistent in their choices. 100%, 96.6% and 95% of those in the CONTROL, RISK and AMBIGUITY treatments, respectively, show consistent choice behaviour in the risk attitudes elicitation in terms of a maximum of one switching point in the direction risky-to-safe. The corresponding numbers for the ambiguity attitudes elicitation are 98%, 97% and 93%.

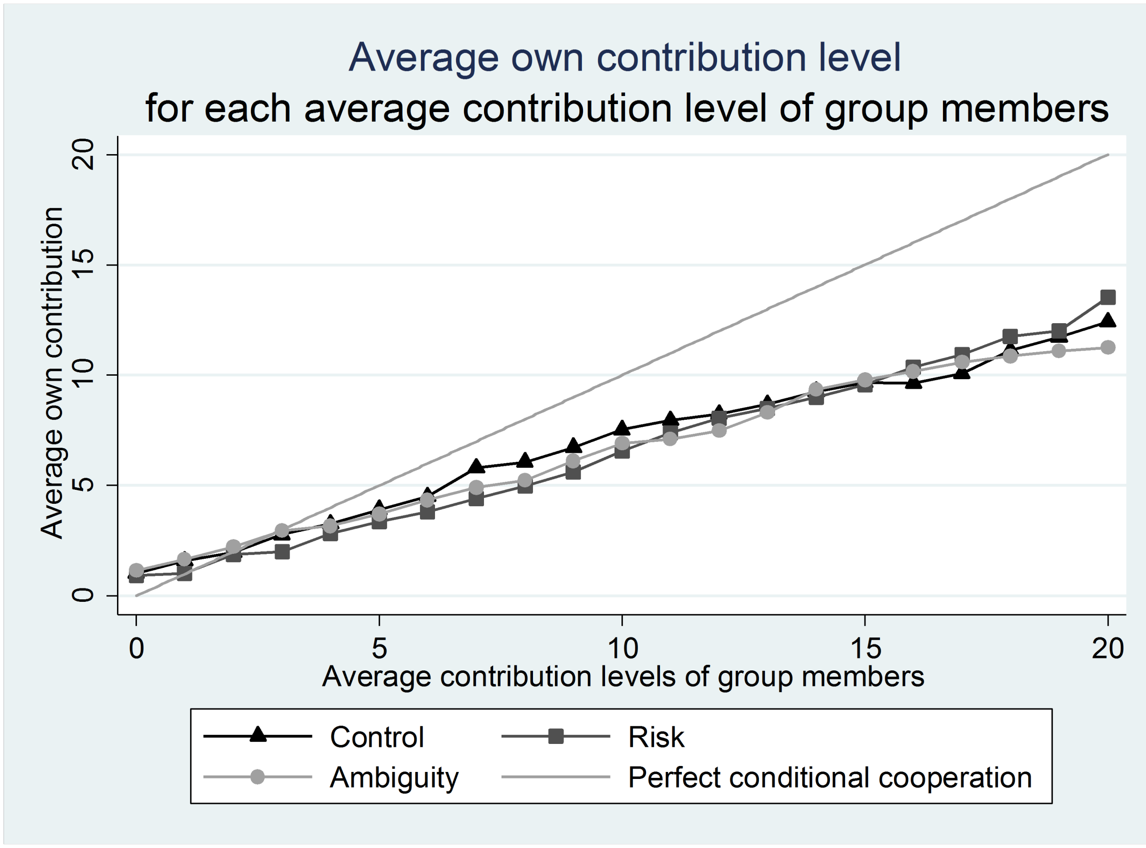


Figure 2: Average conditional contribution schedule

In a more detailed analysis of the conditional contribution patterns, we investigate individual heterogeneity. Following Fischbacher and Gächter and Renner (2010), we fit a linear regression for each individual. We can then compare different attitudes by plotting the relation between the individual slope coefficient (x-axis), which shows how much an individual increases her contribution if the others on average increase theirs by one unit, and the average individual contribution in the schedule (y-axis), represented by a circle (Figure 3). The circles are scaled such that a larger size represents higher relative frequency of the average individual contribution. It is useful to use perfectly conditional cooperators (people who match the others' average contributions perfectly for all levels) and free riders as reference points when interpreting the figures. A perfect conditional cooperator will have a mean contribution level of 10 and a slope of 1. For a free rider, both the mean contribution and the slope will be zero. Most subjects have positive slopes, meaning that they increase their contributions as the group's average contribution increases. Although there is considerable heterogeneity in cooperative attitudes within our three treatments, there are no significant differences across conditions (F-test, p=0.7983)[14]. This can also be seen more clearly when combining the fitted slopes, which relate the individual slopes from the contribution schedules to the individual average contributions in the contribution table, into one graph (Figure 3, bottom right).

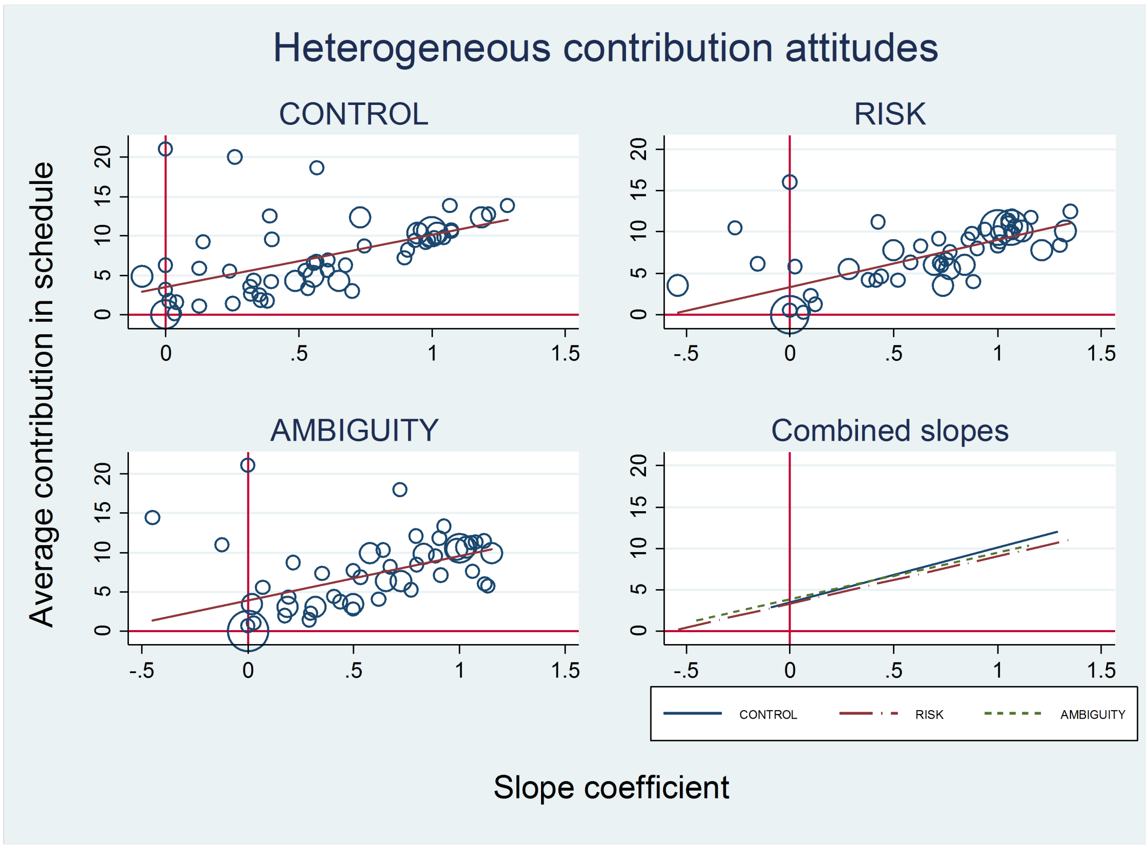


Figure 3: Heterogeneous contribution attitudes

RESULT 1: Cooperative attitudes are not affected by natural uncertainty.

Findings from numerous replications of the Fischbacher et al. (2001) design are conclusive in that attitudes to cooperation differ across individuals. The most common categorization, based on the full contribution schedules, is to form four types of

[14]Nor is there any statistical difference in terms of purely altruistic contributions, defined as positive contributions conditional on the average contribution in the group being zero (Mann-Whitney tests: CONTROL=RISK, p=0.229; CONTROL=AMBIGUITY, p=0.674; RISK=AMBIGUITY, p= 0.424; proportion test: CONTROL=RISK, p=0.207; CONTROL=AMBIGUITY, p=0.658; RISK=AMBIGUITY, p= 0.408).

groups. *Free riders* are the subjects who never contribute anything, irrespective of the contributions of others. *Conditional cooperators* are subjects whose contributions monotonically increase with the average contribution of the other group members, or for whom the Spearman rank correlation coefficient between own and others' contributions is positive and significant at the 1% level. *Hump-shaped* is the term for those who increase their contributions up to a certain point, after which they decrease their contributions (creating a 'hump' in the contribution schedule). Finally, the remaining subjects are classified as *others*.

Figure 4 shows the distribution of types. By far, conditional cooperators are the most frequent type in all conditions: 82% in CONTROL, 72% in RISK and 70% in AMBIGUITY. Overall, the frequency of contribution types does not differ statistically across conditions (Pearson's χ^2: p=0.551; Fisher's exact test: p=0.574). The conditional contribution schedules of the different types are also similar in the three treatments (see Appendix I, Figure A1). The distribution of types is consistent with previous findings in the literature (Chaudhuri, 2011).

