Risk attitudes in a social environment

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RISK ATTITUDES
IN A
SOCIAL ENVIRONMENT

Ingrid M.T. Rohde

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RISK ATTITUDES IN A SOCIAL ENVIRONMENT

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~ The End~

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1

INTRODUCTION

Risk is inherent in life. Ever since the first hominids wandered around in East Africa a few million years ago, our fates have been determined by natural incidents. Not only natural disasters such as earthquakes, floods, and storms, but also plagues, have always threatened our existence. At the same time, our lives were at stake by the exposure to predators while searching for food and shelter. The fears and risks created by such threats shaped our attitudes towards risk in general. Avoiding risk played a crucial role in human behavior since the early times of humanity.

Through time, we created a deep awareness of the consequences of risks and the possibilities to avoid such risks through e.g. religious beliefs and practices, legends and myths, and paintings and drawings. One of the earliest examples is the Paleolithic drawing known as “The Shaft of the Dead or Wounded Man” in the caves of Lascaux, France. This drawing shows a confrontation between a prehistoric hunter and a bison who evidently seems to gore the hunter to death. Such Paleolithic drawings suggest that people were indeed aware of the risks that surrounded them. The drawings are nowadays considered to be an attempt to gain some sort of magical control over the violent forces of nature.

As time went by, societies evolved through domestication and technological innovation from small hunter gatherer societies to large and complex societies. As the hunter gatherer societies were based on strong family ties, the society was in no need to establish institutions and the society was egalitarian. The more the societies expanded, the more complex and interlinked the interaction structures between the individuals became. A complex social hierarchy arose and a need for institutional governments developed. Furthermore, increasing populations led to an increase in anonymity. Societies could no longer be seen as isolated, homogenous entities, but rather were based on numerous subcultures, and countercultures, of which individuals could be part of at the same time.

As societies modernized and became more interlinked, a new type of risk, which is the product of human activity and human interaction arose. As individuals became more interconnected, they also became more exposed to risks such as pollution, crime and acts of terrorism. Societies adapted to this multitude of risks by changing the social organization of the society to manage risks. We now live in what sociologists call a “risk society.” According to the sociologist Giddens (1999) a risk society is “a society increasingly preoccupied with the future (and also with safety), which generates the notion of risk.” A logical inference would be that the society and the interconnectedness within the society also shape the attitudes of individuals towards risk.

This thesis investigates the effect of an individual’s social environment on his risk attitude. In the first part of the thesis the level of risk an individual faces is not dependent on his or her social environment, whereas in the second part the level of risk is dependent on his or her social environment. Furthermore, in the second part of the thesis, the role of the evolution of the social environment of an individual on his or her risk attitude is examined.

Risk Attitudes in a Non Strategic Social Environment

There is ample evidence that individuals do not only care about their own payoffs but also the payoffs of others around them. This evidence suggests that people’s risk attitudes are shaped by the payoffs and risks others in their social environment face. When deciding whether or not to join the Postcode Lottery, the scenario that your neighbors are a member of the Postcode Lottery and that your postal code is randomly drawn as the winning postal code does cross one’s mind. In this situation, the risk attitude might very well be influenced by the social environment.

At the same time, individuals are sometimes in a position in which they have to decide for others what type of risk these others will face. Consider for instance the allocation of a donor liver. At the moment, the criteria for receiving a donor liver is the blood group, the weight of the donor, the urgency and the waiting time, which are all objective. Should the allocation of a donor liver also not be dependent on the lifestyle and age of the person receiving the liver? Does a 60 year old woman who has lived a healthy life, deserve the liver more than a 35 year old man who has been an alcoholic for 15 years? Or should they have equal chances of receiving the liver?

In chapter 2, the role of social environments on individual decision making is investigated from both a theoretical and an experimental perspective. We analyze,

by making use of a new methodology, whether the payoffs and risks faced by others have an impact on an individual's risk attitude, as is suggested by theory. We conduct an experiment where subjects are faced with two types of questions. In the first type of question, subjects choose between lotteries for themselves, given the lottery that other subjects receive. By varying the lottery that others receive, we test whether the payoffs and risk faced by others have an impact on an individual's risk attitude. In the second type of question, subjects choose between random allocation rules for the other subjects, while their own lottery is fixed. The results of the experiment are mixed. The impact of others' lotteries on subjects' choices is unexpectedly weak, in comparison to the existing literature. The results for the second type of question are striking, though. Subjects do not want to be held responsible for bad outcomes for others, and prefer procedures in which fate determines the allocation.

Risk Attitudes in a Strategic Social Environment

At the same time, individuals face situations in which strategic uncertainty is present. One's risk attitude is determined by one's attitude towards strategic uncertainty. One possible way of mitigating such risk is coordinating with others in the environment on decisions and actions.

A situation which received much attention from the media over the past years is the spread of the swine influenza type H1N1, better known as the swine flu. Once it became clear that there would be a pandemic outbreak, on all levels of the society, individuals were preoccupied with making arrangements to minimize the consequences of such an outbreak. Governments had to decide on which advice to spread among the citizens when being confronted with the swine flu. Furthermore, they had to decide on the number of vaccines to order, and whether or not to decline the entrance of flight passengers into the country who have symptoms of the flu, or who are from a country where people are not vaccinated. At the same time, people debated on whether or not to act upon the advice of getting vaccinated and staying at home once being diagnosed with the swine flu. Would you temporarily give up a friendship with someone who has been diagnosed with the swine flu in order to decrease the risk of becoming infected and in order to decrease the risk of others to become infected via you? And what if that person is not infected yet, but does not want to be vaccinated?

In the second part of this thesis, we experimentally examine the implications of being able to choose the social environment on the attitude towards strategic

uncertainty.

In chapter 3, subjects propose interactions to the people with whom they would like to play a standard 2×2 coordination game, and simultaneously decide which action they would like to play in this coordination game. In one treatment, proposing an interaction will be costly. Whether or not the coordination game is played is dependent on the requirements made on the interaction proposal. Subjects only play the coordination game against subjects with whom the requirements on the interaction proposals are met. These subjects will be called neighbors. Our results show that as long as the neighborhood size and the composition of the neighborhood are not imposed, subjects will coordinate on the payoff dominant equilibrium. Furthermore, as long as proposing an interaction is costless, all subjects will interact with each other.

However, in many coordination problems like the swine flu example, the weakest player determines the outcome for all involved parties. Hence, in such situations there is a maximum of strategic uncertainty. The minimum effort game is a special type of coordination game, which exactly has this characteristic.

In chapter 4, we introduce a modified version of the minimum effort game. In the modified version, individuals can decide with whom they would like to play the minimum effort game rather than being imposed with whom to play. They can propose interactions to other persons, but an interaction only takes place if both individuals involved agree on interacting. This allows for exclusion of people whose behavior in the minimum effort game is disapproved upon. Our main finding is that having the chance to exclude others makes subjects willing to play the highest effort level possible. Interestingly, this result also holds for large groups.

Part I

Risk Attitudes in a Non Strategic Social Environment

2

RISK ATTITUDES IN A SOCIAL CONTEXT

By extending existing models of social preferences in a risk-free environment, this chapter develops models that capture social preferences when payoffs are risky. Each of these models predicts not only that utility levels are influenced by payoffs and risks faced by others, but also that an individual's choices between lotteries depend on the payoffs and risks his environment faces. In order to investigate how payoffs of others influence risk attitudes, this chapter introduces a new experimental methodology. The feasibility of the methodology is demonstrated in an experiment.

Subjects are faced with two types of questions. In the first type of question, subjects choose between lotteries for themselves, given the lottery that other subjects receive. By varying the lottery others receive, we test whether the payoffs and risks others face have an impact on an individual's risk attitude. In the second type of question, subjects choose between random allocation rules for the other subjects, while their own lottery is fixed. Thus, our subjects never simultaneously influence their own payoff and the payoff of others. In particular, in the first type of question, choices are not confounded by intentions and social pressure. The results of the experiment are mixed. The influence of others' lotteries on subjects' choices is unexpectedly weak, in comparison to the existing literature. The results of the second type of question are striking, though. Subjects have a clear preference for one allocation rule over the other, suggesting an unexplored type of decision aversion, which can be captured by only one of the models we introduce, namely the expected social rank utility model.

2.1 Introduction

There is ample evidence that people care not only about their own payoffs, but also about the payoffs of others (Fehr and Schmidt, 2002 and Sobel, 2005). Many

experiments have demonstrated that people show concerns for the fairness of income allocations. In general, people especially dislike being worse off than others: they try to ‘keep up with the Joneses’ (Galí, 1994). Most studies showing that people care about the income of others in society, assume that the incomes of all involved are certain, i.e. they abstract from risk.

Several models of other regarding preferences have been developed to capture people’s behavior in a risk-free social context. These models are all based on the idea that the utility one derives from a payoff depends on the payoffs of others. This dependence of own utility on others’ payoffs is likely to hold not only in a risk-free context, but also in a risky one. This chapter introduces three models to capture social preferences in a risky context by extending the utility functions of Neilson (2006) and Sandbu (2008). We show that all three models lead to the prediction that people’s risk attitudes depend on the payoffs others face.

It is well-known that in decisions under risk people evaluate their payoffs by comparing them to a reference point (Kahneman and Tversky, 1979). By drawing on models of decision making in social contexts, this chapter shows how payoffs and risks of people’s social environment can shape this reference point.

Knowing how individuals’ attitudes towards risk are affected by the payoffs and risks faced by people around them, may yield important insights into behavior in financial markets, and, for instance, behavior in times of a pandemic.¹ If one’s risk attitude is affected by risks faced by one’s environment, financial booms and crises do not only directly impact one’s investment behavior, but also indirectly, through their impact on risks faced by others and the resulting influence on one’s risk taking behavior. Similarly, a pandemic will not only have a direct, but also an indirect impact on behavior through its impact on risk attitudes.

In order to study how risk attitudes are influenced by others’ payoffs, this chapter proposes a new experimental methodology. Our methodology consists of two types of questions. The first type of question asks subjects to choose between two lotteries for themselves, while keeping the other subjects’ lotteries fixed. By repeating the same question for various lotteries for the other subjects, we can explore whether the lotteries that others face affect the decision maker’s choices. This allows us to investigate how distributions of risks and payoffs for the other subjects influence risky choice, by excluding any emotions and motives related to social interactions, such as group compliance or avoiding the feeling of guilt. Thus, the choices in this first type of question are not confounded by adherence to social norms, feelings of social pressure, or fear for reciprocal behavior.

¹Evidence suggests that in financial markets and in pandemics, risk attitudes are influenced by a type of social contagion (e.g. see Christakis and Fowler, 2007, and Shiller, 2008).

In the second type of question, subjects are asked to choose between random allocation procedures that affect only the other subjects' payoffs. In these questions subjects choose between, for instance, (1) an allocation where every 'other subject' receives an independent lottery yielding 20 euro with 30% probability and 10 euro otherwise, and (2) an allocation yielding 20 euro to 30% of the other subjects and 10 euro to the rest of the other subjects. We refer to the first option as a "lottery" and to the latter as the "corresponding allocation." The expected value and the possible outcomes are the same in both options. There is one crucial difference between the options, though: in the "lottery" risks are perfectly independent across subjects, whereas in the "allocation" risks are correlated. Two of our models, the expected social differences utility model and the expected social rank utility model, predict that people care about the correlation of risks in society. This may have a strong influence on our experience of facing risks of natural disasters, influenza pandemics, terrorist attacks, and airplane crashes, where risks show a strong correlation with others in our environment, compared to events with similar, but uncorrelated risks.

The second type of question allows us to analyze, using real incentives, subjects' preference towards the equity of distributions of social or public risks, an issue which received considerable attention in the literature on social risk analysis in the 1980's (e.g. Broome 1982, Fishburn 1984, Hammerton, Jones-Lee, Abbott 1982, Keeney 1980, Keller and Sarin 1988). Furthermore, this second type of question provides sufficient variation in questions in the experiment. If we were to ask only questions of the first type, subjects would soon find out that their decisions never influence the payoffs of others, which might induce them to completely ignore the payoffs of others in order to reduce cognitive load. Ignoring the payoffs of others just to reduce cognitive load would bias the results. By including questions of the second type, subjects also faced questions where their decision would influence the payoffs of others, which made it less attractive for them to reduce cognitive load by ignoring the payoffs of others.