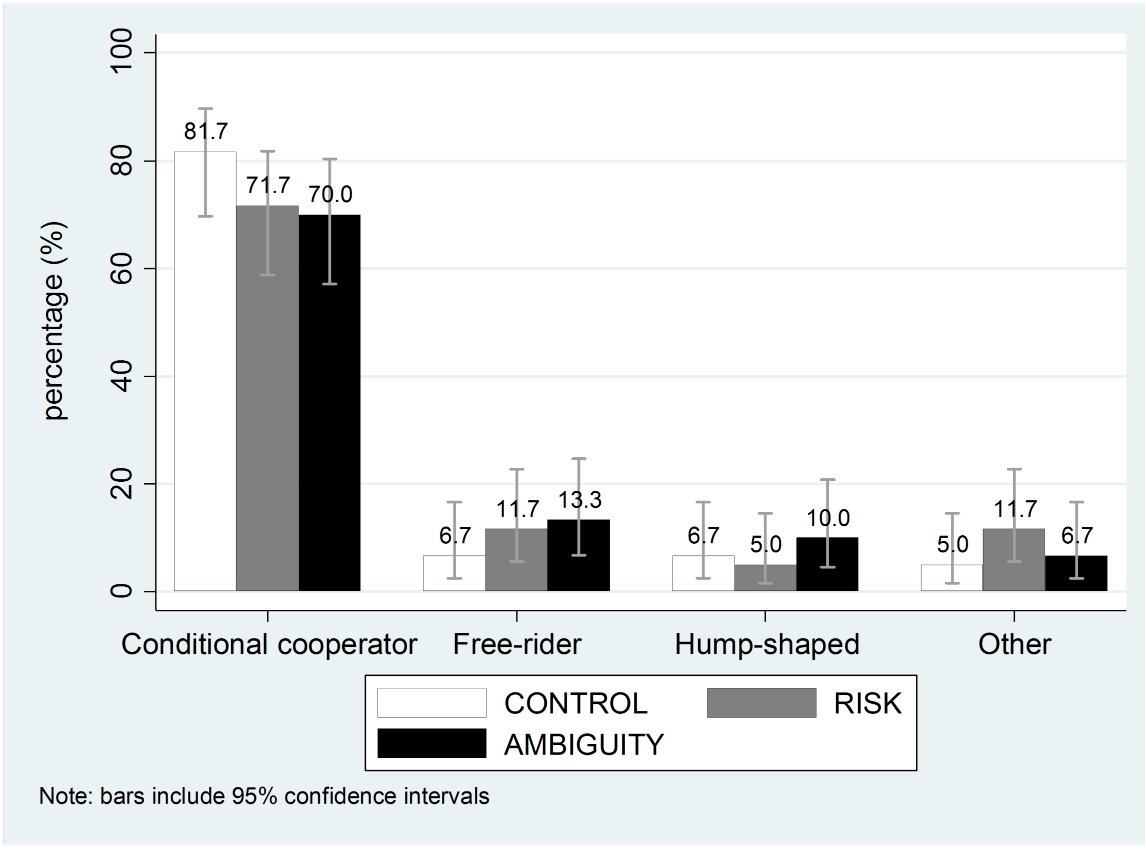


Figure 4: Distribution of contributor types

RESULT 2: The distribution of contribution types is unaffected by natural uncertainty.

4.2 Beliefs

Are beliefs in the RISK and AMBIGUITY conditions different from those in the CONTROL condition? Overall, subjects do extremely well in guessing the average contribution of their group members in all three conditions. We find no significant difference between the average one-shot contributions in Part 1 and the average beliefs about group members' mean contributions, as shown in Table 2. Average beliefs are somewhat lower in both uncertainty conditions, and so is the average contribution in the one-shot public goods game in Part 1. Particularly, when looking at the cumulative distribution of beliefs (Appendix I, Figure A4), it seems that a higher share of participants in the RISK and AMBIGUITY conditions believe that the other group members' contributions are low: 75% and 72%, respectively, of the

Table 2: Mean beliefs and unconditional contributions (std. dev in brackets)

	Belief	Contribution (one-shot)	H_0: Belief=Contribution Wilcoxon signed-ranks test
CONTROL	9.25	9.42	p=0.97
	(4.47)	(6.42)	
RISK	8.57	7.87	p=0.39
	(3.40)	(5.96)	
AMBIGUITY	8.09	8.12	p=0.90
	(5.02)	(6.90)	

	Mann-Whitney U-test	
H_0: CONTROL=RISK	p=0.57	p=0.21
H_0: CONTROL=AMBIGUITY	p=0.15	p=0.21
H_0: RISK=AMBIGUITY	p=0.36	p=0.92

subjects believe that the average contribution is 10 or less; the corresponding number in the CONTROL condition is 65%. However, the difference in belief distribution is too small to be significant (Kolmogorov-Smirnov: CONTROL=RISK, p=0.660; CONTROL=AMBIGUITY, p=0.660; RISK=AMBIGUITY, p= 0.509). Our null result also holds if we break down the analysis into types (see Appendix I, Table A1). Although there are indications of lower beliefs in the uncertainty conditions, we cannot reject our null hypothesis of equal beliefs across conditions.

RESULT 3: There are no differences in beliefs about other group members' mean contribution levels under natural uncertainty, compared with the deterministic situation.

4.3 Effect of attitudes and beliefs on contributions

Table 2 reveals that one-shot unconditional contributions are not significantly different from each other in the three treatments using pairwise tests. If at all, average contributions to the public good are lower in RISK and AMBIGUITY than in CONTROL (in contrast to both theoretical utility specifications put forward in Section 3), even though the differences fail by far to reach conventional levels of significance in pairwise tests. Remember that we have a comparatively large sample (N=60) and that all absolute differences are small in economic terms. Section 4.5 provides some additional power analyses for our main results.

The elicitation of beliefs in Part 1, together with the unconditional and conditional contributions, allows us to analyse how beliefs relate to actual average contribution decisions at the individual level. We use the belief from Part 1 and the respective conditional contribution from the contribution schedule in Part 1 to see how they can explain the unconditional contributions from Part 1.

Following Fischbacher and Gächter (2010), we predict the unconditional contribution, $\hat{c}_i$ as: $\hat{c}_i = a_i(b_i)$. That is, we take the belief of a subject, look up her conditional contribution for the specific belief and see how the 'predicted unconditional contribution' matches the actual unconditional contribution in Part 1. If we define subjects who deviate within two units from the predicted contributions as consistent, as in Gächter et al. (2014), we have 50% consistent decision makers in CONTROL, 65% in RISK and 58% in AMBIGUITY (Pearson $\chi^2 : p = 0.414$; Fischer's exact: p=0.452, for the comparison across treatments), which is similar to the finding in Gächter et al. (2014), where 64% are classified as consistent. Moreover, on average there are no significant differences across treatments in terms of the magnitude of deviations from the predicted contribution (Mann-Whitney test; CONTROL=RISK: p=0.438; CONTROL=AMBIGUITY: p=0.197; RISK=AMBIGUITY: p=0.533).

The next step is to explain the impact of attitudes and beliefs on unconditional contributions. We use OLS to run a regression of contributions as a function of beliefs and predicted contributions:

$$c_i = \alpha + \beta \hat{c}_i + \gamma b_i + \epsilon_i \tag{7}$$

The predicted contribution captures how well beliefs about others' behaviour correlate with attitudes to cooperation. If attitude is the only thing that matters for decisions, the coefficient of $\hat{c}_i$ should be 1, i.e. $\beta = 1$. If both attitudes and beliefs matter, and there is nothing else explaining contribution behaviour, the sum of their coefficients should be 1, i.e. $\beta + \gamma = 1$, assuming no problem related to multi-collinearity between attitudes and beliefs (see further Fischbacher and Gächter, 2010, footnote 17).

The regression results are presented in Table 3. Panel A includes the whole sample of subjects, whereas panel B is restricted to subjects categorized as conditional cooperators. The sample is restricted to conditional cooperators because beliefs are expected not to affect the behaviour of free riders, while they play the most important role for conditional cooperators. For both panels, we estimate one regression per treatment in order to simplify readability compared with a regression with interaction effects of the main variables with the treatment dummies. Consistent with previous findings (Gächter et al., 2014; Gächter and Renner, 2010), both beliefs and predicted contributions are positive and significant in explaining the first period contribution in both panels. The F-test in Table 3 shows that the sum of the coefficients is not statistically different from one in either of the conditions. This implies that the magnitude of the coefficients is similar across the three treatments. Table A3 in Appendix I introduces the independent variables separately to give an indication of possible multi-collinearity. Our conclusions remain unchanged.

Looking at the whole sample (Panel A), the regression results indicate that beliefs are playing the most important role in explaining contributions in all conditions, particularly so in the RISK condition. This result is further supported when looking at the R^2 in the regression in the Appendix, which uses only one of the independent variables at a time. F-tests on the equality of the coefficients reveal no significant difference across the three treatments. Note, however, that in the RISK treatment, the influence of the beliefs on cooperation is on average a bit higher than in the two other treatments.

RESULT 4: The relative impact of attitudes and beliefs on contributions is unaffected by natural uncertainty.

Table 3: The explanatory power of attitudes and beliefs for first period contribution decisions

VARIABLES	CONTROL (1)	RISK (2)	AMBIGUITY (3)	CONTROL (1)	RISK (2)	AMBIGUITY (3)
$\hat{c}$	0.455***	0.398***	0.437**	0.537***	0.440**	0.426*
	(0.136)	(0.116)	(0.175)	(0.158)	(0.167)	(0.232)
Belief	0.554***	0.763***	0.577**	0.393*	0.629**	0.522*
	(0.201)	(0.158)	(0.231)	(0.225)	(0.253)	(0.297)
Constant	0.965	-1.161	0.571	2.512*	-0.0587	1.829
	(1.254)	(1.129)	(1.121)	(1.377)	(1.573)	(1.501)
F-test: $\hat{c} + Belief = 1$	p=0.933	p=0.181	p=0.899	p=0.559	p=0.681	p=0.703
F-test: $\hat{c} = Belief$	p= 0.761	p=0.150	p=0.725	p=0.700	p=0.634	p=0.854
Observations	60	60	60	49	43	42
R^2	0.672	0.641	0.665	0.687	0.576	0.618

Note: Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1.

4.4 Repeated contributions

Our findings indicate that outcome uncertainty does not significantly change the relative importance of beliefs and attitudes for contribution decisions. However, in a repeated setting other factors such as learning, reputational concerns and dynamics in the beliefs might play an important role. It these factors play a different role when interacted with natural uncertainty, contribution behaviour could change. We thus conclude our empirical assessment by looking at Part 2 of the experiment, i.e. the 10-period repeated VCM in fixed groups.

In Figure 5 we average over group contributions for each period and condition. Indeed, the contribution levels in the AMBIGUITY condition seem to be somewhat lower until period 7. However, the difference in absolute levels is small and the mean level of group contributions over all ten periods does not differ significantly across the three treatments (Kruskal-Wallis text, p=0.392).