The main difference between our methodology and the various forms of dictator and ultimatum games used to study behavior in a social context, is that in these games the decision maker simultaneously influences his own and others' payoffs, whereas in our setup the decision maker influences either his own or others' payoffs. This allows us to study the impact of risks and payoffs of others on attitudes towards individual risks and payoffs rather than the tradeoff subjects make between (1) individual risks and payoffs and (2) others' risks and payoffs. Dictator and ultimatum games cannot be used to explain how the risks faced by others might influence one's own risk attitude. Both games can only be used to give an

answer to whether or not subjects behave according to self interest in the sense that their own attitude towards risk will have an impact on what they will give others who are facing either similar or different risks. In these games the reasoning starts from one's *own* risk attitude and then considers the effect this risk attitude has on justifying how much to give to *others*. Our methodology allows for a line of reasoning, which starts with the risks *others* face and then studies what effect these risks have on one's *own* risk attitude. Furthermore, we avoid the criticism made on the dictator game that giving is a response to the demand characteristics of the game or that subjects' choices are affected by the composition of the choice set (Bardsley, 2008).

To illustrate the feasibility of our methodology, we conducted an experiment. The results of the experiment are mixed. We find relatively weak evidence for the lotteries of others to influence a subject's choice between lotteries for himself. Nevertheless, the evidence does suggest behavioral patterns of which the robustness can be tested in future studies. The results of the second type of question are striking and show a clear preference for the lottery rather than for the corresponding allocation. Subjects thus prefer situations where risks are independent rather than correlated. Overall, the results favor a rank dependent utility model of social preferences that is driven by rankings in payoffs, rather than a model driven by differences in payoffs.

The chapter proceeds as follows. Section 2 provides a theoretical foundation, which shows that extending social utility functions to allow for risky payoffs, predicts risk attitudes to depend on payoffs and risks faced by others. Section 3 introduces our methodology to measure risk preferences in a social context. Sections 4 and 5 discuss the experiment and report its results. Finally, Sections 6 and 7 provide a discussion and interpretation of the results of the experiment and a conclusion.

2.2 Theoretical Foundation

This section develops models that capture social preferences when outcomes are risky. We start with a discussion of social preference models for risk-free payoffs. Then we extend two of these models to allow for risky payoffs, which results in three different models. We show that all three extended models predict payoffs and risks of others to have an influence on an individual's risk attitude.

2.2.1 Social Preferences in a Risk-Free Environment

Consider $n + 1$ individuals $0, \dots, n$. This subsection studies preferences $\succsim$ of individual 0 over *allocations* $\mathbf{x} = (x_0, \dots, x_n)$ yielding riskless *payoff* $x_i \in \mathbb{R}$ for individual i . Though many utility functions have been developed to represent social preferences (see Sobel, 2005, for an excellent overview), in this section we focus on the social utility function introduced by Fehr and Schmidt (1999, FS henceforth)

$$U(\mathbf{x}) = x_0 - \alpha \frac{1}{n-1} \sum_{i=1}^n \max\{x_i - x_0, 0\} - \beta \frac{1}{n-1} \sum_{i=1}^n \max\{x_0 - x_i, 0\}$$

with $\beta \leq \alpha$, $0 \leq \beta \leq 1$. For every unit by which another individual's payoff exceeds individual 0's payoff, individual 0's utility is decreased by α . For every unit by which another individual's payoff is lower than individual 0's payoff, individual 0's utility is decreased by β . Rohde (2010) showed which preference conditions underly FS, by axiomatizing their model. Neilson (2006) and Sandbu (2008) extended FS to allow for more general nonlinear utilities. We will now discuss both of these extensions.

Neilson (2006) assumes that preferences are mainly driven by the absolute differences in payoffs between the other individuals and the decision-maker, as reflected in his *social differences utility (SDU) function*:

$$SDU(\mathbf{x}) = u(x_0) + \sum_{i=1}^n v(x_i - x_0),$$

with $v(0) = 0$. It can easily be seen that FS is a special case of SDU.

Another approach is to assume that preferences are driven by the payoffs others receive and the rank of the decision-maker's payoff in the allocation (Rablen, 2008; Sandbu, 2008). In this approach ranks, rather than differences are the driving forces in social preferences. Schmeidler's (1986, 1989) rank-dependent utility model captures this approach as a special case. First, we order the payoffs from best to worse, i.e. we take a permutation ρ on the set of individuals $\{0, \dots, n\}$ such that $x_{\rho(0)} \geq \dots \geq x_{\rho(n)}$. The function $\rho(i)$ gives the individual with payoff ranked i in the allocation, i.e. the individual with *social rank* i . *Social rank utility (SRU)* is given by

$$SRU(\mathbf{x}) = \sum_{i=0}^n \pi_i u(x_{\rho(i)}),$$

where u is a *utility function*, and π_i is the *utility weight* given to the individual

with social rank i . The utility weight for individual $\rho(i)$ is defined by

$$\pi_i = W(\{\rho(0), \dots, \rho(i)\}) - W(\{\rho(0), \dots, \rho(i-1)\})$$

for all i , where W is a *weighting function* that assigns a value to every subset of individuals. We assume that $W(\emptyset) = 0$ and $W(\{0, \dots, n\}) = 1$. Note that social rank utility in interpersonal choice is equivalent to rank-dependent utility in choice under risk where in the latter the states of nature play the role of individuals. Under social rank utility, the weight that an individual attaches to the payoff of another individual depends on the rank of this other individual's payoff in the allocation. It can, for instance, be the case that the decision maker weighs the payoff of an individual more when the latter is poorest than when this individual is richest. Rohde (2010) showed that FS is the special case of SRU with utility $u(x_i) = x_i$ and a weighting function given by $W(I) = 1 - (n - |I| + 1)\beta$ if $0 \in I$ and $W(I) = -|I|\alpha$ if $0 \notin I$, where $|I|$ gives the number of individuals in the set I .

2.2.2 Social Preferences in a Risky Environment

In the previous subsection, the allocations we considered were risk-free. If individuals care about others' payoffs as well as their own, then they are expected to do so not only in a risk-free environment, but also in a risky environment. In this subsection we will show how social preferences in a risky environment can be modeled.

We consider *allocation lotteries* $(p_1 : \mathbf{x}_1, \dots, p_l : \mathbf{x}_l)$ which yield allocation $\mathbf{x}_j$ with probability p_j for $j = 1, \dots, l$. By $x_{j,i}$ we now denote the payoff that individual i receives in allocation $\mathbf{x}_j$. We will assume that individual 0 evaluates allocation lotteries by calculating expected utilities. More precisely, we assume that in an isolated context with $n=0$, individuals behave according to expected utility.² Thus, in this chapter we use the rank dependent utility model only to model the interpersonal dimension of preferences, not the risk dimension. We introduced the term social rank utility in order to distinguish rank dependent utility in the interpersonal dimension from rank dependent utility in the risk dimension.

We extend both the social differences utility function and the social rank utility function to allow for risky payoffs. To illustrate how the risks and payoffs of individuals 1 to n can influence the risk attitude of individual 0, we consider the following example.

Example 1 Consider two individuals, i.e. $n=1$. When an individual receives payoff

²They do not satisfy rank dependent utility in the sense of non-linear probability weighting.

x with probability p and payoff y with probability $1 - p$ we say that he receives the lottery $(p : x, 1 - p : y)$. Individual 0 is offered the choice between the lotteries $(50\% : 15, 50\% : 5)$ and $(50\% : 20, 50\% : 0)$ twice: once when individual 1 receives 10 for sure and once when individual 1 receives the lottery $(50\% : 20, 50\% : 0)$, where this lottery is independent from the lottery of individual 0. We will get back to this example later in this section. $\square$

Expected Social Differences Utility

Extending the social differences utility function to capture risk attitudes yields the *expected social differences utility function*

$$ESDU(p_1 : \mathbf{x}_1, \dots, p_l : \mathbf{x}_l) = \sum_{j=1}^l p_j SDU(\mathbf{x}_j).$$

Example 1.1 Suppose individual 0 in Example 1 evaluates the lotteries according to ESDU with $u(x) = \ln(1 + x)$ and $v(x) = 0.2|x|^{1.3}$ if $x \leq 0$ and $v(x) = -0.01x^2$ if $x > 0$. Thus, he likes being better off than others and dislikes being worse off. If individual 1 gets 10 for sure, then the ESDU of lottery $(50\% : 15, 50\% : 5)$ equals

$$ESDU \approx \frac{1}{2} (4.392 + 1.542) = 2.967.$$

and the ESDU of lottery $(50\% : 20, 50\% : 0)$ equals

$$ESDU \approx \frac{1}{2} (7.035 - 1) = 3.0175.$$

Thus, given that individual 1 gets 10 for sure, individual 0 prefers $(50\% : 20, 50\% : 0)$.

If individual 1 gets $(50\% : 20, 50\% : 0)$ then the ESDU of lottery $(50\% : 15, 50\% : 5)$ equals

$$ESDU \approx \frac{1}{4} (2.523 + 9.533 - 0.458 + 3.412) = 3.753$$

and the ESDU of lottery $(50\% : 20, 50\% : 0)$ equals

$$ESDU \approx \frac{1}{4} (3.045 + 12.870 - 4 + 0) = 2.979.$$

Hence, given that individual 1 gets $(50\% : 20, 50\% : 0)$, individual 0 prefers $(50\% : 15, 50\% : 5)$. It follows that the choice of individual 0 depends on the lottery individual 1 faces. $\square$

The social rank utility function can be extended in two ways, depending on whether the utility weights are calculated before or after taking expectations.

Expected Social Rank Utility

Let us first assume that individual 0 first computes the social rank utility corresponding to every possible allocation and then computes the expectation of these utilities, which yields the *expected social rank utility function*

$$ESRU(p_1 : \mathbf{x}_1, \dots, p_l : \mathbf{x}_l) = \sum_{j=1}^l p_j SRU(\mathbf{x}_j).$$

Example 1.2 Suppose individual 0 in Example 1 evaluates the lotteries according to ESRU with $u(x) = (10 + x)^{0.8}$, $W(0) = 0.7$, and $W(1) = 0.5$. If individual 1 gets 10 for sure then the ESRU of lottery (50% : 15, 50% : 5) equals

$$ESRU \approx \frac{1}{2} (12.489 + 9.856) = 11.173$$

and the ESRU of lottery (50% : 20, 50% : 0) equals

$$ESRU \approx \frac{1}{2} (13.932 + 8.648) = 11.290.$$

If individual 1 gets (50% : 20, 50% : 0) the ESRU of (50% : 15, 50% : 5) equals

$$ESRU \approx \frac{1}{4} (14.164 + 11.086 + 11.961 + 8.002) = 11.303$$

and the ESRU of (50% : 20, 50% : 0) equals

$$ESRU \approx \frac{1}{4} (15.195 + 12.592 + 10.752 + 6.310) = 11.212.$$

Thus, if individual 1 gets 10 for sure, individual 0 prefers (50% : 20, 50% : 0) and if individual 1 gets (50% : 20, 50% : 0), individual 0 prefers (50% : 15, 50% : 5). $\square$

Social Rank Expected Utility

Individual 0 could instead also first calculate the expected utility of every individual:

$$EU_i(p_1 : \mathbf{x}_1, \dots, p_l : \mathbf{x}_l) = \sum_{j=1}^l p_j u(x_{j,i})$$

and then base the utility weights on the ranking of these expected utilities as follows. Consider a permutation ρ on the set of individuals $\{0, \dots, n\}$ such that

$EU_{\rho(0)}(p_1 : \mathbf{x}_1, \dots, p_l : \mathbf{x}_l) \geq \dots \geq EU_{\rho(n)}(p_1 : \mathbf{x}_1, \dots, p_l : \mathbf{x}_l)$. The *utility weight* for individual $\rho(i)$ is then defined by

$$\pi_i = W(\{\rho(0), \dots, \rho(i)\}) - W(\{\rho(0), \dots, \rho(i-1)\})$$

for all i . Then *social rank expected utility (SREU)* is given by

$$SREU(\mathbf{x}) = \sum_{i=0}^n \pi_i EU_{\rho(i)}(p_1 : \mathbf{x}_1, \dots, p_l : \mathbf{x}_l).$$

Example 1.3 Suppose individual 0 in Example 1 evaluates the lotteries according to SREU with $u(x) = \ln(10 + 10x)$, $W(0) = -0.1$, and $W(1) = -0.1$. Thus, individual 0 has a strong preference for equality: as long as he receives more expected utility than individual 1, he is willing to give up some of his payoff in order to obtain equality of the expected utilities. If individual 1 gets 10 for sure then the SREU of lottery (50% : 15, 50% : 5) equals

$$SREU \approx -0.1 \times 4.700 + 1.1 \times 4.585 \approx 4.57$$

and the SREU of lottery (50% : 20, 50% : 0) equals

$$SREU \approx -0.1 \times 4.700 + 1.1 \times 3.825 \approx 3.74.$$

If individual 1 gets (50% : 20, 50% : 0) the SREU of (50% : 15, 50% : 5) equals

$$SREU \approx -0.1 \times 4.585 + 1.1 \times 3.825 \approx 3.75.$$

and the SREU of (50% : 20, 50% : 0) equals

$$SREU \approx -0.1 \times 3.825 + 1.1 \times 3.825 = 3.825.$$

Thus, if individual 1 gets 10 for sure, individual 0 prefers (50% : 15, 50% : 5) and if individual 1 gets (50% : 20, 50% : 0), individual 0 prefers (50% : 20, 50% : 0).