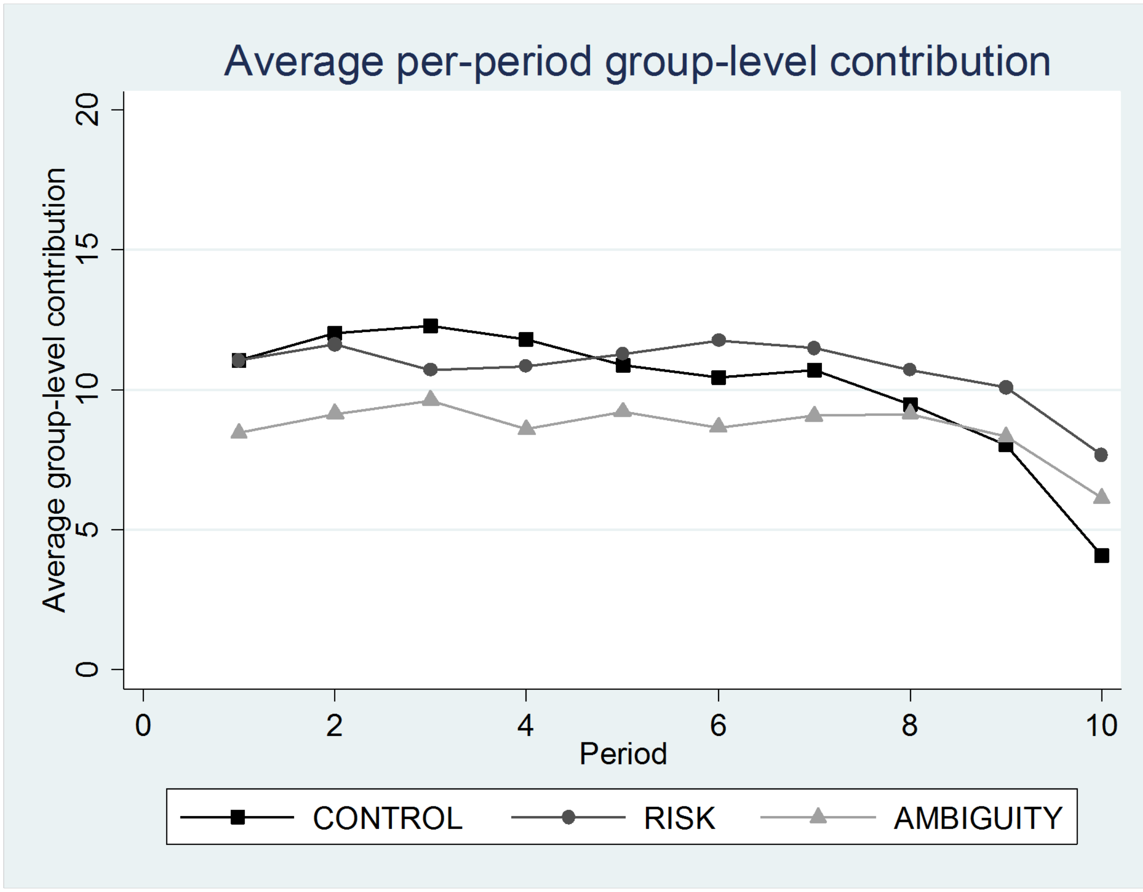


Figure 5: Repeated contributions across conditions

Going beyond the non-parametric comparison, we look at an individual random-effect panel regression that can take the dynamics of contributions into account. The most parsimonious way of looking at individual contributions is to model them as a function of the treatment and a time trend.

We also modify our base model by adding the positive and negative deviations in own contributions from the average contribution of the other group members in the previous period, $c_{i,t-1}^{devPos}$ and $c_{i,t-1}^{devNeg}$, respectively, and a dummy, $HighMPCR_{i,t-1}$, indicating whether the realization of the MPCR was high or low in the previous period, as well as the interactions $\sum I$. The econometric specification is:

$$
\begin{aligned}
c_{it} = \alpha + \gamma_{RISK} RISK + \gamma_{AMBIGUITY} AMBIGUITY + \beta_1 c_{i,t-1}^{devPos} + \beta_2 c_{i,t-1}^{devNeg} + \\
\beta_3 HighMPCR_{i,t-1} + \delta' Period + \sum I + \epsilon_{it}
\end{aligned}
\tag{8}
$$

The deviations from group members' previous decisions are introduced to capture the dynamics within the group. For conditional cooperators, the contributions of others relative to their own contributions matter by definition. The dummy for the realization of the previous period's marginal per capita return is introduced to get a grasp of whether individuals adhere to simplifying decision heuristics (gambler's fallacy or hot hand fallacy) and how this differs between risk and ambiguity. In effect, the realization of the marginal per capita return is independent across periods. Nevertheless, the latest realization might be used, deliberately or subconsciously, as some sort of guide for the next decision. We run the model as a pooled OLS with errors, ϵit, clustered at the group level[15]. As a robustness check we also run a random effects Tobit model where the contributions are censored at 0 (lower limit) and 20 (upper limit). Such censoring is ignored in an OLS framework, which might lead to inconsistent and downward-biased estimates (Merrett, 2012). The results do not affect the interpretations of the effects at play (results in Appendix 1, Table A4).

[15] We tested whether we could use GLS. However, a Hausman test applied to the base model suggested choosing a fixed effects specification above a random effect (χ^2 = 16.46, P ¡ 0.001). As we want to capture time-invariant explanatory variables, we specified a pooled OLS with clustered standard errors at the group level.

Table 4: Regression results from pooled OLS for individual contribution decisions

VARIABLES	(1)	(2)	(3)
RISK	0.645	1.406	Reference
	(1.726)	(2.613)	
AMBIGUITY	-1.443	-0.851	-2.249
	(2.033)	(2.914)	(2.655)
$c_{i,t-1}^{devPos}$		0.0909	-0.0513
		(0.206)	(0.200)
$c_{i,t-1}^{devPos} * RISK$		-0.213	Reference
		(0.251)	
$c_{i,t-1}^{devPos} * AMBIGUITY$		-0.0876	0.225
		(0.285)	(0.292)
$c_{i,t-1}^{devNeg}$		-0.430**	-0.499**
		(0.201)	(0.232)
$c_{i,t-1}^{devNeg} * RISK$		-0.102	Reference
		(0.283)	
$c_{i,t-1}^{devNeg} * AMBIGUITY$		-0.241	-0.0245
		(0.291)	(0.317)
$HighMPCR_{i,t-1}$			0.956
			(0.889)
$HighMPCR_{i,t-1} * AMBIGUITY$			-0.139
			(2.045)
$HighMPCR_{i,t-1} * c_{i,t-1}^{devNeg}$			-0.0689
			(0.196)
$HighMPCR_{i,t-1} * c_{i,t-1}^{devNeg} * AMBIGUITY$			-0.254
			(0.333)
$HighMPCR_{i,t-1} * c_{i,t-1}^{devPos}$			-0.161
			(0.208)
$HighMPCR_{i,t-1} * c_{(i,t-1}^{devPos} * AMBIGUITY$			-0.198
			(0.313)
Constant	10.48***	12.53***	13.31***
	(1.214)	(2.237)	(1.649)
Period FE	✓	✓	✓
Observations	1,800	1,620	1,080
R-squared	0.047	0.111	0.111

Note: Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

The results from our most basic model (Table 4) confirm the impression from Figure 2. Average contributions are lower in the AMBIGUITY condition and higher in the RISK condition. However, the dummy variables for the conditions are not significant. When adding deviations from group members' average contributions in the previous period, and their interaction with the condition dummies (Table 4, Column (2)), we find not surprisingly that subjects respond the most to negative deviations. A one-unit increase in the average negative deviation is matched with a -0.43 contribution response, irrespective of condition. In other words, the large share of conditional cooperators identified in Part 1 base their contribution decisions on the other group members' previous contributions. However, their reactions are stronger to negative than to positive deviations.

The results hold when we introduce dummies for the realization of the high MPCR level in the previous period (Column (3)). To this end, we run a regression using only the observations from the AMBIGUITY condition, using RISK as reference condition. The results do not provide any support for subjects using last period's realization as a simplifying heuristic for the current period's contribution decision. This finding is interesting in light of the findings in Köke et al. (2015), where the experience of a loss event triggered people to start cooperating in the next period despite the fact that realizations of losses were independent.

RESULT 5: There is no difference in contribution behaviour to a public good over time under natural uncertainty, compared with a deterministic situation.

4.5 Power test

This paper provides a set of null results. We believe that they are informative, since the theoretical priors are unclear. However, null results need to rely on sufficient sample sizes. We have 60 independent observations for each treatment in Part 1 of the experiment. This is a comparatively high number for experimental public goods games, yet a more formal assessment of the robustness of our results with regard to sample size is desirable. Since the non-existence of comparable results made an a priori test plan unobtainable, we look at an ex-post assessment of statistical power. Table 5 shows the number of independent observations required per treatment to reach a significance level of p=0.05 in a two-sided test of independent means (based on the values in Table 2). We use the observed means and variances as well as a test power of 0.8, i.e. an 80 % chance to distinguish an effect size from pure randomness. The results show that our null results are very robust and that the sample size would have to be much higher to come close to significant differences between the treatments. In any respect, the economic magnitudes of the differences are very small.

Table 5: Power test indicating N for each treatment to reach p=0.05

	Belief	Contribution
CONTROL and RISK	N=536	N=251
CONTROL and AMBIGUITY	N=264	N=413
RISK and AMBIGUITY	N=1253	N=10440

5 Conclusion

The objective of this paper was to investigate the effect of uncertainty regarding the MPCR on contributions to public goods. Many, if not most, real-life public goods have the feature that the relationship between contributions to and the return from the public good is uncertain. Meanwhile, most knowledge about cooperative behaviour from public goods experiments conducted in the laboratory is based on purely deterministic returns. By conducting both a one-shot public goods experiment using the strategy method and a 10-period public goods experiment with deterministic, risky and ambiguous return conditions in a between-subject design, we can separate the effect of natural and strategic uncertainty. Our main finding is that the standard results with deterministic return hold in the presence of uncertainty.

We do not observe significant differences between the three treatments CONTROL, RISK and AMBIGUITY. These null results hold for cooperative attitudes (contribution schedules), beliefs, one-shot contributions, the type distribution and the repeated interaction. While null results are often considered less interesting in economics, we think that we provide a very relevant null result here. First, theoretical predictions are ambiguous and do not give clear guidance regarding what to expect. Second, our null result holds consistently in related domains (attitudes, beliefs and contributions) and thus seems systematic rather than idiosyncratic. Third, our power analysis shows convincingly that the null results are robust to a strong increase in sample size, despite the fact that we already use a comparatively large sample in our experiment. Hence, we believe that we provide a very informative null result in the domain of research on social dilemmas.

Our results lend themselves to some relevant methodological implications and to apparent implications for the world outside the laboratory. It seems that existing empirical evidence based on deterministic public goods games can be taken as good indicators for situations outside the laboratory that involve natural uncertainty. Hence, the existing research has not neglected an important dimension in the provision of public goods so far. Our findings also have more general implications for uncertainty in the provision of public goods. Our results are consistent with the interpretation that strategic uncertainty overshadows natural uncertainty in social dilemmas and that the focus when designing cooperation-enhancing mechanisms should be on reducing strategic uncertainty rather than natural uncertainty. Given that the latter is often not possible by the very nature of the problem, this is good news for the solving of real-world social dilemmas. A natural extension of our research is to study the external validity of our main findings directly in the field, but this will be left for future research.

References

Anderson, S., Goeree, J., and Holt, C. (1998). A theoretical analysis of altruism and decision error in public goods games. *Journal of Public Economics*, 70(2):297–323.

Berger, L. A. and Hershey, J. C. (1994). Moral hazard, risk seeking, and free riding. *Journal of Risk and Uncertainty*, 9(2):173–186.

Bohnet, I., Greig, F., Herrmann, B., and Zeckhauser, R. (2008). Betrayal Aversion: Evidence from Brazil, China, Oman, Switzerland, Turkey, and the United States. *American Economic Review*, 98(1):294–310.

Bohnet, I., Herrmann, B., and Zeckhauser, R. (2010). Trust and the Reference Points for Trustworthiness in Gulf and Western Countries. *The Quarterly Journal of Economics*, 125(2):811–828.

Bohnet, I. and Zeckhauser, R. (2004). Trust, risk and betrayal. *Journal of Economic Behavior & Organization*, 55(4):467–484.