Accounting for social concerns only after first considering individual expectations, as done when computing SREU, is similar in spirit to the models of Krawczyk (2007) and Trautmann (2009a). Note that in the social differences model it does not matter whether we first take expectations of u and v and then take the sum or whether we first take the sum and then take the expectations.

From Examples 1.1-1.3 it becomes clear that the utility a person derives from a lottery depends on the lotteries that others in his environment face and that his risk attitude depends on the risks others face.

2.3 Experimental Methodology

In most of the literature the way to analyze social preferences is to let people play a game like a dictator game or an ultimatum game (Bolton, Brandts, and Ockenfels 2005, Charness and Rabin 2002, Karni, Salmon, and Sopher 2008, Sebald 2007, Trautmann 2009b). The driving forces of decisions in the ultimatum game are not only preferences over final allocations, but also reciprocity concerns: people may behave in a certain way to induce others to behave in a certain way. It may well be that a social norm and reciprocity concerns conflict with a person's preferences over final allocations, which makes it impossible to disentangle preferences over final allocations from reciprocity concerns in the existing experiments. Reciprocity is not present in one-stage games. Therefore, one could argue that in the dictator game reciprocity plays no role. As we are interested in preferences over final allocations rather than reciprocity concerns, the dictator game might be more suitable for our purposes than the ultimatum game.

The dictator game, however, has been criticized for a possible framing effect with respect to the demand characteristics of the game, which result in socially prone behavior to be biased upwards. Bardsley (2008) argues that, as subjects in a dictator game can either do nothing or give, subjects might believe that the dictator game is about giving. The fact that subjects give might, therefore, be induced by the desire to be seen as a good subject. Furthermore, List (2007) and Bardsley (2008) show that as soon as taking is introduced into the choice set, the number of individuals who give drops significantly.

More importantly, both dictator and ultimatum games cannot give insights on how the risks others face might influence one's own risk attitude. The decisions subjects make in these games always simultaneously influence both their own payoff and the payoff of at least one other player. Risky versions of the dictator game (e.g. Bohnet, 2004, and Bohnet, 2008) or the ultimatum game can only answer how the decision maker's own attitude towards risk will have an impact on what he will give others who are facing either similar or different risks. We, however, want to investigate the impact of lotteries of others on subjects' choices over lotteries that affect only their own payoffs.

We propose a new methodology to explore preferences over final allocations, which allows us to investigate how a subject's own risk attitude depends on the payoffs and risks faced by others. Our methodology consists of two procedures, each of which can be implemented separately.

Procedure I

Procedure I of our methodology allows us to examine preferences over allocations as well as risk preferences. We consider a group of subjects and let each person choose between two lotteries while fixing the lotteries that the others in the group receive, i.e. we let each subject choose between allocation lotteries that vary only in the lottery the subject himself receives. Thus, when choosing, the decision maker cannot influence the payoffs and risks of the other subjects in the group. While the payoffs and risks of other subjects cannot be influenced, this does not mean that they play no role, as we showed in Examples 1.1-1.3.

Procedure II

The second procedure of our methodology is complementary to the first. It allows us to analyze the decision models of Section 2 in a different way than procedure I. Here, we fix the lottery that the decision maker will receive and let him choose between allocation lotteries for the other individuals in his group. The lotteries for the other individuals in the group are such that the total aggregate expected payoff for the others remains constant. Thus, we rule out concerns for efficiency in the sense of Engelmann and Strobel (2004): an individual's choice cannot be driven by a concern for maximizing total expected payoffs, as these are the same across options.

In this procedure, we focus on different types of allocation lotteries. Each type of allocation lottery can be seen as a different allocation rule, where the decision maker acts as a social planner. We let subjects choose between, for instance, an allocation where each 'other subject' receives an independent lottery yielding 20 euro with 30% probability and 10 euro otherwise, and an allocation yielding 20 euro to 30% of the other subjects and 10 euro to the rest of the other subjects. We refer to the first option as a *lottery* and to the latter as the *corresponding allocation*. In the latter, the subjects receiving a particular payoff will be randomly determined, so that every subject still has 30% probability of receiving 20 euro and 70% probability of receiving 10 euro. The resolution of the latter lottery, however, is not independent across subjects. This type of question allows us to analyze how subjects care about the correlation of their payoffs and risks with the payoffs and risks of others.

This type of question also indicates how concerns for procedural fairness may arise. If subjects would prefer the lottery to the corresponding allocation, then they prefer to let fate determine the final payoffs as much as possible and prefer to give everybody an equal chance on payoffs, independently of what the others

receive. A preference for the lottery over the corresponding distribution received considerable attention in the literature on social risk analysis in the 1980's (e.g. Broome 1982, Fishburn 1984, Hammerton, Jones-Lee, Abbott 1982, Keeney 1980, Keller and Sarin 1988). Procedure II allows us to test whether the mentioned findings in the 1980's are robust to real incentives.

A nice illustration of preferences over allocation rules is the following case in the Supreme Court of the United States: *Holmes v. United States* (Broome, 1984). In 1841, an American ship struck an iceberg close to Newfoundland. The crew and half of the passengers managed to escape in two available lifeboats. One of these lifeboats was overcrowded. In a desperate attempt to keep this lifeboat from sinking, the crew members threw persons overboard by using the criteria that no woman would be thrown overboard and that no couples would be separated. Crewman Alexander Holmes was later on convicted to 'unlawful homicide' and was sentenced to jail by the judge. The interesting aspect of this story is that Holmes was not convicted because of the manslaughter but rather because of the fact that he had not casted lots: "In no other than this or some like way are those having equal rights put upon equal footing ..." The council, however, argued that the principle of selection the crewman used was more human than using lots. The council and the crewman, thus, had different preferences over allocation rules than the judge.

According to ESDU, individuals should be indifferent between lotteries and the corresponding allocations. SREU would predict indifference as well. Under ESRU, however, individuals may have a strict preference. The reason for the latter is that the number of possible attainable social ranks for the decision maker may be larger in the lottery than in the corresponding allocation. Consider, for instance, the choice between the lottery and the corresponding allocation as described in example 1 and assume that the decision maker receives 15 euro for sure, no matter whether he chooses the lottery or the allocation. If he chooses the allocation, he will for sure not have rank 0 or rank n . If he chooses the lottery, he may still attain rank 0 or rank n . Thus, this type of question allows us to test for ESDU versus ESRU and for SREU versus ESRU.

2.4 Experiment

We implemented both procedures of our methodology in an experiment. All experimental sessions were conducted at the Behavioral and Experimental Economics laboratory Maastricht (BEELab) with 121 (65 male, 56 female) students from

Maastricht University. The vast majority (88%) were students from Economics and Business Administration. The other subjects were students from Law, Cultural Sciences, and from University College Maastricht. They were recruited through email announcements and announcements on the students' intranet. Each subject participated in only one session. The experiment was programmed in Z-tree (Fischbacher, 2007).

In every session, exactly 11 subjects participated. They all received a show-up fee of 4 euro. The average earnings per subject, including this show-up fee, was 12.98 euro. The experiment lasted 70 minutes on average. Between 20 and 35 minutes were spent on reading the instructions. At the end of the instructions there was a short questionnaire to test whether subjects understood the instructions. The experiment would continue only after all subjects completely understood the instructions. The instructions can be found in Appendix B. At the end, subjects were asked to answer some debriefing questions with respect to their demographics.

In reality individuals compare themselves with many others: friends, colleagues, neighbors, family, etc. In order to replicate the situation of one individual comparing himself with many others, we let subjects compare themselves not with only one other subject, but with all other subjects in the same session. Thus, when a subject makes a decision, there are 10 others, i.e. $n = 10$.

The experiment consisted of 40 questions where subjects had to make choices between allocation lotteries. There were 28 questions in the format of procedure I, 3 in the format of procedure II, and 9 of a different format as discussed below. At the start of the experiment 3 practice questions were given. The order of the questions was randomized. We also randomized the left-right presentation on the screen. To determine the earnings of all subjects, at the end of each session, one of the subjects and one of his questions was chosen at random. If this implied that the other subjects would receive a lottery the lottery was played for each of these subjects independently.

The allocation lotteries to choose from were displayed on the computer screen as in Figure 2.3 in Appendix A. The allocation lotteries are displayed as a 2×2 matrix. The left column shows one allocation lottery, and the right one shows the other one. Thus, the subjects choose between the left and the right column, named 'option A' and 'option B'. In each column, the upper half gives the lottery that the decision maker will receive and the lower half specifies the lotteries the others will receive.

In every question we would like our subjects to look at all entries of the 2×2 matrix. In particular, we want our subjects to be aware of the lotteries that the others face in the questions of type I. It is important to note that this is cognitively

demanding. If there were only questions of type I, subjects would soon discover that their choices would never affect the payoffs of other subjects. They could then be tempted to ignore others' payoffs as a heuristic to avoid cognitive load. Moreover, they could guess what the experimenter is testing, which could bias their answers as well. Therefore, in order to avoid biases, we randomize the order of questions of the type of procedure I and procedure II.

Procedure I

The 28 questions in the format of procedure I are given in Tables 2.4, 2.5, and 2.6 in Appendix A. The columns 'lottery 1' and 'lottery 2' give the two lotteries between which the decision maker has to choose given that the other 10 subjects receive the lottery described in the third column. The subjects are offered 4 types of choices. In the first type of choice the subject chooses between (30% : 23, 70% : 3) and 10 for sure for himself. As in this question one of the lotteries is a payoff to be received with certainty, we label this type of question 'Certainty'. The second type of choice is between (40% : 13, 60% : 8) and (50% : 20, 50% : 0) for the decision maker. Here the latter is a mean preserving spread (MPS) of the former, which is why we label these questions 'MPS'. The third type of choice is between (80% : 12, 20% : 2) and (80% : 7, 20% : 22). Neither of these two is a MPS of the other. An important difference between these lotteries is the minimum payoff attainable, which the subjects may choose to maximize. Therefore, we label this type of question 'Maximin'. We added two questions with higher stakes where the subjects choose between (20% : 60, 80% : 0) and (40% : 13, 60% : 8). We label these two questions 'Maximin High Stakes'. For each of the four types of questions we varied the lotteries that the other subjects received in order to check whether this would influence decisions. Some lotteries would ensure the same payoff as the decision maker, others would ensure the same lottery. Furthermore, we varied the lotteries the others would receive with respect to the probabilities and payoffs. By varying the lotteries the other receive, we can infer whether the level of risks and the levels of payoffs others receive influences the decision maker's risk attitude.

As this is the first experiment of its type, we wanted to ask many different types of questions in order to obtain richness in the data that would allow us to explore the basic patterns of behavior that can be observed in a risky social environment. Certain questions also serve to test the models discussed in Section 3.

As a benchmark, in each of the three categories, Certainty, MPS, and Maximin, we have one question where the other subjects receive the same payoff as the decision maker. In that question, the resulting allocation would always be constant,

i.e. without any inequity. This question, therefore, reveals subjects' individual preferences in isolation, i.e. if n were equal to 0. A similar question, which does allow for inequity in final allocations, is the one where the other subjects receive the same lottery as the decision maker, but where this lottery is independently resolved for each subject. A subject only concerned with ex ante opportunities of others, like a SREU maximizer, would not behave differently in this question compared to the benchmark question. Subjects who are concerned with the equity of final allocations might behave differently, though.

For the other questions, we varied the payoff and risks of the other subjects' lottery. In some questions the others would always receive more than the decision maker. In other questions, they would always receive less. There are also questions where the others would receive outcomes that are between the maximum and the minimum of what the decision maker would get. Finally, there are questions, like C6, that are of the lottery type as discussed in the description of procedure II and there are questions of the corresponding allocation type, like C7. Note that in C7, the subjects that would receive 15 would be determined randomly.

The predictions of the models of Section 3 can be found in Table 2.1. ESDU predicts that the choice in C6 is the same as that in C7. Similarly, the choice in MPS8 is the same as in MPS9, the choice in MM1 is the same as in MM4, and the choice in MM2 is the same as in MM5. ESRU predicts that the choice in MPS1 equals the choice in MPS2 and MPS6. Finally, SREU with concave utility predicts that the choice in C2 equals the choice in C4, the choice in MPS1 equals the choice in MPS2 and MPS5, the choice in MPS4 equals the one in MPS10, the choice in MPS7 equals the one in MPS8, and the choice in MM3 equals the choice in MM7.