Bolton, G. E. and Ockenfels, A. (2010). Betrayal aversion: evidence from Brazil, China, Oman, Switzerland, Turkey, and the United States: comment. *American Economic Review*, 100(1):628–33.

Brock, J. M., Lange, A., and Ozbay, E. Y. (2013). Dictating the Risk: Experimental Evidence on Giving in Risky Environments. *American Economic Review*, 103(1):415–37.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: a selective survey of the literature. *Experimental Economics*, 14(1):47–83.

Cox, J. and Sadiraj, V. (2006). On Modeling Voluntary Contributions to Public Goods. *Experimental Economics Center, Andrew Young School of Policy Studies, Georgia State University, Experimental Economics Center Working Paper Series, 2006-26.*

Dannenberg, A., Löschel, A., Paolacci, G., Reif, C., and Tavoni, A. (2015). On the provision of public goods with probabilistic and ambiguous thresholds. *Environmental and Resource Economics*, 61(3):365–383.

Ellsberg, D. (1961). Risk, Ambiguity, and the Savage Axioms. *The Quarterly Journal of Economics*, 75(4):643–669.

Fehr, E. and Schmidt, K. M. (1999). A Theory of Fairness, Competition, and Cooperation. *The Quarterly Journal of Economics*, 114(3):817–868.

Fischbacher, U., Gächter, S., and Fehr, E. (2001). Are people conditionally cooperative? Evidence from a public goods experiment. *Economics Letters*, 71(3):397–404.

Fosgaard, T. R., Hansen, L. G., and Wengström, E. (2014). Understanding the nature of cooperation variability. *Journal of Public Economics*, 120:134–143.

Gächter, S. and Renner, E. (2010). The effects of (incentivized) belief elicitation in public goods experiments. *Experimental Economics*, 13(3):364–377.

Gangadharan, L. and Nemes, V. (2009). Experimental analysis of risk and uncertainty in provisioning private and publi goods. *Economic Inquiry*, 47(1):146–164.

Klibanoff, P., Marinacci, M., and Mukerji, S. (2005). A smooth model of decision making under ambiguity. *Econometrica*, 73(6):1849–1892.

Kocher, M. G., Cherry, T., Kroll, S., Netzer, R. J., and Sutter, M. (2008). Conditional cooperation on three continents. *Economics Letters*, 101(3):175–178.

Kocher, M. G., Lahno, A. M., and Trautmann, S. (2015). Ambiguity aversion is the exception. *CESifo Working Paper Series No. 5261.*

Köke, S., Lange, A., and Nicklisch, A. (2015). Adversity is a school of wisdom: experimental evidence on cooperative protection against stochastic losses. *WiSo-HH Working Papers Series, Working Paper No. 22.*

Kölle, F., Gächter, S., and Quercia, S. (2014). The ABC of cooperation in voluntary contribution and common pool extraction games. *ZBW - Deutsche Zentralbibliothek für Wirtschaftswissenschaften Leibniz-Informationszentrum Wirtschaft.*

Krawczyk, M. and Le Lec, F. (2016). Dictating the risk: experimental evidence on giving in risky environments: comment. *American Economic Review*, 106(3):836–39.

Levati, M. V. and Morone, A. (2013). Voluntary contributions with risky and uncertain marginal returns: the importance of the parameter values. *Journal of Public Economic Theory*, 15(5):736–744.

Levati, M. V., Morone, A., and Fiore, A. (2009). Voluntary contributions with imperfect information: An experimental study. *Public Choice*, 138(1):199–216.

Mckelvey, R. D. and Palfrey, T. R. (1998). Quantal response Eeuilibria for extensive form games. *Experimental Economics*, 1(1):9–41.

Merrett, D. (2012). Estimation of public goods game data. *University of Sydney, Economics Working Papers, 2012-09.*

Smith, A. (2013). Estimating the causal effect of beliefs on contributions in repeated public good games. *Experimental Economics*, 16(3):414–425.

Suleiman, R., Rapoport, A., and Budescu, D. V. (1996). Fixed position and property rights in sequential resource dilemmas under uncertainty. *Acta Psychologica*, 93(1):229–245.

Sutter, M., Kocher, M. G., Glätzle-Rüetzler, D., and Trautmann, S. T. (2013). Impatience and uncertainty: experimental decisions predict adolescents' field behavior. *American Economic Review*, 103(1):510–31.

Appendix I

Table A1: Summary statistics of unconditional contribution, conditional contribution and belief by type

	Average conditional contribution			Pairwise Mann-Whitney		
Type	CONTROL	RISK	AMBIGUITY	A=C	R=C	A=R
Conditional cooperator	7.60	7.72	7.91	p=0.187	p=0.526	p=0.482
	(6.69)	(6.46)	(6.53)			
Free rider	0	0	0	-	-	-
Hump-shaped	4.92	4.59	6.21	p=0.046	p=0.795	p=0.089
	(5.43)	(4.29)	(5.31)			
Other	6.52	7.13	6.51	p=0.278	p=0.914	p=0.505
	(3.76)	(5.86)	(5.44)			
	Beliefs			Pairwise Mann-Whitney		
Type	CONTROL	RISK	AMBIGUITY	A=C	R=C	A=R
Conditional cooperator	9.71	8.55	9.06	p=0.449	p=0.333	p=0.905
	(4.65)	(3.43)	(5.31)			
Free rider	6.5	6.5	3.75	p=0.225	p=0.634	p=0.520
	(3.11)	(6.02)	(2.17)			
Hump-shaped	7.25	6.5	6.42	p=0.592	p=0.593	p=0.999
	(3.80)	(4.09)	(3.67)			
Other	8	11.64	9	p=0.697	p=0.059	p=0.181
	(1.73)	(3.84)	(2.82)			
	Unconditional contribution			Pairwise Mann-Whitney		
Type	CONTROL	RISK	AMBIGUITY	A=C	R=C	A=R
Conditional cooperator	10.51	8.56	9.88	p=0.572	p=0.169	p=0.510
	(6.31)	(5.50)	(7.02)			
Free rider	2.5	2.86	0.5	p=0.514	p=0.773	p=0.845
	(5)	(7.56)	(1.41)			
Hump-shaped	5.75	4.66	6	p=0.828	p=0.589	p=0.513
	(5.56)	(4.04)	(5.83)			
Other	5.67	10	8.25	p=0.138	p=0.190	p=0.848
	(1.15)	(5.60)	(2.36)			

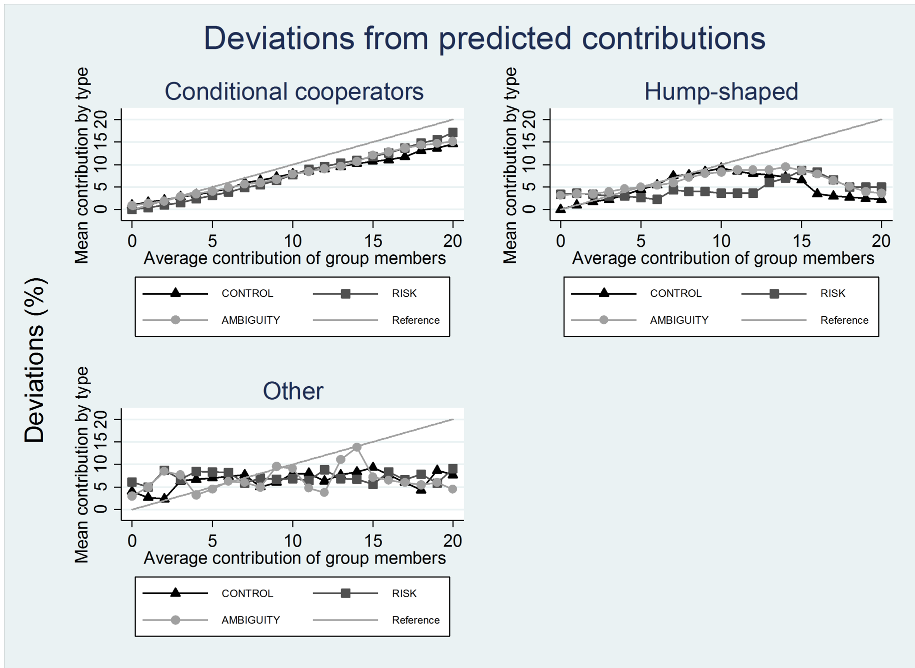


Figure A1: Conditional contribution across types

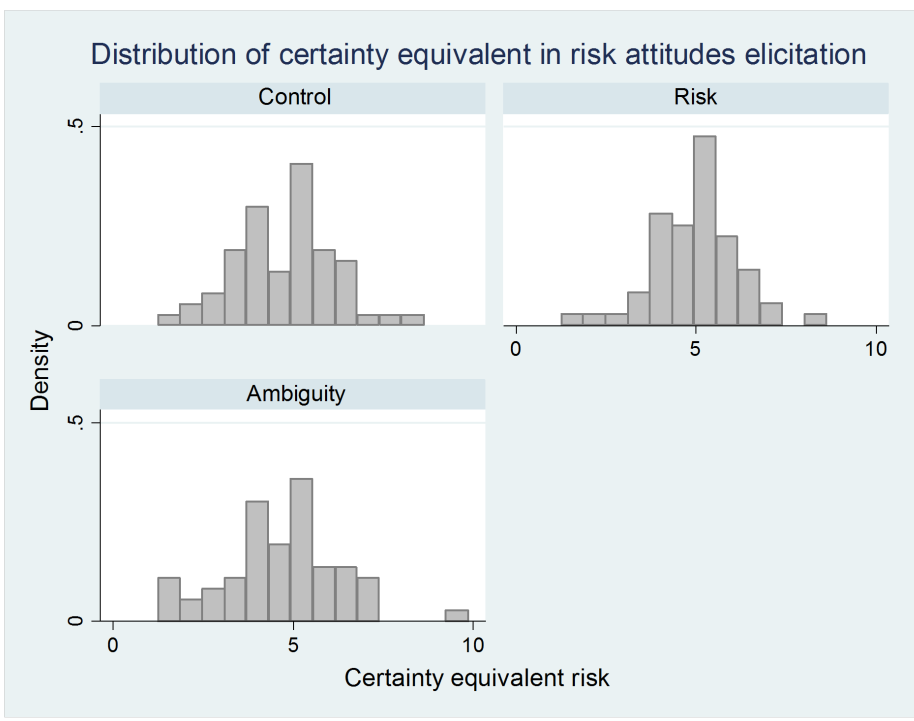


Figure A2: Distribution of certainty equivalents in the risk attitudes elicitation across treatments

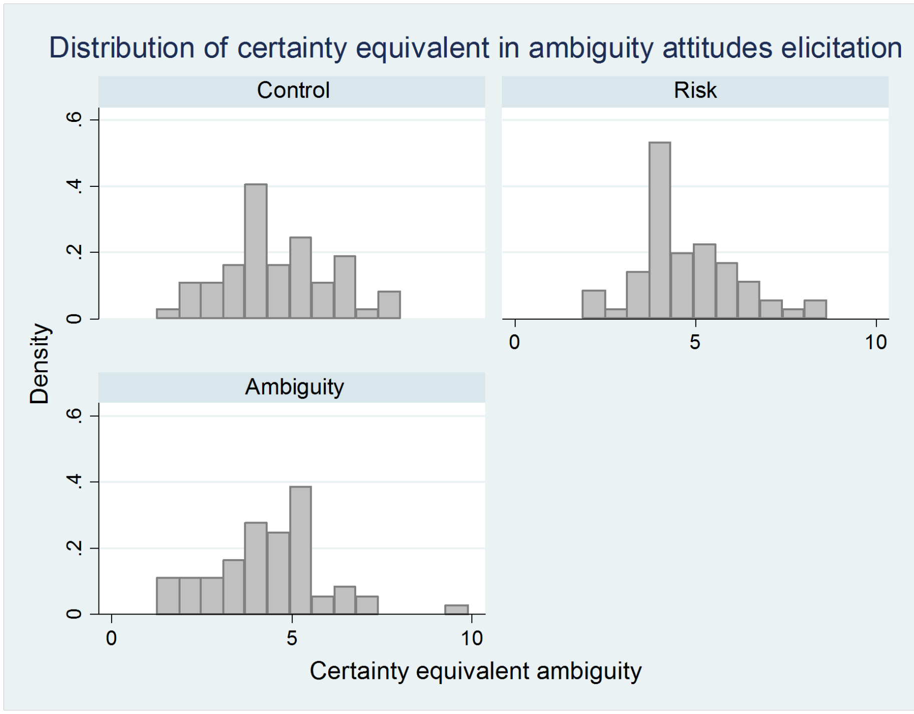


Figure A3: Distribution of certainty equivalents in the ambiguity attitudes elicitation across treatments

Table A2: Switching points

	CONTROL		RISK		AMBIGUITY	
Number of switches	Ambiguity	Risk	Ambiguity	Risk	Ambiguity	Risk
0			2	2	1	1
1	59	60	56	56	55	56
2			2		1	
3	1				1	
4						1
5				2	1	1
6					1	
9						1

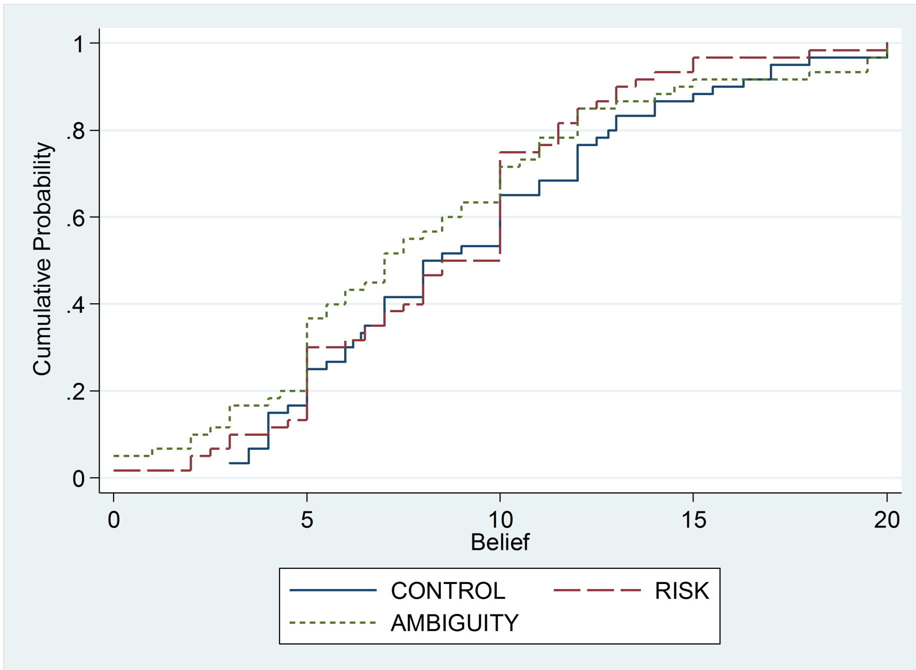


Figure A4: Cumulative distribution function of beliefs across conditions

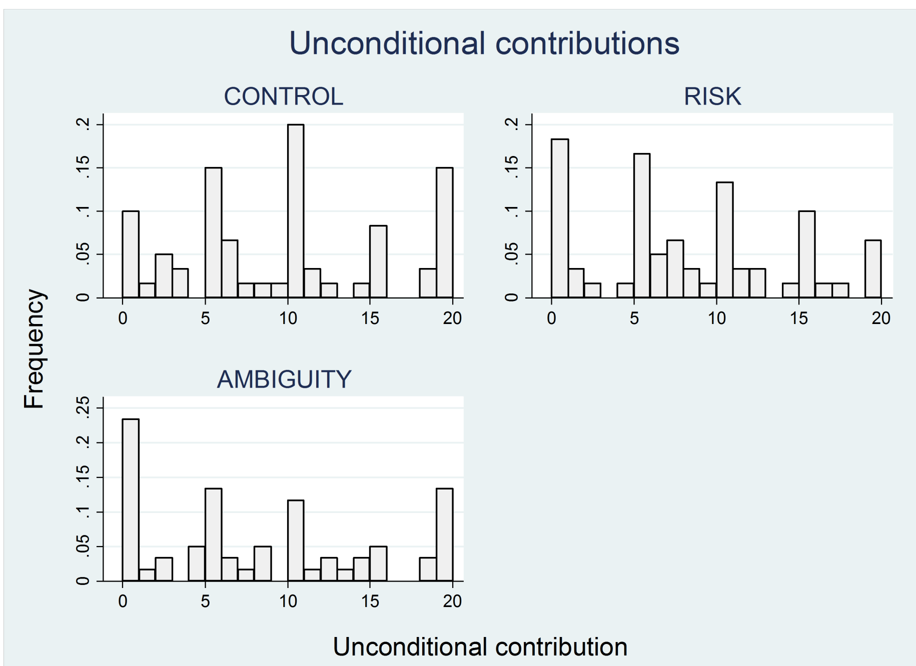


Figure A5: Cumulative distribution function of beliefs across conditions

Table A3: The explanatory power of attitudes and beliefs for first period contribution decisions

VARIABLES	CONTROL (1)	CONTROL (2)	RISK (3)	RISK (4)	AMBIGUITY (5)	AMBIGUITY (6)
$\hat{c}$	0.771***		0.769***		0.827***	
	(0.0779)		(0.102)		(0.0835)	
Belief		1.120***		1.121***		1.089***
		(0.118)		(0.129)		(0.110)
Constant	3.783***	-0.936	3.053***	-1.739	2.668***	-0.692
	(0.763)	(1.210)	(0.846)	(1.216)	(0.777)	(1.044)
Observations	60	60	60	60	60	60
R^2	0.629	0.608	0.493	0.566	0.628	0.628

Note: Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1.

Table A4: Regression results from random effects Tobit. Dependent variable is the per period individual contribution decisions.

VARIABLES	(1)	(2)	(3)
RISK	0.522	0.602	
	(1.071)	(1.091)	
AMBIGUITY	-1.677	-1.598	-2.193**
	(1.073)	(1.093)	(1.113)
$c_{i,t-1}^{devPos}$		-0.0938**	-0.149***
		(0.0401)	(0.0475)
$c_{i,t-1}^{devNeg}$		-0.201***	-0.235***
		(0.0447)	(0.0556)
$HighMPCR_{i,t-1}$			0.595**
			(0.298)
Period FE	✓	✓	✓
Observations	1,800	1,620	1,080

Note: Robust standard errors in parentheses.

The results are reported at the means of the marginal effects on the expected value of the censored outcome.

*** p<0.01, ** p<0.05, * p<0.1.

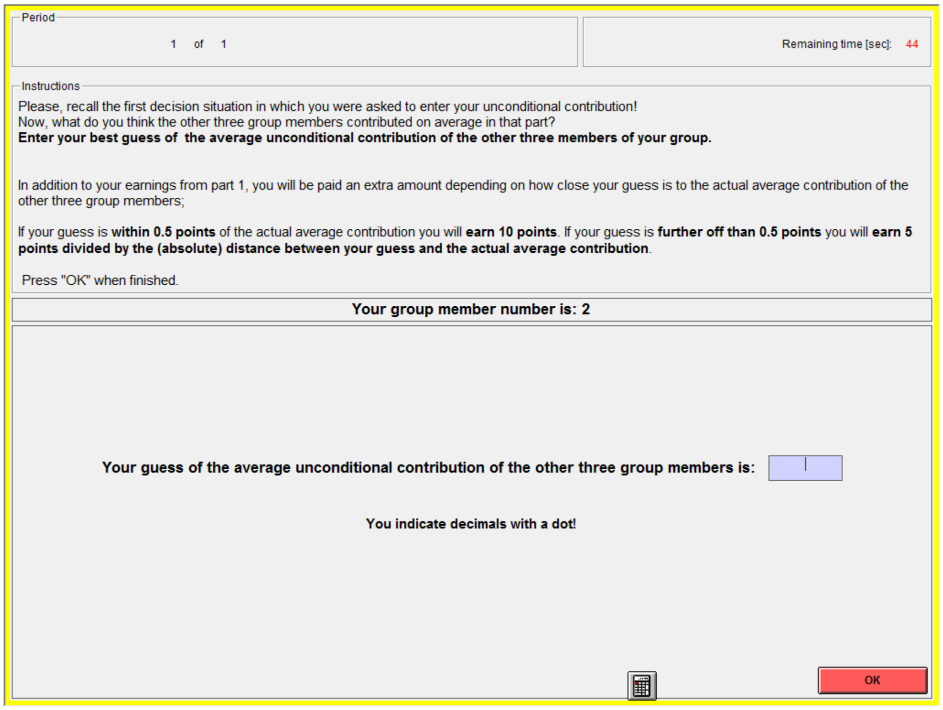


Figure A6: Screenshot belief elicitation

Appendix II

Experiment Instructions*

* Only instructions for the AMBIGUITY treatment are presented here. Alterations of these were used for the RISK respectively CONTROL treatments, making sure to preserve as much resemblance as possible between the three instruction sets.

Welcome to the experiment and thank you for participating!

Please do not talk to other participants.

General

This is an experiment on decision making. You receive 4 Euro for showing up on time. During the experiment you can earn more money that will be paid out to you in cash at the end of the experiment.

The experiment will last approximately 120 minutes. If you have any questions, please raise your hand, and one of the experimenters will come to you and answer your questions privately. You are not allowed to communicate with any other participants during the experiment. If you do so, you shall be excluded from the experiment as well as from all payments. During the experiment, your earnings will be calculated in **experimental points**. At the end of the experiment, all points that you earn will be converted into Euro at the exchange rate announced at the beginning of each part.