ESDU	ESRU	SREU
C6 $\sim$ C7	MPS1 $\sim$ MPS2 $\sim$ MPS6	C2 $\sim$ C4
MPS8 $\sim$ MPS9		MPS1 $\sim$ MPS2 $\sim$ MPS5
MM1 $\sim$ MM4		MPS4 $\sim$ MPS10
MM2 $\sim$ MM5		MPS7 $\sim$ MPS8
		MM3 $\sim$ MM7

Table 2.1: Hypotheses for Procedure I

Procedure II and other choice questions

Table 2.7 in Appendix A lists the questions where the lottery for the decision maker is given and he has to choose between the allocation rules for the others. II1, II2, and II3 are of the type of procedure II. ESDU and SREU maximizers should exhibit indifference in these questions. O1, O2, and O3 were used to see whether the lotteries of the decision maker in II1, II2, and II3 were considered to be better or worse than the lottery that guarantees equity. We added O4 to test for consistency, as the answer in O3 and II3 would, together with transitivity, predict the answer in O4. O5, O6, and O7 test whether subjects are concerned with the equity among the others, as would be predicted by ESDU with non-linear v and by SREU and ESRU with non-linear u or non-linear W . Finally, O8 and O9 test whether the subjects like to be ahead of others and whether they dislike others being ahead.

Demographic questions

At the end of the experiment, we asked subjects for subjects' age, gender, number of brothers, and number of sisters. We also asked what kind of study programme they are enrolled in: Economics, Psychology, Healthcare, or other. Finally, we asked whether they are a member of a study- or student association, whether they are a member of a sports club, and how many subjects in their session they know.

2.5 Results**Procedure I**

In the Certainty and MPS questions, the majority of the choices (79.75% and 82.19%, respectively) are in accordance with risk aversion, and in the Maximin questions the majority of choices (73.56%) is in accordance with maximin. The exact percentages of the choices for each question can be found in Table 2.8 in Appendix A. These results are in accordance with the choices we would expect from subjects in an isolated context. Thus, the social context provided here does not seem to strongly influence subjects' risk attitudes.

Although in the Certainty, MPS, and Maximin questions subjects often chose one particular lottery, they did not always choose that lottery. This suggests that there were questions that made subjects' preferences switch when changing the lottery that others would receive. These switches can be caused by random error, but also by the social component of preferences being strong enough to make

preferences between lotteries switch. In order to test whether switches are mainly random or clearly in favor of one or the other lottery, we used a sign test. Figure 2.1 shows which switches are significant and in which direction. An arrow from C1 to C4 indicates that most switches from C1 to C4 were from lottery 1 to lottery 2. Thick arrows indicate significance at a 5% level (one-sided), and the other arrows indicate significance at the 10% level. Table 2.2 gives the corresponding p-values. As overall we do not observe many switches, significance is hard to be found.

Figure 2.1: Significant switches from lottery 1 to lottery 2.

Significant Switches from lottery 1 to lottery 2					
Certainty		MPS		Maximin	
Switch	p-value	Switch	p-value	Switch	p-value
C1 → C4	0.095	MPS2 → MPS6	0.073	MM1 → MM5	0.067
C1 → C8	0.068	MPS2 → MPS7	0.067	MM1 → MM6	0.084
C2 → C4	0.058	MPS2 → MPS8	0.058	MM3 → MM2	0.067
C2 → C8	0.032	MPS3 → MPS6	0.033	MM3 → MM5	0.014
C5 → C4	0.032	MPS3 → MPS7	0.047	MM3 → MM6	0.035
C5 → C8	0.013	MPS3 → MPS8	0.032	MM4 → MM5	0.072
C6 → C8	0.095			MM7 → MM5	0.084
				MM8 → MM5	0.084

Table 2.2: Significance of switches (one-sided p-values).

Using Figure 2.1, we investigate whether the few observed significant switches nevertheless help us distinguish between ESDU, ESRU, and SREU. ESDU predicts

that the choices in C6, MPS8, MM1, MM2, are the same as in C7, MPS9, MM4, and MM5, respectively (see Table 2.1). None of these predictions are rejected by the data. ESRU predicts that the choice in MPS1, MPS2, and MPS6 coincide. Though the choices in MPS1 and MPS2 are not significantly different, the switches from MPS2 to MPS6 are significantly non-random at a 10% level. SREU predicts that the choices in C2, MPS1, MPS4, MPS7, and MM3 are the same as in C4, MPS2, MPS10, MPS8, MM7, respectively, and that the choice in MPS2 is the same as in MPS5. None of these predictions could be rejected, except the switches from C2 to C4 being significantly non-random, at a 10% level. Thus, these findings do not show a strong evidence against one of the three models.

Possible other determinants that might play a role in the choice behavior are demographic and individual characteristics. We examine the effects of such characteristics on the choice behavior. For each characteristic, we calculated per block (i.e. C, MPS, MM, MMH) the number of times one particular lottery was chosen, and ran a Mann Whitney U test on these values. We found no significant effects, except for male subjects choosing lottery 1 significantly more often than female subjects in MMH (MWU: $p=0.001$, two-sided). Thus, men seem more sensitive to higher stakes than women.

Procedure II

II1, II2, and II3 are of the type of procedure II. Subjects have a significant preference for the lottery rather than the corresponding allocation (signtest: $p < 0.001$, two-sided). This holds for all questions. In II1, 67.77% of the subjects choose the lottery. In II2 and II3 these percentages are 67.77% and 82.64%, respectively. The exact percentages of the choices for all questions of procedure II can be found in Table 2.8 in Appendix A.

For each subject, we counted the number of times he or she chose the lottery in II1, II2, and II3. Figure 2.2 summarizes the results. In order to get a more detailed picture, Table 2.3 shows in which questions subjects chose the lottery rather than the corresponding allocation. As we can see, 47.93% of the subjects always prefer to give a lottery rather than the corresponding allocation to the other subjects, whereas only 6.61% prefer the exact opposite. Of the remaining, 45.45%, 28.92% and 16.53% prefer the lottery to the allocation twice and once, respectively. Thus, we indeed observe a clear regularity in the preferences for the lottery over the corresponding allocation. The results, hence, provide clear evidence that many subjects do not behave according to ESDU and SREU, but rather according to ESRU.

Figure 2.2: Consistency of Choices

Lottery preferred	II1	II2	II3	% of subjects
Always	x	x	x	47.93%
Twice	x	x		4.96%
	x		x	13.22%
		x	x	10.74%
Once	x			1.65%
		x		4.13%
			x	10.74%
% of subjects	67.8%	67.8%	82.6%	

Table 2.3: Choice patterns in procedure II

O1, O2, and O3 test whether the lotteries and corresponding allocations in II1, II2, and II3 are considered to be better or worse than the lottery that guarantees equity. Interestingly, we do not observe an overall preference for the lottery that guarantees equity. In O2 and O3 subjects clearly prefer to give the same as they will receive to the other subjects (signtest: $p < 0.001$, two-sided). The percentages are 69.42%, and 88.43%, respectively. However, in O1 69.42% of the subjects prefer to give the others the allocation rather than the same payoff as they themselves will receive. In overall, subjects prefer the lottery over the corresponding allocation no matter whether this allocation or lottery is considered to be better or worse than the lottery which would guarantee equity. In O4, subjects clearly prefer to give the same as they will receive to the other subjects (signtest: $p < 0.001$, two-sided), which is consistent with the findings in O3 and II3.

Again, we found no significant influence of the demographic variables on the choices made by subjects.

Remaining questions

O5, O6 and O7 test whether subjects are concerned with the equity of allocations among other subjects. Subjects did not significantly prefer one allocation over the other in these questions, suggesting that they were not concerned with the equity of the allocation among other subjects.

Finally, in O8 and O9, the subjects preferred to give the others the highest possible outcome in 87.60% and 85.95% of the cases, which was highly significant. This illustrates that subjects are willing to maximize the payoff of others, even if this leads to being worse off than these other subjects.

2.6 Interpretation and Discussion

Further Interpretation

We will now further interpret the findings reported in Figure 2.1 and Table 2.2. Overall, not many switches were observed in Figure 2.1, suggesting that choices are not strongly affected by the payoffs and risks of others. This was confirmed by the debriefing of subjects after each experimental session. Most subjects wrote down that they made their choices by first choosing the best lottery for themselves and only then caring about the lotteries of the others, suggesting a lexicographic type of decision making.

We will now investigate whether the few switches that are observed, though, do suggest consistent behavioral patterns. If such behavioral patterns can be found, future studies can test the robustness of these patterns. First, consider the Certainty questions. The interesting feature of the lotteries in these types of questions is that subjects can avoid the standard risk by choosing for lottery 2, which gives them a certain payoff of 10. On top of that, in C4 and C8 they can even avoid another type of risk, namely the risk of facing an unequal allocation, by choosing lottery 2. Choosing lottery 1 in C4, could lead to inequity as the others will face the exact same lottery. Choosing lottery 1 in C8 would anyhow lead to inequity. Figure 2.1 shows that in C4 and C8 lottery 2 is significantly more chosen in comparison to the questions where the other subjects receive a certain payoff.

In C2 and C5, lottery 1 is significantly more chosen. In both these questions, subjects can never end up being worse off than other subjects. In C2 strict equity will arise no matter which lottery is chosen. In C5, the worst possible payoff for a

subject in the risky lottery is the payoff that all other subjects receive. Choosing the risky lottery, therefore, will not lead to disadvantageous inequity in the sense of the decision maker being worst off.

In C1, a subject will for sure face inequity by choosing lottery 2, as he would then receive a payoff of 10, whereas all others would receive a payoff of 16. A subject might therefore be induced to choose lottery 1 as there he still faces the chance of being better off than the other subjects. The certainty in the other subjects' payoff leads to a relatively higher choice of the risky lottery 1.

In the MPS and Maximin questions certainty can never be assured, as no payoff is given for sure to the decision maker. Certainty in terms of equity can only be assured in MPS10 and MM3 where the other subjects receive the same outcome as the decision maker. The results of the MPS and Maximin do not show a clear choice pattern.

The results of procedure II are striking. Subjects appear to have a strong preference for one allocation rule over the other. They prefer the lottery to the corresponding distribution. This result suggests that subjects are not being willing to be held responsible for determining the allocation of outcomes. They rather have fate determine the actual payoffs of the other subjects. In that sense, they are decision averse. Interestingly, we observe this preference irrespective of whether the other subjects face a higher, an equal or a lower expected value than the decision maker. However, we do observe significantly more subjects choosing the lottery when the expected value for the other subjects is lower than the expected value for the decision maker (signtest II1 vs II3: $p=0.001$, one-sided, and signtest II2 vs II3: $p=0.003$, one-sided).

Two possible explanations can be given for the fact that in O2, O3 and O4 subjects prefer to give the same payoff to the others as they will receive themselves, while this preference is not present in O1. Subjects seem to be maximizing the expected values of the other subjects. However, this interpretation does not explain why we find a significant preference for 'the same payoff as you' in case where the expected values of all subjects are identical. This brings us to the second possible explanation. In all questions where subjects prefer to choose the same payoff as themselves for the other subjects, the lottery or allocation they would otherwise get contains the worst possible outcome in comparison to the lowest possible outcome in their own lottery. Maximizing the other subjects' worst possible outcome, therefore seems to be another plausible motive. Both motives are actually confirmed by the results found for O8 and O9. In these two questions the lottery which maximizes the other subjects' (worst possible) payoff is significantly more often chosen (signtest: $p<0.001$ for both questions). Subjects are thus willing to

maximize the (worst possible) payoff of others, even if this may lead to being worse off than these other subjects. In O8, 87.60% and in O9, 85.95% of the subjects behaved in this way.

Discussion

We are aware of three studies that are close in spirit to ours. Brennan et al. (2008) did an experiment in the spirit of our methodology. They considered two lotteries: a risky and a sure one, which gives the expected payoff of the risky one for sure. Every subject was paired with another subject. The authors considered four allocation lotteries: (1) both subjects receive the lottery, (2) both subjects receive the sure payoff, (3) one subject receives the lottery and the other the sure payoff, and (4) the reverse. Then they elicited the willingness to pay (WTP) and the willingness to accept (WTA) of the decision maker for each of these allocation lotteries, given that the other player does not pay or receive anything. Thus, strictly speaking, in the WTA treatment the decision maker chooses between an allocation lottery and an allocation where he receives the WTA and his partner receives nothing. Therefore, in the choice the lottery of the other player is not kept fixed. When choosing (or determining the WTA or WTP) the player thus simultaneously determines his own and his partner's payoff. In the analysis of the results, though, Brennan et al. compare the WTP and WTA from the four allocation lotteries. In that sense their experiment is close in spirit to our proposed methodology. Interestingly, Brennan et al. (2008) also find no significant effect of the risk of others on individual behavior.

Another experiment in the spirit of our methodology, is Linde and Sonnemans (2009). Linde and Sonnemans studied whether risk attitudes depend on whether others receive more or less than the decision maker. They show that subjects are relatively more risk averse when they are guaranteed to earn less than their partner, though the vast majority of subjects behaves according to risk aversion. Linde and Sonnemans' study differs from ours in some important aspects. First, they only consider others' payoffs to be riskless. Second, their experiment includes a large proportion of questions where the decision maker simultaneously influences his own and the other's payoff. Third, subjects are randomly paired with one other subject in their study, while we consider all subjects in one session as one group. Fourth, each subjects first had to play several Bertrand games against the subject he was paired with. Only after these Bertrand games, did the subjects answer the

questions in the spirit of our methodology. Between the Bertrand games and the next questions every subject was shown the picture of his partner.

The experiment by Kroll and Davidovitz (2003) is in a similar spirit as our Procedure II in the sense that it concerns allocation rules. They let children choose between two allocation lotteries. The first allocation lottery, which they call ‘common game’, would give the decision maker a particular lottery and the others would receive the same as the decision maker. In the second allocation, which they call ‘individual game’ the lottery was the same, but it was resolved for every subject independently. They found a significant preference for the first lottery. This finding predicts that in Procedure I C2, MPS10, and MM3 are perceived to be different than C4, MPS4, and MM7, respectively. We only find a significant switch in a particular direction between C2 and C4, though.

2.7 Conclusion

By extending existing models of social preferences in a risk-free environment, this chapter developed models that capture social preferences when payoffs are risky. All models predict not only that utility levels are influenced by payoffs and risks faced by others, but also that an individual’s choices between lotteries depend on the payoffs and risks his environment faces.

In order to examine how risks and payoffs of others influence risk attitudes, we developed a new experimental methodology. The key feature of our methodology is to keep either the lottery of the decision maker or the lottery that others receive fixed, and to vary the other lottery. Then repeating the questions for a different fixed lottery allows us to explore risk attitudes in a social context. It allows us to analyze whether risk attitudes depend on the lotteries others face. Since the decision makers do not influence the payoffs of others in this context, choices cannot be driven by intentions, social pressure or reciprocity. Thus, our results are not confounded by reciprocity and fully reflect preferences over allocations. Our methodology allows us to analyze how the risks and payoff others face affect the decision maker’s risk attitude, which cannot be answered with the help of a dictator or ultimatum game. In the latter games, the focus is on the decision maker’s own risk attitude and its impact on how much is given to others.

Our results show that risk attitudes are not so much affected by the risks others face. Striking, though, is the finding that subjects prefer lotteries to their corresponding allocations, where risks are perfectly independent across subjects. This indicates that subjects prefer everybody to undergo the same procedure,

thereby avoiding the possibility to be held responsible for bad outcomes of others. This result provides strong evidence in favor of the expected social rank utility model, and against the expected social differences utility model and the social rank expected utility model.

2.8 Appendix A

Option A		Option B	
you receive		you receive	
15 euro	with probability $1/2$	13 euro	with probability $2/3$
5 euro	with probability $1/2$	7 euro	with probability $1/3$

the others receive		the others receive	
16 euro	with probability $3/5$	17 euro	with probability $1/5$
6 euro	with probability $2/5$	9 euro	with probability $4/5$

☐ I prefer option A		☐ I prefer option B	
<input type="button" value="OK"/>			

Figure 2.3: Screenshot

Table 2.4: **The lotteries for procedure I: Certainty.**³

		Lottery 1	Lottery 2	Lottery Others
Certainty	C1	(30%: 23, 70%: 3)	10	16
	C2	(30%: 23, 70%: 3)	10	same payoff as you
	C3	(30%: 23, 70%: 3)	10	(20%: 25, 80%: 5)
	C4	(30%: 23, 70%: 3)	10	same lottery as you
	C5	(30%: 23, 70%: 3)	10	3
	C6	(30%: 23, 70%: 3)	10	(50%: 15, 50%: 5)
	C7	(30%: 23, 70%: 3)	10	15 for 50% of subjects 5 for 50% of subjects
	C8	(30%: 23, 70%: 3)	10	10

Table 2.5: **The lotteries for procedure I: MPS.**

		Lottery 1	Lottery 2	Lottery Others
MPS	MPS1	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	10
	MPS2	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	13
	MPS3	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	(50%: 25, 50%: 5)
	MPS4	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	same lottery as you
	MPS5	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	20
	MPS6	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	8
	MPS7	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	0
	MPS8	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	(20%: 20, 80%: 0)
	MPS9	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	20 for 20% of subjects 0 for 80% of subjects
	MPS10	(40%: 13, 60%: 8)	(50%: 20, 50%: 0)	same payoff as you

³Note that the expected value of lottery 1 is 9, while the expected value of lottery 2 is 10. We chose this expected value of 9, because we expected the social context to have a strong impact on risk attitudes. Thus, we expected that subjects would be risk seeking in this context, so as to still be able to get more than the other subjects in at least some instances. As the results show, though, the impact of the social context on choices appeared not to be that strong.

Table 2.6: The lotteries for procedure I: Maximin.

		Lottery 1	Lottery 2	Lottery Others
Maximin	MM1	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	(80%: 12, 20%: 2)
	MM2	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	(80%: 7, 20%: 22)
	MM3	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	same payoff as you
	MM4	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	12 for 80% of subjects 2 for 20% of subjects
	MM5	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	7 for 80% of subjects 22 for 20% of subjects
	MM6	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	10
	MM7	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	same lottery as you
	MM8	(80%: 12, 20%: 2)	(80%: 7, 20%: 22)	(50%: 11, 50%: 9)
Maximin	MMH1	(20%: 60, 80%: 0)	(40%: 13, 60%: 8)	(33%: 33, 67%: 0)
High Stakes	MMH2	(20%: 60, 80%: 0)	(40%: 13, 60%: 8)	11

Table 2.7: The lotteries for procedure II and others.

	You	Others 1	Others 2
II1	(40%: 13, 60%: 8)	(30%: 20, 70%: 10)	20 for 30% of subjects 10 for 70% of subjects
O1	(40%: 13, 60%: 8)	same payoff as you	20 for 30% of subjects 10 for 70% of subjects
II2	(30%: 17, 70%: 7)	(50%: 15, 50%: 5)	15 for 50% of subjects 5 for 50% of subjects
O2	(30%: 17, 70%: 7)	(50%: 15, 50%: 5)	same payoff as you
O3	(50%: 16, 50%: 4)	(20%: 20, 80%: 0)	same payoff as you
O4	(50%: 16, 50%: 4)	same payoff as you	20 for 20% of subjects 0 for 80% of subjects
II3	(50%: 16, 50%: 4)	(20%: 20, 80%: 0)	20 for 20% of subjects 0 for 80% of subjects
O5	(20%: 20, 80%: 8)	13 for 40% of subjects 8 for 60% of subjects	14 for 20% of subjects 12 for 20% of subjects 10 for 30% of subjects 6 for 30% of subjects
O6	(20%: 20, 80%: 8)	13 for 40% of subjects 8 for 60% of subjects	13 for 40% of subjects 10 for 30% of subjects 6 for 30% of subjects
O7	(20%: 20, 80%: 8)	13 for 40% of subjects 8 for 60% of subjects	14 for 20% of subjects 12 for 20% of subjects 8 for 60% of subjects
O8	(40%: 13, 60%: 8)	13	8
O9	10	13	8

RISK ATTITUDES IN A SOCIAL CONTEXT

Question	Percentage	Question	Percentage	Question	Percentage
C1	22.3%	MPS1	83.5%	MM1	28.1%
C2	23.1%	MPS2	85.1%	MM2	24.8%
C3	20.7%	MPS3	86.0%	MM3	31.4%
C4	16.5%	MPS4	83.5%	MM4	27.3%
C5	24.0%	MPS5	81.8%	MM5	21.5%
C6	20.7%	MPS6	80.2%	MM6	22.3%
C7	19.8%	MPS7	78.5%	MM7	28.1%
C8	14.9%	MPS8	78.5%	MM8	28.1%
		MPS9	82.6%	MMH1	55.4%
		MPS10	83.5%	MMH2	53.7%

Table 2.8: Percentage choice Lottery 1 across different questions

Question	Percentage	Question	Percentage
II1	67.8%	O5	47.9%
O1	30.6%	O6	52.1%
II2	67.8%	O7	47.1%
O2	30.6%	O8	87.6%
O3	11.6%	O9	86.0%
O4	87.6%		
II3	82.6%		

Table 2.9: Percentage choice Others 1 across different questions

2.9 Appendix B

Instructions

Introduction

Welcome to this decision-making experiment. In this experiment you can earn money. How much you earn depends on your decisions and the decisions of other participants and random events. At the end of the experiment your earnings will be paid out privately and confidentially in cash.

It is important that you have a good understanding of the rules in the experiment. Therefore, please read these instructions carefully. In order to check that the instructions are clear to you, you will be asked a few questions at the end of the instructions. The experiment will start only after everybody has correctly answered those questions. At the end of the experiment you will be asked to fill in a short questionnaire. Thereafter you will receive your earnings.

During the whole experiment, you are not allowed to communicate with other participants.

If you have a question, please raise your hand. We will then come to you and answer your question in private.

Explanation experiment

During this experiment there are **eleven** participants, which means that there are ten other participants. The other participants answer the same questions as you do, only in a different order.

The experiment consists of 40 questions. In each question you will be asked to **choose between two allocations of lotteries** for the participants in this experiment. Your choices will be anonymous. There is no wrong or right answer. We are only interested in your own preferences. During the experiment, you will not receive any information about the choices of the other participants. They will

also not receive any information about your choices.

You will encounter three types of allocations. We will now explain these three types of allocations. Note that in each question you will have to choose between **two** allocations.

Independent lotteries

In the first type of allocation everyone receives a lottery. You may receive a different lottery than all the other participants, but all other participants receive a common lottery. An example of such an allocation is as follows

<i>Allocation I</i>	
You receive	
	17 euro with probability $1/5$
	18 euro with probability $4/5$
The others receive	
	15 euro with probability $2/5$
	19 euro with probability $3/5$

In this allocation a lottery is played for you, which yields 17 euro with probability $1/5$ and 18 euro with probability $4/5$. For each other participant a lottery is played, which yields 15 euro with probability $2/5$ and 19 euro with probability $3/5$. The lotteries of different participants are thus independent and do not necessarily yield the same payoff. This means that when your lottery turns out to yield 17 euro, this does not increase or decrease the probability of another person getting 15 euro. Moreover, if the lottery of one other participant, called participant A, turns out to yield 15 euro, then the probability that another participant, called participant B, also gets 15 euro remains $2/5$. Participant B does not necessarily then also receives 15 euro. For him the lottery is also played, and he also gets 15 euro with the probability $2/5$. Thus the lottery is played for each player separately, not only once for all "others" at the same time.

Let's consider another allocation:

In this allocation everybody receives the same lottery. Depending on the realizations of the lotteries, it is likely that not everybody will receive the same payoff, because the lottery is played for each player separately, not only once for all "oth-

Allocation II

You receive

17 euro with probability $1/5$ 18 euro with probability $4/5$

The others receive

17 euro with probability $1/5$ 18 euro with probability $4/5$

ers” at the same time.

Others receive the same as you

In the second type of allocation you receive a lottery and all other participants will receive the same payoff as you. An example is as follows:

Allocation III

You receive

10 euro with probability $1/5$ 18 euro with probability $4/5$

The others receive

the same as you

In this lottery you receive 10 euro with probability $1/5$ and 18 euro otherwise. If it turns out that you receive 10 euro, then all other participants will also receive 10 euro. If it turns out that you receive 18 euro, then all other participants will also receive 18 euro. In this sense your outcome will determine what the others get.

Others receive different payoffs with certainty

In the third type of allocation you receive a lottery and one part of the other participants gets one payoff and the other participants get another payoff for sure. Consider the following example:

In this allocation you receive the lottery, which yields a payoff of 25 euro with probability $1/5$ and a payoff of 8 euro with probability $4/5$. From the other participants the computer will randomly select 3 people who will receive 15 euro and the others will receive 19 euro.