Anonymity

You will learn neither during nor after the experiment, with whom you interact(ed) in the experiment. The other participants will neither during nor after the experiment learn how much you earn(ed). Your decisions will be anonymous. At the end of the experiment you will be asked to sign a receipt regarding your earnings which serves only as a proof for our sponsor.

Means of help

You will find a pen at your table which we ask that you, please, leave on the table when the experiment is over. While you make your decisions, a clock at the top of your computer screen will run down. This clock will inform you regarding how long we think that the decision time will be. However, if you need more time, you may exceed the limit. The input screens will not be dismissed once time runs out. However, the output/information screens (here you do not have to make any decisions) will be dismissed after time is up.

Experiment

The experiment consists of three parts. You will receive instructions for each part after the previous part has ended. These instructions will be read to you aloud. Then you will have an opportunity to study them on your own. The three parts are independent of each other.

Decision colour choice

Before we continue with the instructions, you will choose a decision colour – either yellow or white. The decision colour will be relevant later on, and we will describe in detail how it will be relevant.

Part 1

Exchange rate

Any point earned in Part 1 will be converted into Euro at the following exchange rate:

1 points = 0.10 Euro

The basic decision situation

The basic decision situation will be explained to you in the following. Afterwards you will find some questions on the screen that will help you better understand the decision making environment.

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

Your income from the private account:

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 put anything into the group account) 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.

Your income from the group account:

Each group member will profit equally from the amount you put into the group account. Similarly, you will also get a payoff from the other group members' allocation into the group account. The individual income for each group member out of the group account will be either Option A or Option B:

OPTION A
Individual income from group account =

Sum of all group members' contributions to the group account $\times 0.3$

OR

OPTION B
Individual income from group account =

Sum of all group members' contributions to the group account $\times 0.9$

Option A and Option B become relevant with unknown probability; how the relevant option is determined will be explained below.

Examples

If, for example, Option A is relevant and the sum of all group members' contributions to the group account is 60 points, then you and the other members of your group each earn 60×0.3=18 points out of the group account. If instead the four group members contribute a total of 10 points to the group account, you and the other members of your group each earn 10×0.3=3 points out of the group account.

If, for example, Option B is relevant and the sum of all group members' contributions to the group account is 60 points, then you and the other members of your group each earn 60×0.9=54 points out of the group account. If instead the four group members contribute a total of 10 points to the group account, you and the other members of your group each earn 10×0.9=9 points out of the group account.

Relevant option

How do we determine whether Option A or Option B is relevant? Remember the decision colour choice in the beginning of this experiment. First, we determine the majority colour in your group. If three group members chose yellow, yellow is the group decision colour. If one chose yellow, white is the group decision colour, etc. If two group members chose yellow and two chose white, the decision colour is selected randomly.

This opaque bag has already been filled with exactly 100 coloured chips before the experiment. These chips are either yellow or white. The distribution of the colours is unknown to you: A student assistant has randomly drawn 100 chips from a bigger bag that contained far more than 100 chips – only yellow and white ones. Thus, you do not know how many of the 100 chips are yellow or white. At the end of the experiment, one randomly selected participant will draw one chip without looking into the bag for each of the groups in this room, starting with group 1, group 2, group 3, … (each time returning the chip into the bag). If the colour of the drawn chip for your group does not match your group decision colour, Option A is relevant for your group; if the colour of the drawn chip matches your group decision colour, Option B is relevant for your group. You are allowed to inspect the content of the bag at the end of the experiment if you want to.

Total income:

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

Income from your private account (= 20 – contribution to group account)

EITHER

+ Income from group account (= 0.3× sum of contributions to group account)

if OPTION A is relevant (if chip colour ≠ group decision colour)

OR

+ Income from group account (= 0.9× sum of contributions to group account)

if OPTION B is relevant (if chip colour = group decision colour)

= Total income

Before we proceed, please try to solve the questions on your screen. If you want to compute something, you can use the Windows calculator by clicking on the calculation symbol on your screen.

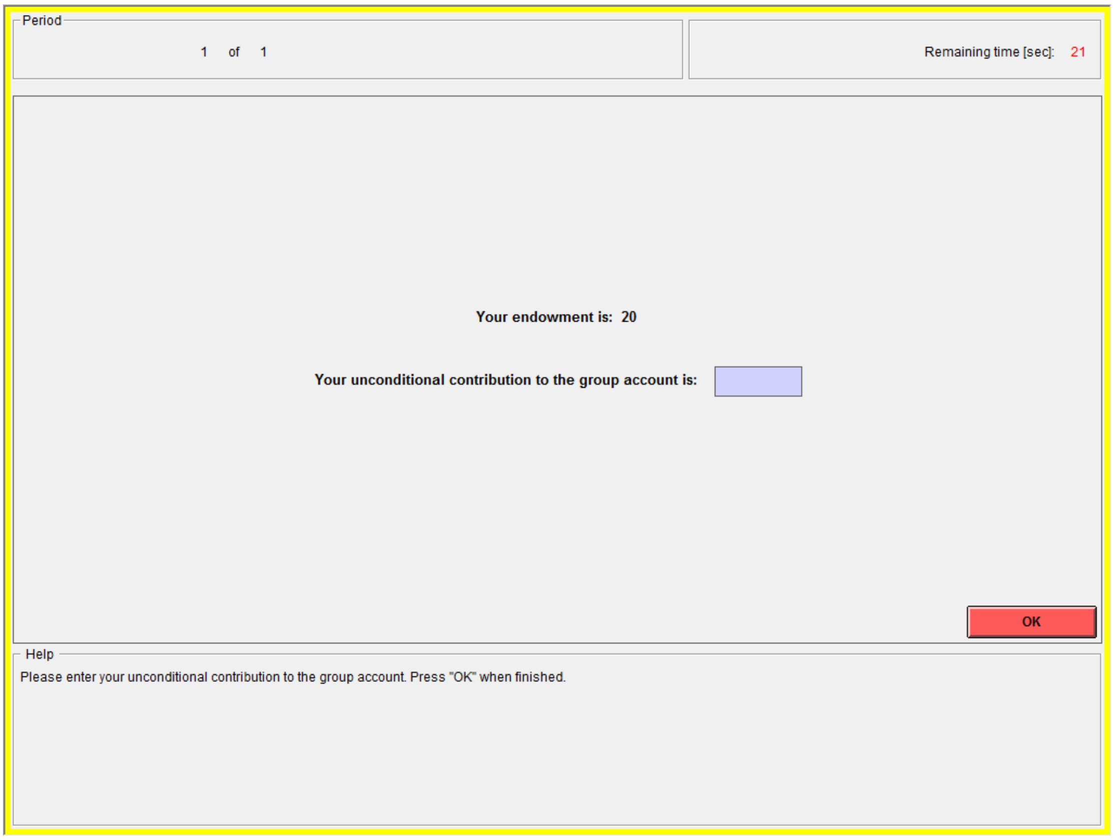
Procedure of Part 1

Part 1 includes the decision situation just described to you. The decisions in Part 1 will only be made **once**.

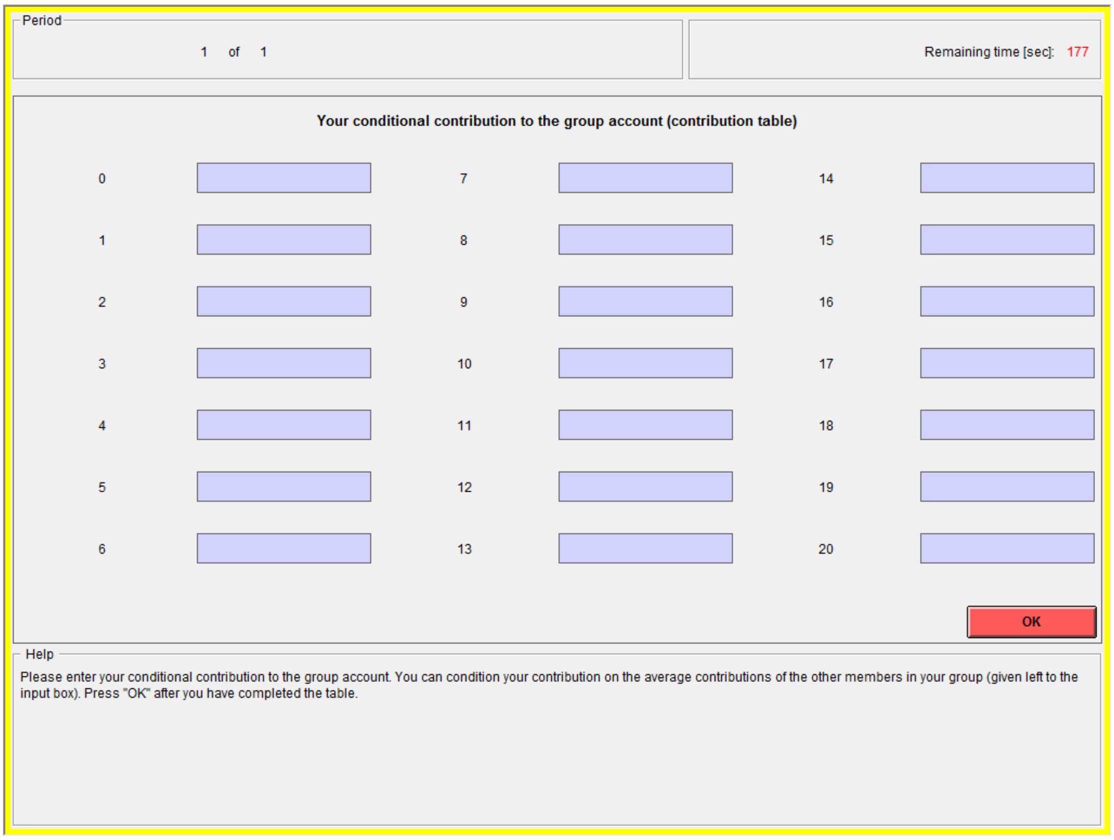
On the first screen you will be informed about your group membership number. This number will be of relevance later on. If you have taken note of the number, please click "OK".

As you know, you will have 20 points at your disposal. You can put them into your private account or you can put them into the group account. Each group member has to make **two types** of contribution decisions which we will refer to below as the **unconditional contribution** and the **contribution table**.

- In the **unconditional contribution** case, you decide how many of the 20 points you want to put into the group account. Please insert your unconditional contribution in the respective box on your screen. You can insert integers only (e.g. numbers like 0, 1, 2…). Your contribution to the private account is determined automatically by the difference between 20 and your contribution to the group account. After you have chosen your unconditional contribution, please click "OK".