<i>Allocation IV</i>	
You receive	
	25 euro with probability $1/5$
	8 euro with probability $4/5$
The others receive	
	3 persons receive 15 euro
	7 persons receive 19 euro

During the experiment we will repeatedly ask you to make a choice between two allocations. The screen you will see during the experiment looks as follows.

Option A		Option B	
you receive		you receive	
15 euro	with probability $1/2$	13 euro	with probability $2/3$
5 euro	with probability $1/2$	7 euro	with probability $1/3$
the others receive		the others receive	
16 euro	with probability $3/5$	17 euro	with probability $1/5$
6 euro	with probability $2/5$	9 euro	with probability $4/5$
☐ I prefer option A		☐ I prefer option B	
<input type="button" value="OK"/>			

Figure 2.4: Computerscreen 1

In the two boxes you see two different allocations, called option A and option B, from which you have to choose. The circles show a graphical representation of the corresponding allocations. After selecting one of the two allocations, you can press the “OK” button.

The first 3 questions will be “practice questions”. The next questions all may determine your payoff at the end of this experiment. **At the end of the experiment the computer will select one person out of the 11 participants at random. From that selected person one of the questions will randomly be selected and played out for real money, to determine the payoff of all participants. Note that this does not mean that the others will not receive anything. If you are the one selected, one of the questions you answered will be randomly selected and your chosen lottery will be played for you. Afterwards, the option you chose in that question will also be used to calculate the payoff of the others by playing the allocation you chose for them. The person who is selected thus determines the payoffs for all participants.**

Thus, every time you answer a question, keep in mind that this question may be the one that will determine your payoff and the payoffs of the others in the end. Every allocation we describe may be the one you and the other participants really end up with.

Everybody will be paid his or her payoff from the experiment plus 4 euro for showing up.

Part II

Risk Attitudes in a Strategic Social Environment

3

NEIGHBORHOOD CHOICE AND EFFICIENT COORDINATION

Experiments have shown that in a variety of environments people fail to coordinate on welfare maximizing equilibria. Yet, outside the lab they seem to agree on rather efficient arrangements. The possibility to choose interaction partners is a natural feature of almost any interaction between human beings. Yet, this feature is largely neglected in the experimental and theoretical economic literature.

In this chapter, we examine the implications of endogenous interaction structures on coordination problems. Groups of six subjects play a 2 x 2 coordination game. A participant's strategy involves both an action decision in the coordination game and interaction proposals regarding the interaction partners. In a baseline treatment each participant has to play the coordination game with all five other group members. The experimental treatments vary in the required consent and in the costs of proposing interactions. The results clearly show that the endogenous choice of interaction partners is a powerful force to achieve coordination on the payoff dominant outcome. If proposing an interaction is costly though, subjects face an additional coordination problem, which they are unable to resolve.

3.1 Introduction

Societies are shaped by the interactions and decisions of its members. Many situations are such that coordination of individuals' actions is beneficial. One example is the adoption of academic writing software at the beginning of an academic career. Each researcher decides either to use a word processor like Microsoft Word or a document processor like LaTeX. The decision is often based on whether or not the preferred software is compatible with the software package used by co-authors and fellow researchers, as compatibility allows researchers to collaborate efficiently. This compatibility is ensured by using the same software package.

Another example is choosing which language to learn as a second language. The benefits of learning a second language depend on the languages spoken by the persons with whom one will interact. Currently, English prevails as the most widely used language internationally, mainly due to the economic and political influence of English speaking countries and the Internet. As more people are able to speak English, it also becomes more beneficial to learn English as a second language, reinforcing favoritism towards the English language. Furthermore, due to increased mobility, both physically and virtually, distances between individuals have become smaller, coordination on the same language becomes increasingly important. Empirical research shows that changing patterns of interaction due to migration have had a significant impact on the extinction and supremacy of different languages (e.g. Brenzinger (1998) and Watkins (1991)).

In both examples, the choices individuals will make crucially depend on the choices of those persons with whom the individuals expect to interact and the number of persons the individuals expect to interact with. In this chapter, we will experimentally investigate the effect of endogenizing the choice of interaction partners on the choices made in a coordination game.

In most of the early literature on coordination games, the influence of the choices made by the persons with whom an individual interacts on the individuals' choices has been analyzed within exogenous interaction structures. In theoretical models, individuals either possibly interact with any other player in the population (e.g. Kandori, Mailath and Rob (1993), and Young (1993)) or with a small fixed subset of the population (e.g. Anderlini and Ianni (1996) and Ellison (1993)). In both types of interaction structures, the same insights are obtained, namely that in the long run, the risk dominant equilibrium is the unique and stable outcome.

Since the late nineties, several authors have experimentally examined the relationship between different interaction structures and individuals' action choices. Berninghaus, Ehrhart and Keser (2002) find that when subjects are located on a circle and only interact with their direct neighbors, subjects tend to move to the risk dominant outcome, whereas if subjects interact in isolated groups of three, there is a tendency to move towards the payoff dominant equilibrium. This result is in line with the finding of van Huyck, Battalio and Beil (1990), who find that smaller population sizes facilitate the coordination on the payoff dominant outcome. Furthermore, Berninghaus et al.(2002) find that a larger overlap of neighborhoods induces more coordination on the payoff dominant outcome. Recently, Weber (2006) showed that exogenously increasing group sizes may also help to coordinate on the payoff dominant equilibrium in larger groups.

Still, all these approaches do not take into account the fact that the interaction

structure in a society is subject to a dynamic process. In reality, one can almost always choose with whom one wants to interact. In theory, this implies that instead of imposing an interaction structure, players are allowed to choose the neighbors they want to interact with. This enables players to limit interaction to situations where coordination is present, which in turn may strongly influence the actions chosen in the coordination game. We hypothesize that endogenizing the choice of interaction partners can be a powerful force to achieve coordination on the payoff dominant equilibrium. To test this hypothesis, our subjects repeatedly play two person coordination games with their interaction partners. In each round, subjects simultaneously decide with whom they would like to interact and which action they are going to play in the coordination game.

Our experimental design is related to the theoretical literature on endogenous network formation and coordination games (e.g. Goyal and Vega-Redondo (2005), and Jackson and Watts (2002)). Though the authors analyze models that are similar in spirit, the models also differ in some important respects. Whereas Goyal and Vega-Redondo assume that interactions are formed unilaterally, Jackson and Watts assume that interactions can only take place if there is mutual consent between the players involved. Another difference is that in Goyal and Vega Redondo, the decisions with whom to interact and which action to choose in the coordination game are made simultaneously, whereas in Jackson and Watts they are made sequentially. Both studies focus on the effect of interaction costs on the equilibrium strategy and associated network structure. Both find that as interacting becomes costly, people move from a complete network in which all coordinate on the risk dominant outcome to the complete network in which all coordinate on the payoff dominant outcome. In addition, Jackson and Watts find that as interacting becomes very costly, the empty network where all choose the risk dominant action is also a possible equilibrium state.

Corbae and Duffy (2008) conducted an experiment that is closest in spirit to our experiment. They consider a four person, two stage game where in the first stage the network structure is determined via mutual consent, and in the second stage subjects play a repeated coordination game with their entire neighborhood for 5 rounds. At the start of the second stage one subject in each group is randomly chosen and is forced to play the risk dominant action. This allows them to explore the issue of contagious spread of actions. Their main finding is that the networks where subjects interact in isolated groups of two, are most frequent and most stable. The crucial difference between our study and theirs is that in their study subjects can not immediately respond to the actions chosen in the coordination game by influencing the set of players whom they will interact with. We

believe that this possibility is critical in understanding the implications of endogenous interaction structures, and that it will shed light on why in reality individuals are seemingly able to reach rather efficient arrangements. In our experiment individuals can at all times decide with whom they would like to interact and can decide which action they would like to choose.

3.2 The Experiment

In this section, we first introduce the network game and the coordination game followed by the different treatments and associated treatment variables. At the end of this section, we discuss the theoretical predictions and related behavioral hypotheses.

3.2.1 Network Game

The game is based on the model of Goyal and Vega-Redondo (2005). Players are situated in an endogenous social network. At each point in time, they play two person coordination games with their neighbors, i.e., all players with whom they interact. The set of neighbors might vary across different points in time. Let $N = \{1, 2, 3, \dots, n\}$ be a finite set of players and let $A = \{B, G\}$ be a set of actions in the coordination game. The payoff of player i for playing the coordination game with player j is determined as follows

		Action Player j	
		B	G
Action Player i	B	a,a	d,e
	G	e,d	b,b

Table 3.1: Payoff Matrix of the Coordination Game

where

$$a > e, \quad b > d, \quad a > b, \quad a + d < b + e.$$

Coordination, i.e., playing (B,B) or (G,G), is therefore always better than no coordination. Furthermore, the game has two pure strategy Nash equilibria that can be Pareto ranked. The payoff dominant equilibrium is (B,B) whereas the risk dominant equilibrium is (G,G) (Harsanyi and Selten, (1988)).

In each round, player i simultaneously chooses *one* action and decides with whom he would like to interact in the coordination game. Formally, player i 's strategy is $s_i = \{a_i, g_i\}$ where $a_i \in \{B, G\}$ and $g_i = (g_{i,1}, \dots, g_{i,i-1}, g_{i,i+1}, \dots, g_{i,n})$ where $g_{i,j} \in \{0, 1\}$ for each $j \in N \setminus \{i\}$. In our experiment, we will consider two different conditions for an interaction to occur, namely, one-sided and two-sided interaction proposals. In the case of one-sided interaction proposals, an interaction between player i and j takes place when either $g_{i,j} = 1$ or $g_{j,i} = 1$, i.e., one player's proposal is sufficient for the players involved to interact. Hence, the neighborhood of player i is denoted by $N_i(g) = \{j | g_{i,j} = 1 \text{ or } g_{j,i} = 1\}$. In the case of two-sided treatments, an interaction between player i and j takes place only when $g_{i,j} = g_{j,i} = 1$, i.e., mutual consent of players is required in order for them to interact. Consequently, the neighborhood of player i is denoted by $N_i(g) = \{j | g_{i,j} = g_{j,i} = 1\}$.

Proposing an interaction entails a cost $c \geq 0$ for the proposer. Since the cost of proposing an interaction is constant across different players and different rounds, the cost function for player i is, $c(g_i) = c \sum_{j \in N \setminus \{i\}} g_{i,j}$.

In our experiment, player i will play his chosen action a_i against *all* his neighbors. In each round the payoff for player i will then be

$$\Pi_i(s_i, s_{-i}) = \sum_{j \in N_i(g)} \pi_i(s_i, s_j) - c(g_i).$$

Treatments

Our experiment consists of three neighborhood treatments that differ in the requirements imposed on the interaction proposals and in the costs of interaction, and one baseline treatment. In the baseline treatment the coordination game is transformed into a population game, in the sense that each player plays the coordination game with all others. Table 3.2 summarizes the implemented treatments and their associated conditions on interactions.

		Required Interaction Proposal		Enforced Interactions
		<i>one-sided</i>	<i>two-sided</i>	
Interaction	$c = 0$	I-NC	II-NC	B
Costs	$c > 0$	I-C		

Table 3.2: Implemented Treatments

3.3 Hypotheses

3.3.1 Theoretical Hypotheses

Goyal and Vega-Redondo (2005) provide theoretical predictions for each of our three neighborhood treatments which we will summarize below. As our network game is a repeated game, we are interested in the long run predictions, i.e., in the stochastically stable outcomes.¹ A state is assumed to be stochastically stable if it takes relatively more errors to exit this state than the other state.

Treatment B: baseline treatment

In this treatment, each player plays the coordination game with all others, as in a population game. The unique stochastically stable equilibrium is where all players coordinate on the risk dominant action. The assumption made earlier that $a + d < b + e$, ensures that playing the risk dominant action is a best response if the other player places equal probability on his two actions. Now suppose player i has to decide whether to play action B or G . The minimum of other players needed for him to choose B is given by $x = (n - 1)(a - e) / [(b - d) + (a - e)]$, whereas the minimum of players needed for him to play G is given by $y = (n - 1)(b - d) / [(b - d) + (a - e)]$. Given the assumption that $a + d < b + e$, it follows that $y < n/2 < x$. Now suppose that the initial situation is such that everyone plays the risk dominant strategy. In order for the myopic best response dynamics to induce an alteration in the selected equilibrium, more than half of the population must randomly alter their strategy choice in favor of the payoff dominant action. Only then the dynamics will move toward the payoff dominant outcome. However, less than half of the population is needed to go from the payoff dominant to the risk dominant outcome. As a result, in the long run, there will be a higher chance that in any given round players will be coordinating on the risk dominant outcome.