- On the next screen you are asked to fill in a **contribution table**. In the contribution table you indicate **how much <u>you</u> want to contribute to the group account for each possible average contribution of the <u>other</u> group members** (rounded to the nearest integer). Thus, you condition your contribution on the other group members' average contributions. The contribution table looks as follows:



The numbers in each of the left columns are the possible (rounded) average contributions of the **other** group members to the group account. This means, they represent the average amounts of the other group members' allocations into the group account. You simply have to insert into the input boxes how many points you will contribute to the group account. **You have to make an entry into each input box**. For example, you will have to indicate how much you contribute to the group account if the others contribute 0 points to the group account on average, how much you contribute if the others contribute 1, 2, or 3 points on average, etc. You can insert any whole number from 0 to 20 into each input box. You can of course insert the same number more than once. Once you have made an entry into each input box, please 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 one group member from every group. **The contribution table** will be the only payoff-relevant decision for the **randomly determined participant** in this part. The **unconditional contribution** will be the only payoff-relevant decision for the **other three group members** not selected by the random mechanism in this part. 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 to you.** Two examples should make this clear.

Examples

Example 1: Assume that Option A turns out to be relevant in the end (chip colour unmatches your group decision colour). Assume further 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, 3 and 6 points. The average rounded contribution of these three group members, therefore, is 3 points ((0+3+6)/3=3).

- If you indicated in your contribution table that you will contribute 1 point to the group account, keeping 20-1=19 in your private account, if the others contribute 3 points on average, then the total contribution to the group account is given by 0+3+6+1=10 points. All group members, therefore, earn 0.3×10=3

points out of the group account plus their respective income from the private account. You would then earn (20–1)+3=22 points.
- If, instead, you indicated in your contribution table that you would contribute 16 points to the group account, keeping 20-16=4 points in your private account, if the others contribute 3 points on average, then the total contribution of the group to the group account is given by 0+3+6+16=25 points. All group members therefore earn 0.3×25=7.5 points out of the group account plus their respective income from the private account. You would then earn (20–16)+7.5=11.5 points.

Assume instead that Option B turns out to be relevant in the end (chip colour matches your group decision colour) and again that **the random mechanism selects you. This implies that your relevant decision will be your contribution table**.

- If you indicated in your contribution table that you will contribute 1 point to the group account, keeping 20-1=19 in your private account, if the others contribute 3 points on average, then the total contribution to the group account is given by 0+3+6+1=10 points. All group members, therefore, earn 0.9×10=9 points out of the group account plus their respective income from the private account. You would then earn (20–1)+9=28 points.
- If, instead, you indicated in your contribution table that you would contribute 16 points to the group account, keeping 20-16=4 points in your private account, if the others contribute 3 points on average, then the total contribution of the group to the group account is given by 0+3+6+16=25 points. All group members therefore earn 0.9×25=22.5 points out of the group account plus their respective income from the private account. You would then earn (20–16)+22.5=26.5 points.

Example 2: Assume that Option A turns out to be relevant in the end (chip colour unmatches group decision colour). Assume further that **the random mechanism did not select you,** implying that **the unconditional contribution is taken as the payoff-relevant decision** for you and the other two unchosen group members. Assume that your unconditional contribution to the group account is 14 points and that of the other two unchosen group members is 10 and 18 points. The average unconditional contribution of you and the other group members, therefore, is 14 points (=(14+10+18)/3).

- If the group member whom the random mechanism selected indicates in her contribution table that she will contribute 3 points to the group account if the other three group members contribute, on average, 14 points, then the total contribution to the group account is given by 14+10+18+3=45 points. All group members will therefore earn 0.3×45=13.5 points out of the group account plus their respective income from the private account. You would then earn (20-14)+13.5=19.5 points.
- If, instead, the randomly selected group member indicates in her contribution table that she will contribute 18 points to the group account if the others contribute, on average, 14 points, then the total contribution to the group account is given by 14+10+18+18=60 points. All group members will therefore earn 0.3×60=18 points out of the group account plus their respective income from the private account. You would then earn (20-14)+18=24 points.

Assume instead that Option B turns out to be relevant in the end and again that **the random mechanism did not select you,** implying that **the unconditional contribution is taken as the payoff-relevant decision** for you and the other two unchosen group members.

- If the group member whom the random mechanism selected indicates in her contribution table that she will contribute 3 points to the group account if the other three group members contribute, on average, 14 points, then the total contribution to the group account is given by 14+10+18+3=45 points. All group members will therefore earn 0.9×45=40.5 points out of the group account plus their respective income from the private account. You would then earn (20-14)+40.5=46.5 points.
- If, instead, the randomly selected group member indicates in her contribution table that she will contribute 18 points to the group account if the others contribute, on average, 14 points, then the total contribution to the group account is given by 14+10+18+18=60 points. All group members will therefore earn 0.9×60=54 points out of the group account plus their respective income from the private account. You would then earn (20-14)+54=60 points.

Random mechanism

The random selection of the participants will be implemented as follows: One participant will be randomly select to throw a four-sided die – **after** all participants have made their unconditional contribution and have filled in their contribution table. The die throw will determine a number – 1, 2, 3, or 4. The thrown number will then be compared with the group membership number, which was shown to you on the first screen. If the **thrown number equals** your group membership number, then your **contribution table is payoff-relevant** for you and the unconditional contribution is payoff-relevant for the other three group members. **Otherwise**, your **unconditional contribution** is the relevant decision for you.

After the end of Part 1 you will get the instructions for Part 2. How much your group members contributed, and how much you earned in Part 1 will be revealed at the end of the experiment.

Part 2

Exchange rate

Any point earned in Part 2 will be converted into Euro at the following exchange rate:

1 point = 0.04 Euro

Periods

The second part of the experiment will last 10 periods. The 10 periods are identical. **You are randomly matched anew into groups of 4 at the beginning of this part.** The group composition does not change over the 10 periods. **That means your group consists of the same people in all 10 periods**. You may now have a new group decision colour, depending on the individual colour choices of your group members at the beginning of the experiment. **Again, the majority within the group determines the decision colour.** Each group member receives a random identification number from 1 to 4. This number will also remain fixed in all 10 periods.

The basic decision situation

The basic decision situation is the same as the one described in the instructions for the previous part. In every period, each member of the group has to decide upon the allocation of the 20 points. You can put these 20 points into your private account or you can invest them fully or partially into a group account. Each point you do not invest into the group account is automatically placed into your private account. *The only difference to the first part is that you can only provide an unconditional contribution*. *There is no contribution table in this part*. Every member's payoff in each period depends on all members' unconditional contribution decisions.

Your income from the private account:

As in Part 1, you will earn one point for each point you put into your private account. No one except you earns something from your private account.

Your income from the group account:

The per period individual income for each group member out of the group account will be either Option A or Option B as in Part 1:

OPTION A
Individual income from group account =

Sum of all group members' contributions to the group account $\times 0.3$

OR

OPTION B
Individual income from group account =

Sum of all group members' contributions to the group account $\times 0.9$

Option A and Option B become relevant with unknown probability; how the relevant option is determined exactly will be explained below.

<u>Total income:</u>

Your per period total income is determined in the same way as in Part 1:

Income from your private account (= 20 – contribution to group account)

EITHER

+ Income from group account (= $0.3\times$ *sum of contributions to group account)*

if OPTION A is relevant

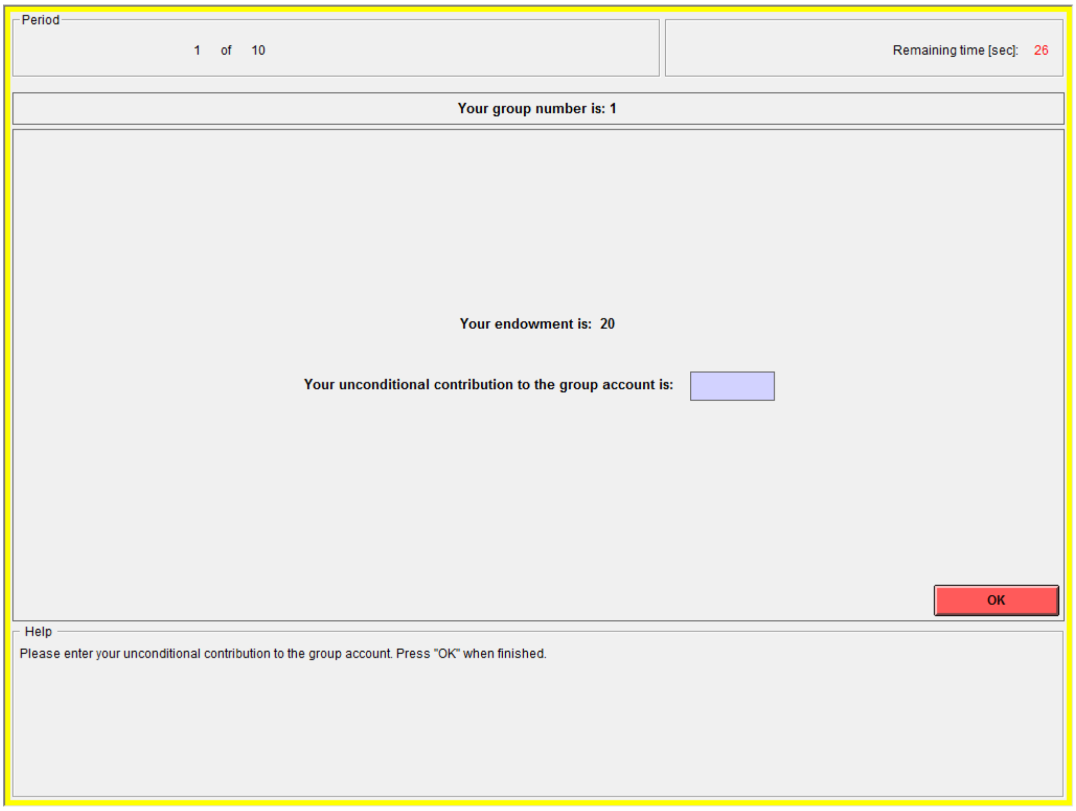
OR

+ Income from group account (= $0.9\times$ *sum of contributions to group account)*

if OPTION B is relevant

= Total income

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



As you can see, there is no conditional contribution table. You only need to decide on your unconditional contribution in every period. At the end of every period, each participant receives feedback on the results of the period, including the individual contributions made by each group member, the total amount contributed to the group account, and the participant's own earnings from the period.

<u>Option A or B?</u>

These 10 opaque bags have already been filled with exactly 100 coloured chips before the experiment and labelled Period 1, Period 2, Period 3, …, Period 10. These chips in the bags are either yellow or white. The distribution of the colours is unknown to you: A student assistant has randomly drawn 100 chips for each bag from a bigger bag that contained far more than 100 chips – only yellow and white ones. Thus, you do not know how many of the 100 chips in each bag are yellow or white. At the end of every period, one randomly selected participant will draw one chip from the appropriate bag (bag "Period 1" after period 1, bag "Period 2" after period 2 ,…) without looking into the bag for each of the groups in this room, starting with group 1, group 2, group 3, … (each time returning the chip into the bag). If the colour of the drawn chip for your group does not match your group decision colour, Option A is relevant for your group; if the colour of the drawn chip matches your group decision colour, Option B is relevant for your group. You are allowed to inspect the content of the bag at the end of the experiment if you want to.

At the end of every period, each participant receives feedback on the results of the period, including the individual contributions made by each group member, the total amount contributed to the group account, the relevant option (A or B) and the participant's own earnings from the period.