Treatment I-NC: one-sided, costless interaction proposals

In the main model of Goyal and Vega-Redondo, an interaction proposal has to be at least one-sided in order for the interaction to take place. They find that if interaction costs are close to zero, and the gross payoffs that can be earned are positive, each player has an incentive to interact with everyone, irrespective of the actions these neighbors choose. As a result, in the stage game, a complete network

¹The advantage of using stochastic stability over using the concept of repeated games, is that in case of stochastic stability the predictions are clear. Furthermore, it allows for errors.

emerges where players either all coordinate on the risk dominant, or on the payoff dominant action. In the long run, however, the only stochastically stable outcome is the complete network where all players coordinate on the risk dominant action. The intuition is similar as in treatment B, due to the complete network that arises.

Treatment I-C: one-sided, costly interaction proposals

When proposing an interaction is sufficiently costly, players will only want to interact with players whose action choice will lead to positive payoffs. We will consider the situation where the interaction costs c lies between the payoff of playing the payoff dominant and the risk dominant action, i.e., $a > c > b$. This implies that only playing the payoff dominant action is profitable for *both* players. The equilibrium network structure, and the associated equilibrium in the stage game is either a complete network in which all players coordinate on the payoff dominant outcome, or an empty network where all players choose the risk dominant action. The complete network, where all players coordinate on the payoff dominant action results from the fact that interacting is only beneficial if the neighbor plays the payoff dominant action. Otherwise, no interaction will take place, resulting in an empty network where all players choose the risk dominant action. The only stochastically stable outcome in this condition is the situation where a complete network emerges with all players coordinating on the payoff dominant action.

Treatment II-NC: two-sided, costless interaction proposals

In treatment II-NC, mutual consent is required in order to interact. As there are no interaction costs, all interactions are profitable, irrespective of the actions chosen by the neighbors. As mutual consent is needed in order to interact, multiple equilibrium network structures can arise in the stage game. For instance, consider an empty network. One person alone cannot change this network structure. For all players, both deciding to propose an interaction and deciding *not* to propose an interaction are best responses, as interacting requires mutual consent. Due to the inability of one person to change the state of the network, many states can arise that are equilibria. Note, however, that not proposing an interaction is a weakly dominated strategy, as interacting leads to positive earnings, while not interacting leads to no earnings. Therefore, the unique stochastically stable outcome is the complete network where all players coordinate on the risk dominant outcome.

The theoretical long-run predictions are summarized in table 3.3.

		Required Interaction Proposal		Enforced Interactions
		<i>one-sided</i>	<i>two-sided</i>	
Interaction Costs	$c = 0$	Complete network	Complete network	Risk dominance
		Risk dominance	Risk dominance	
	$c > 0$	Complete network		
		Payoff dominance		

Table 3.3: Theoretical Long-Run Predictions

3.3.2 Behavioral Predictions

There is ample evidence that the theoretical predictions in network formation based on standard assumptions are not always accurate.² In this section we discuss the behavioral predictions based on experimental evidence.

Treatment B

The results found in experiments with standard coordination games will serve as a benchmark hypothesis for this treatment (See Ochs (1995) and Devetag and Ortmann (2007) for excellent surveys.) We expect to find a strong tendency towards coordination on the risk dominant outcome, as theory also predicts.

Treatment I-NC

In this treatment, we expect to find all subjects coordinating on the risk dominant outcome. As soon as one subject proposes to interact, the interaction will take place. So, a subject can neither threaten nor teach subjects by not proposing an interaction. He can merely signal disapproval of others' behavior.

As interactions are costless and only require one-sided interaction proposals in order for interactions to take place, subjects playing the risk dominant action will always propose interactions to subjects playing the payoff dominant or risk dominant action. The unique best response to this strategy for the subjects playing the payoff dominant action is to switch to the risk dominant action. As proposing interactions with other subjects is always costless, we expect that in the long run all subjects will interact, i.e., the complete network will emerge, and all subjects will coordinate on the risk dominant outcome, as theory predicts.

²See Kosfeld (2004) for an excellent survey.

Treatment I-C

A particularly interesting feature of treatment I-C, which is not addressed in the theoretical models, is the additional coordination problem that arises in the network game, with respect to who will pay the interaction costs. The difference in payoffs between proposing an interaction or just “receiving” the interaction, given that both subjects choose the same action, is the interaction cost c .

As the interaction costs in this treatment are $a > c > b$, from a fairness point of view, subjects will favor a situation where all subjects propose on average $\frac{n-1}{2}$ interactions, such that all interactions take place and at the same time all subjects on average pay the same amount of interactions costs. Still, due the possibility of free riding, it will be very difficult for subjects to coordinate on the interaction proposals so as to ensure that each subject, on average, proposes $\frac{n-1}{2}$ interactions. We, therefore, expect that subjects will not be able to overcome this additional coordination problem, and very unstable network structures, or even an empty network will emerge. We do expect all subjects to choose the payoff dominant action, as subjects will only propose an interaction to a subject who is expected to choose the payoff dominant action. By choosing the payoff dominant action, subjects send a positive signal and thereby increase their chances of being proposed to interact in the future rounds.

Treatment II-NC

In treatment II-NC, mutual consent is needed in order to interact. Subjects playing the payoff dominant action are able to punish subjects that play the risk dominant action by not “reciprocating” the interaction proposal of the other in the next round. This punishment in the form of exclusion, may induce the punished subjects to switch to the payoff dominant action.

If proposing interactions is costless, both playing the payoff dominant and the risk dominant action yield positive earnings. In this situation a subject choosing the payoff dominant action has to make a tradeoff between punishing his neighbor who chooses the risk dominant action by not interacting, which costs him and the other d , and the earnings he receives by interacting with relatively more subjects. For convenience, we will call subjects who use such punishment “efficiency enforcers”.

At the same time, a subject choosing the risk dominant action has a similar tradeoff to make. Either he can accept to be punished and stay with his original action choice, or he can decide to switch to the payoff dominant action and thereby create an environment where he will interact with other subjects choosing

the payoff dominant action. In the long run, this latter type of behavior will lead to a higher payoff than sticking to the risk dominant action choice. Therefore, we expect to find more and more subjects coordinating on the payoff dominant action. Furthermore, as interacting is costless, all subjects will interact. Table 3.4 below summarizes our behavioral predictions.

		Required Interaction Proposal		Enforced Interactions
		<i>one-sided</i>	<i>two-sided</i>	
Interaction costs	$c = 0$	Complete network	Complete network	Risk dominance
		Risk dominance	<i>Payoff dominance</i>	
	$c > 0$	<i>Unstable networks</i>		
		Payoff dominance		

Note: The behavioral predictions in italic show the predictions that differ from the theoretical predictions

Table 3.4: Behavioral Predictions

3.4 Experimental Design

In this section, we present the experimental design and parameters.

3.4.1 Network Game

Our experimental design with respect to the network game consists of the three neighborhood treatments and the baseline treatment described in the previous section. In all treatments participants are placed into groups of six. To assure anonymity during the experiment, each subject refers to himself as “Me” and to the other members of his group with the letters “A”, “B”, “C”, “D”, and “E”.

In all four treatments, the subjects face the same pure coordination game payoff matrix as given by Table 3.5.

	B	G
B	95,95	5,90
G	90,5	75,75

Table 3.5: Actual Payoff Matrix

In case interacting is costly, the interaction cost is set at 80 points per proposed interaction.

In treatment B, the amount of interactions will be 15 as each subject has to play the game with all five other group members. In contrast, in the neighborhood treatments, in each round of the network game, each subject has to choose with whom he would like to interact in that round, if he wants to interact at all. As each group consists of six subjects, each subject can propose up to 5 interactions: one interaction to each other subject in the group. The maximum number of interactions that can be proposed is thus 30, which would result in 15 interactions. Each subject can interact at most once with each other subject in the group during a given round.

The network game is played repeatedly in 2 blocks of 30 rounds. Throughout one block, the group composition does not change and each subject keeps his identity. After the first block, groups are randomly reshuffled. Before the first block ends, subjects are not informed that they will play the same network game in block 2. They only know that there will be another part of the experiment. The new groups formed in block 2 play the network game for another thirty rounds. Subjects have full information on the past actions and interaction proposals chosen by all subjects in their group in the current block. The instructions of the network game for the different treatments can be found in the Appendix.

3.4.2 Personality Characteristics

As the coordination game deals with the tradeoff between efficiency considerations on the one hand and strategic uncertainty on the other hand, subjects' risk and social preferences may be important determinants of their strategies chosen. We analyze the players' risk attitudes by the ten-paired lottery choice decisions introduced by Holt and Laury (2002). The exact payoff numbers and instructions can be found in the Appendix.

In order to test subjects' attitude towards efficiency we develop an extended version of the circle test of Sonnemans, van Dijk, and van Winden (2006). The circle test has been successfully used to measure social preferences. In our experiment, subjects are asked to select a point on a circle and on two differently shaped ellipses. Each point on the circle or ellipse, corresponds to a certain allocation of points to the person making the decision (S) and to another anonymous individual (O) to which the decision maker is matched according to the perfect stranger protocol. The horizontal dimension represents the allocation for yourself whereas the vertical dimension determines the allocation for the other person. For instance, if S chooses a point on the horizontal axis, this implies that S allocates no points to O and allocates either the minimum or the maximum amount of points to him-

self. Each point on the circle and ellipses yields a measure to quantify people's disposition to others and their disposition to efficiency concerns. Subjects do not receive any feedback from the circle and ellipse test until the end of the experiment. Details on the calculations, instructions and the stimuli, can be found in the Appendix.

The chronological order of the different parts of the experiment is as follows

Circle and Ellipse Test $\Rightarrow$ <i>efficiency attitude</i>
Network game Part I; 30 rounds
Network game Part II; 30 rounds
Ten-paired Lottery-Choice Decisions $\Rightarrow$ <i>risk attitude</i>

Table 3.6: Chronological Order of the Different Parts of the Experiment

3.5 Experimental Procedures

All experiments were conducted in the BEE laboratory at Maastricht University. Subjects were recruited through email announcements and announcements on students' intranet. All 210 subjects (58% male) were students from Maastricht University. The vast majority of subjects were students from economics and business administration (84%). The other subjects were students from law (2%), cultural sciences (8%), humanities and sciences (3%), and from health sciences (3%). Each subject participated in only one session and had not yet participated in a similar BEE experiment. For each session, 18 subjects were recruited and randomly divided into three independent groups of 6 students. Each treatment was played by nine groups, resulting in 9 independent observations per treatment except for the treatment I-C which was played by 8 groups due to some subjects who did not show up. Subjects got computerized and written instructions which they could study at their own pace. Additionally they could ask questions privately.³ Before the game started, subjects had to answer some control questions correctly. The conversion rate of points to euros was set such that the expected value of playing optimally, which is forming a complete network and coordinating on the payoff dominant outcome, was kept the same in all treatments. The points that could be earned in the circle and ellipse test, and the ten-paired lottery-choice decisions was

³We only answered questions about the instructions. No answer was given if it had influenced the subjects expectation or strategy choice.

set accordingly to ensure equal earnings when choosing identically in the different treatments. On average, subjects earned 26.04 euro including a 5 euro show-up fee. Each session took approximately two hours.

3.6 Results Network Game: *Block 1*

In this section, we will present the results for the first block of the network game. We first focus on the interactions that are proposed and that actually took place, and then focus on the actions chosen in the coordination game. We will end this section by looking at possible motives for the decisions made by the subjects. Each group forms an independent observation and if not stated differently statistical tests are based on aggregated measures of these independent groups.

3.6.1 Interaction Density

As the coordination game is identical in all treatments, any observed difference in behavior must be caused by the endogenous choice of interaction partners.

An important indicator of the effect of endogenous choice of interaction partners is a measure which describes whether or not subjects choose to actually interact at all, i.e., the interaction density. It is defined as the relative frequency of interactions in a group. If in a group of 6 players all players interact, the maximum number of interactions is 15. The interaction density is then given by the actual number of interactions divided by 15. Figure 3.1 shows the development of interaction densities of the different treatments over time.

Figure 3.1: Interaction Density

An intriguing result is that in treatment I-NC the interaction density is *always* 1, which means that all subjects always interact with each other. Moreover, in

this treatment, after round 5, *each* subject proposed all his possible interactions.⁴ To be precise, only 0.4 percent of all interactions that could have been proposed over all rounds, were not proposed.

The interaction density in treatment II-NC clearly increases over time, approaching 1 in the later rounds of the game. This is confirmed by a Wilcoxon signed rank test applied to groups' Spearman rank correlation coefficients between the interaction density and round number (Wilcoxon, $n=9$, $p=0.0061$, one-sided). In early rounds we observe that around 13 percent of the interactions do not take place. There are two possible reasons for an interaction density lower than 1. Either both subjects do not propose the interaction, or one subject does not reciprocate the interaction proposal of the other subject. Around 14 percent of all proposed interactions are not reciprocated, indicating the possible existence of efficiency enforcers. The unreciprocated interactions account for 45 percent of the interactions that do not take place.