Your earnings from Part 2 will be determined by the sum of earnings from all 10 periods.

At the end of part 2, we will ask you to choose a colour. This colour will later be used in part 3.

Part 3

Part 3 consists of two sub-parts: Part 3a and Part 3b. All payoffs are stated in Euro. Either Part 3a or Part 3b is paid out for real.

Part 3 is composed of two sets of **individual decision problems**, and they are presented on two subsequent screens. You are not matched to any person; you decide for yourself. In each of those 40decisions you can chose between **two alternatives**. Your decision is valid only after you have reached a decision for all problems on one screen and have clicked on the OK-button at the bottom of the screen. Take enough time for your decisions, because one of your choices will determine your payoff in Part 3, as we describe below.

The first 20 decisions (Part 3a) concern Bag A. **Bag A is filled with 100 chips. Exactly 50 chips are red, and 50 chips are blue.** In the 20 decisions you will have to decide whether you want to bet on the draw from the bag (Option X) or take an increasing amount of money for sure (independent of the draw) (Option Y).

If part 3a is payoff-relevant, a randomly selected participant will blindly draw a chip out of the opaque bag A, at the end of Part 3. **If you have chosen Option X for the payoff-relevant decision problem, and the colour of the chip matches your personal decision colour for Part 3, you receive 10 Euro. If instead you have chosen Option X and the colour does not match your personal decision colour for Part 3, you receive nothing. If you have chosen Option Y, you will receive the corresponding sure payoff, independently of the colour drawn.** This is how Part 3a will look like:

Part 3a. Please indicate wich alternative, X or Y, you prefer:

	Option X		Option Y	
1.	Draw from bag A	or	0.5 € for sure	X ◯ ◯ Y
2.	Draw from bag A	or	1 € for sure	X ◯ ◯ Y
3.	Draw from bag A	or	1.5 € for sure	X ◯ ◯ Y
4.	Draw from bag A	or	2 € for sure	X ◯ ◯ Y
5.	Draw from bag A	or	2.5 € for sure	X ◯ ◯ Y
6.	Draw from bag A	or	3 € for sure	X ◯ ◯ Y
7.	Draw from bag A	or	3.5 € for sure	X ◯ ◯ Y
8.	Draw from bag A	or	4 € for sure	X ◯ ◯ Y
9.	Draw from bag A	or	4.5 € for sure	X ◯ ◯ Y
10.	Draw from bag A	or	5 € for sure	X ◯ ◯ Y
11.	Draw from bag A	or	5.5 € for sure	X ◯ ◯ Y
12.	Draw from bag A	or	6 € for sure	X ◯ ◯ Y
13.	Draw from bag A	or	6.5 € for sure	X ◯ ◯ Y
14.	Draw from bag A	or	7 € for sure	X ◯ ◯ Y
15.	Draw from bag A	or	7.5 € for sure	X ◯ ◯ Y
16.	Draw from bag A	or	8 € for sure	X ◯ ◯ Y
17.	Draw from bag A	or	8.5 € for sure	X ◯ ◯ Y
18.	Draw from bag A	or	9 € for sure	X ◯ ◯ Y
19.	Draw from bag A	or	9.5 € for sure	X ◯ ◯ Y
20.	Draw from bag A	or	10 € for sure	X ◯ ◯ Y

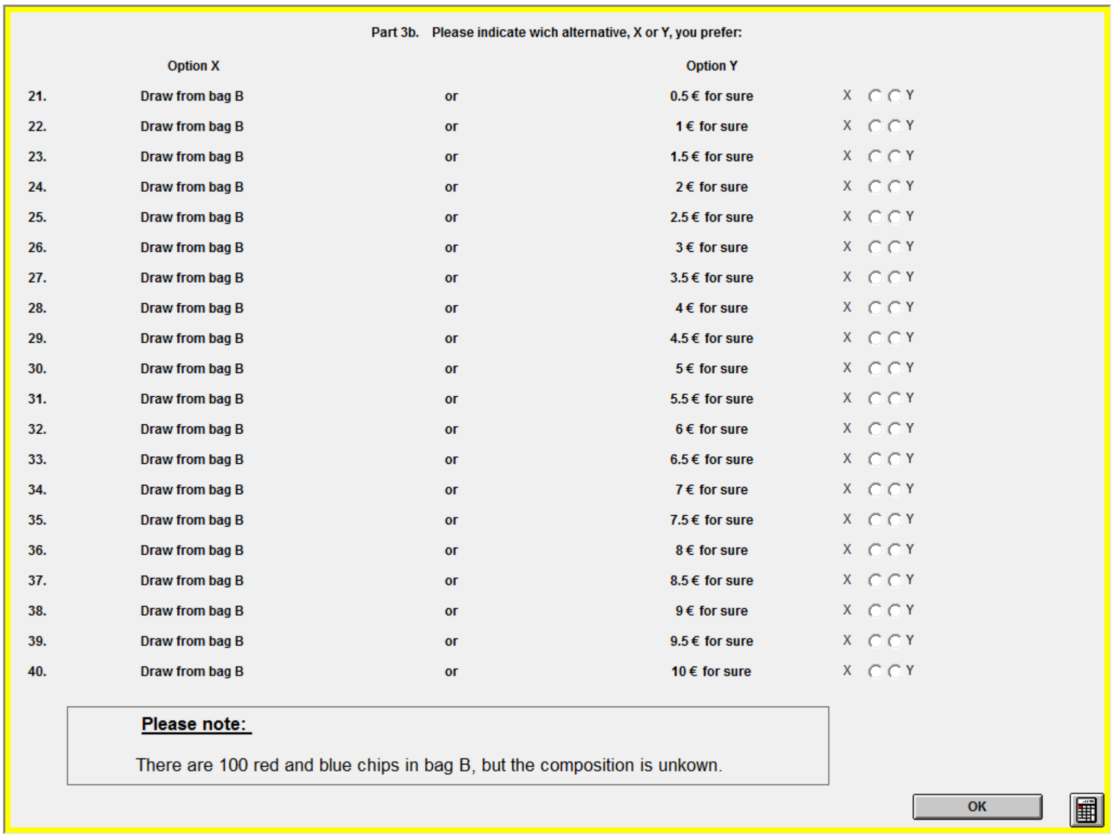
Please note:

There are 50 red and 50 blue chips in bag A.

OK

The second 20 decisions (Part 3b) concern Bag B. **Bag B is filled with 100 chips. The chips are either red or blue. The distribution of the colours is unknown to you**: A student assistant has randomly drawn 100 chips from a bigger bag that contained far more than 100 chips – only red and blue ones. Bag B was filled with 100 chips just before this session began. **Thus, you do not know how many of the 100 chips are red or blue**. In the 20 decisions you will have to decide whether you want to bet on the draw from the bag (Alternative X) or take an increasing amount of money for sure (independent of the draw) (Alternative Y).

If part 3b is payoff-relevant, a randomly selected participant will blindly draw a chip out of the opaque bag B at the end of Part 3. **If you have chosen Option X for the payoff-relevant decision problem**, **and the colour of the chip matches your personal decision colour for Part 3, you receive 10 Euro. If instead you have chosen Option X and the colour does not match your personal decision colour for Part 3**, **you receive nothing. If you have chosen Option Y, you will receive the corresponding for sure payoff independently of the draw**. This is how Part 3b will look like.



Part 3b. Please indicate wich alternative, X or Y, you prefer:

	Option X		Option Y	
21.	Draw from bag B	or	0.5 € for sure	X ◯ ◯ Y
22.	Draw from bag B	or	1 € for sure	X ◯ ◯ Y
23.	Draw from bag B	or	1.5 € for sure	X ◯ ◯ Y
24.	Draw from bag B	or	2 € for sure	X ◯ ◯ Y
25.	Draw from bag B	or	2.5 € for sure	X ◯ ◯ Y
26.	Draw from bag B	or	3 € for sure	X ◯ ◯ Y
27.	Draw from bag B	or	3.5 € for sure	X ◯ ◯ Y
28.	Draw from bag B	or	4 € for sure	X ◯ ◯ Y
29.	Draw from bag B	or	4.5 € for sure	X ◯ ◯ Y
30.	Draw from bag B	or	5 € for sure	X ◯ ◯ Y
31.	Draw from bag B	or	5.5 € for sure	X ◯ ◯ Y
32.	Draw from bag B	or	6 € for sure	X ◯ ◯ Y
33.	Draw from bag B	or	6.5 € for sure	X ◯ ◯ Y
34.	Draw from bag B	or	7 € for sure	X ◯ ◯ Y
35.	Draw from bag B	or	7.5 € for sure	X ◯ ◯ Y
36.	Draw from bag B	or	8 € for sure	X ◯ ◯ Y
37.	Draw from bag B	or	8.5 € for sure	X ◯ ◯ Y
38.	Draw from bag B	or	9 € for sure	X ◯ ◯ Y
39.	Draw from bag B	or	9.5 € for sure	X ◯ ◯ Y
40.	Draw from bag B	or	10 € for sure	X ◯ ◯ Y

Please note:

There are 100 red and blue chips in bag B, but the composition is unkown.

OK

If you want to perform calculations, just click on the **calculator symbol** at the bottom right area of the screen, which will start the Windows calculator (Note: be aware of the order of operations, multiplication before addition!).

Profit from Part 3

Your profit will be determined as follows: When all participants have completed the 40 decisions, a randomly selected participant will blindly draw a card from a deck of 40 cards. The cards are numbered 1 to 40. The number on the drawn card determines which of the 40 decision problems is payoff-relevant (it determines indirectly whether it is Part 3a or Part 3b). Then, he or she draws one chip from either Bag A (if the number is between 1 and 20) or Bag B (if the number is between 21 and 40).

If you have chosen Alternative Y you receive the sure outcome. If you have chosen alternative X, you receive 10 or 0 depending on whether your personal decision colour matches the drawn chip from the relevant bag.

Examples

For example, imagine that decision number 4 is chosen by the card draw and that you preferred alternative X. Then the randomly selected participant draws one chip to determine one of the two outcomes of alternative X. If your decision colour matches the colour drawn, you receive 10 Euro (with a probability of 50%), if not you receive nothing (with a probability of 50%) as payoff for Part 3. If you instead had preferred alternative Y you would have got 2 Euro as payoff for Part 3, independently of your decision colour.

Imagine instead that the number on the card corresponds to decision number 27 and that you preferred alternative X. The randomly selected participant draws one chip to determine the outcome. Again, if your decision colour matches the colour drawn, you receive 10 Euro (with an unknown probability), if not you receive nothing (with an unknown probability). If you instead had preferred alternative Y you would have got 3.5 Euro as payoff for Part 3, independently of your decision colour.

All 40 decisions in Part 3 are made only once. At the end of Part 3, you will be asked a number of questions. Remember, all answers in our experiment remain anonymous. After you have completed the questionnaire page on the screen, the experiment ends. You will be informed about your earnings in each of the three parts of the experiment, and will receive your payoff from the experiment individually and in cash.