The interaction frequency in treatment I-C remains rather stable over time (Wilcoxon applied on groups' Spearman rank correlation coefficients between the interaction density and round number, $n=8$, $p=0.1038$, one-sided), and lies well below the optimal interaction density (MWU applied on interaction density averaged over all rounds, $n=8$, $p=0.0002$, one-sided). A likely reason for this relatively low interaction density is that subjects are unable to solve the problem of who will propose and, therefore, bear the costs of interaction. Furthermore, 15 percent of the interactions that were proposed were redundant in the sense that both subjects involved proposed the interaction, whereas only one subject had to in order for the interaction to take place. Consequently, both persons involved paid the costs of the interaction, which caused an efficiency loss. If we compare the results of treatment I-NC with the results of treatment I-C, it is apparent that interaction costs do play an important role in determining whether or not interaction will take place.

Importantly though, the relatively low frequency of proposed interactions in treatment I-C is not caused by particular groups coordinating on an empty network, while other groups are coordinating on a complete network. All groups face a similar variety in interaction densities and interaction structures.⁵

⁴Recall that *both* subjects involved can propose an interaction, which will result in *one* interaction.

⁵We do not observe formations of circle structures, where all subjects equally contribute to the interaction structure. Furthermore, there is no systematic isolation of players.

3.6.2 Coordination game

For each pair of subjects there are four possible outcomes with respect to the coordination game. First, a pair might not play the coordination game at all. The other three outcomes are the possible combinations of the action choices in the coordination game, namely the payoff dominant outcome, the risk dominant outcome and miscoordination. Our interest is how often, on average, the four different outcomes occurred given that the coordination game could have been played 15 times per group in one round.

We first focus on the outcomes at the aggregate level. The frequencies of the different outcomes for the different treatments are shown in Figure 3.2.

Figure 3.2: Outcomes of Coordination Game

As we know that the interaction densities in treatment II-NC and I-C are not 1, we know that not all coordination games are played. Overall, we observe that in treatment I-C, the game is not played 38 percent of the time, whereas in treatment II-NC the game is not played only 7 percent of the time.

Furthermore, in comparison to the baseline treatment, we observe higher frequencies of coordination on the payoff dominant outcome in the neighborhood treatments. A Kruskal-Wallis test on the group level shows that the four treatments significantly differ in the frequency of coordination on the payoff dominant outcome (KW, χ^2 with d.f.=3, $p=0.0359$, one-sided). In treatment B, coordination on the payoff dominant outcome is observed only 33 percent of the time, whereas in the neighborhood treatments the frequency of playing this outcome is 71 percent in treatment I-NC, 72 percent in treatment II-NC, and 51 percent in treatment I-C. This difference in payoff dominant play is also significant when pairwise comparing treatments I-NC and B (MWU, $n=18$, $p=0.0287$, one-sided), I-C and II-NC (MWU, $n=17$, $p=0.0217$, one-sided), and II-NC and B (MWU, $n=18$, $p=0.0287$, one-sided).

At the same time, we observe relatively few coordination on the risk dominant outcome in the neighborhood treatments in comparison to treatment B. The four treatments do not significantly differ in the frequency of coordination on the risk dominant outcome (KW, χ^2 with d.f.=3, $p=0.1013$, one-sided). In treatment I-NC, II-NC and I-C, we observe coordination on the risk dominant action 24, 12 and 2 percent of the time respectively, whereas in treatment B, we observe this outcome 54 percent of the time. This difference in coordination on the risk dominant outcome is significant when comparing treatments I-C and B, (MWU, $n=17$, $p=0.0331$, one-sided), and marginally significant when comparing treatment I-NC and B (MWU, $n=18$, $p=0.0961$, one-sided), I-C and II-NC (MWU, $n=17$, $p=0.0873$, one-sided), and II-NC and B (MWU, $n=18$, $p=0.0608$, one-sided). In treatment I-C, almost no coordination on the risk dominant outcome is observed. This implies that subjects understand that coordination on this outcome makes no sense as it induces losses.

We observe the highest frequency of miscoordination in treatment B. The four treatments significantly differ in the number of miscoordination (KW, χ^2 with d.f.=3, $p=0.0411$, one-sided). The percentages of miscoordination in treatment B, I-NC, II-NC, and I-C are 13, 5, 9, and 10 respectively. The highest frequency of miscoordination within the neighborhood treatments is observed in treatment I-C. The data show that this result is induced by subjects who choose the risk dominant action and propose an interaction to individuals who have played the payoff dominant action during several consecutive rounds. Subjects playing the risk dominant action are willing to bear the costs of proposing the interaction, as it is beneficial for them to interact with subjects who have proven to play the payoff dominant action consistently. Still, this treatment I-C has only marginally more miscoordination than treatment I-NC (MWU, $n=17$, $p=0.0616$, one-sided). Treatment I-NC has significantly less miscoordination than treatment B (MWU, $n=18$, $p=0.0121$, one-sided) and than treatment II-NC (MWU, $n=18$, $p=0.0189$, one-sided). The latter result is surprising. In treatment II-NC, where mutual consent is needed in order to interact, we expected to observe less miscoordination due to the threat of being excluded by subjects who disapprove one's behavior,⁶ whereas in treatment I-NC such exclusion is impossible.

We will now focus on the development of the frequencies of outcomes over time. Figure 3.3 shows the dynamics of the frequencies for each treatment. Interestingly, if we compare the actions chosen among the subjects in the different treatments in round 1 we do not observe any significant difference. If we compare the number

⁶This reasoning is based on the assumption that the previous action choice is used as a reference point to what a subject will play in the current round.

of coordinations on either the payoff or risk dominant outcome, we only observe significantly less coordination on the risk dominant outcome in treatment I-C than in treatment B (MWU, $n=17$, $p=0.0343$).

Figure 3.3: Dynamics of Coordination Game

We observe that in treatment B the frequency of miscoordination significantly decreases (Wilcoxon applied on groups' Spearman rank correlation coefficients between the interaction frequency and round number, $n=9$, $p=0.0055$, one-sided), indicating that subjects move towards coordination. The remaining miscoordination is caused by two groups in which one subject⁷ changes his action choice, irrespective of the choice he was coordinating on with his neighbors. Importantly, the decrease in miscoordination mainly results in an increase in coordination on the risk dominant outcome. This is indicated by (marginally) significantly more coordination on the risk dominant outcome over time (Wilcoxon applied on groups' Spearman rank correlation coefficients between the interaction frequency and round number, $n=9$, $p=0.0601$, one-sided). On the group level we

⁷Note, this is not always the same subject.

observe that one group coordinates on the risk dominant outcome right from the beginning. Two other groups, on the other hand, never coordinated on the risk dominant outcome. The fact that, over time, we observe more coordination on the risk dominant outcome is in accordance with the results found in other studies with fixed interaction structures (e.g. Ochs (1995)).

In treatment I-NC, subjects quickly learn to coordinate on *either* action, where the vast majority of groups coordinates on the payoff dominant outcome. Two groups coordinate on the payoff dominant outcome right from the beginning. In round 18 we see a sudden reemergence of miscoordination, which lasts until round 23. This miscoordination, is initiated by one single subject who changed his action to the payoff dominant action. Interestingly, this subject managed to “persuade” the rest of his group members to switch to the payoff dominant action as well, a process that took place without any change in the number of interactions proposed. In the final rounds, only two groups coordinated on the risk dominant outcome, whereas the remaining seven groups coordinated on the payoff dominant equilibrium.

In treatment II-NC, the frequency of not played coordination games significantly decreases such that in later rounds all coordination games are played (Wilcoxon applied on groups’ Spearman rank correlation coefficients between the interaction frequency and round number, $n=9$, $p=0.0056$, one-sided). There is a strong tendency towards coordination on the payoff dominant outcome. In the final three rounds, we see an end game effect, which is statistically insignificant though. In four groups, in round 27, either one or two subjects suddenly change their action choice into the risk dominant action. In the last two rounds, other subjects also change their action, resulting in an increase in miscoordination. The level of coordination on the risk dominant action remains stable (Wilcoxon applied on groups’ Spearman rank correlation coefficients between the interaction frequency and round number, $n=9$, $p=0.2382$, one-sided). Interestingly, only one group converges towards a complete network where all coordination is on the risk dominant outcome, causing all observed risk dominant action play until the end game effect. Furthermore, in two groups, subjects interact with all others and coordinate on the payoff dominant outcome right from the beginning.

In treatment I-C, the frequency of not played coordination games *increases* over time (Wilcoxon applied on groups’ Spearman rank correlation coefficients between the interaction frequency and round number, $n=8$, $p=0.0344$, one-sided), indicating that the additional coordination problem concerning the interaction costs is not resolved over time. Miscoordination does significantly decrease over time (Wilcoxon over groups’ Spearman rank correlation coefficients between the

interaction frequency and round number, $n=9$, $p=0.0090$, one-sided). The data show that the miscoordination is caused by unsystematic alterations in the actions chosen, within all groups. Occasionally, few players even coordinate on the risk dominant outcome, which results in losses.⁸ Furthermore, the frequency of coordination in the payoff dominant outcome does not increase over time.

3.6.3 Efficiency

We have seen in the previous sections that in treatment II-NC and I-C not all coordination games are played. Furthermore, the outcomes of the played coordination games differ across the different treatments. The welfare or efficiency levels in the different treatments are therefore likely to be different. We define the welfare level as the sum of the individual payoffs earned within a group. In Figure 3.4 the following three welfare levels are depicted; (1) the optimal welfare levels given that all subjects interact with each other and would play the payoff dominant action, (2) the actual welfare levels, and (3) the welfare level if all subjects would interact with each other, and using the actual actions chosen in the coordination game. Note that all welfare levels are depicted relative to the optimal welfare level.

Figure 3.4 clearly shows that the actual welfare level in treatment I-NC is significantly higher in comparison to treatment II-NC (MWU on welfare levels averaged over all rounds, $n=18$, $p=0.0287$, one-sided) and in comparison to treatment B (MWU on welfare levels averaged over all rounds, $n=18$, $p=0.0059$, one-sided). The actual welfare level in treatment I-NC and treatment B is identical to the welfare level given that every subject would interact, as all subjects indeed interact. In treatment II-NC, the actual welfare level is relatively close to the welfare level given that subjects would all interact. Furthermore, the actual welfare level approaches the optimal welfare level. Exclusion, thus, does not come at a high cost, and indicates that subjects learn that coordination on the payoff dominant action is most efficient. In treatment I-C, the actual welfare level is the furthest from the optimal welfare level in comparison to the other treatments. Interestingly, the welfare level given that all subjects would interact does increase and approaches the optimal welfare level. This indicates that subjects do learn to choose the payoff dominant action, but cannot overcome the coordination problem of the interaction costs.

⁸This behavior is observed in four groups.

Figure 3.4: Welfare Levels

3.6.4 Neighbor's Previous Action Choice

Our next inquiry is whether subjects, when deciding whether or not to interact with another subject in the group, take into account the other's action choice in the previous round. We hypothesize that a person playing the payoff dominant action in a given round, will be less inclined to propose an interaction to a subject who played the risk dominant action in the previous round.⁹ In each treatment, there are different reasons and different implications for not proposing an interaction. Recall that in treatment I-NC and II-NC, any interaction is beneficial, as there are no costs involved in interacting. In treatment I-NC, not proposing an interaction can only be interpreted as a signal to the opponent that the action played by this opponent is disapproved upon. It cannot ensure that an interaction will not take place. In treatment II-NC, this behavior of not proposing an interaction can be interpreted as an act of punishment through exclusion, as it ensures that the

⁹This reasoning is based on the assumption that the previous action choice is used as a reference point to what a subject will play in the current round.

interaction will not take place. In treatment I-C, not proposing an interaction to a subject can have two reasons. A subject may be unwilling to bear the costs of interacting, or, in case where the opponent played the risk dominant action in the previous round, he ensures that no losses are incurred.

As each subject has two possible action choices, there are four possible combinations of current and previous action choices. Not each combination is observed in each group though. Recall that in treatment I-NC, two groups immediately coordinate on the payoff dominant action, resulting in only one observed combination. Table 3.7 shows the relative frequency of *proposed* interactions for each possible combination in the neighborhood treatments, given that the combination was observed.

(a) Treatment I-NC		
<i>Own Action round t</i>	<i>Other's Action round t-1</i>	
	payoff dominant action	risk dominant action
payoff dominant action	99.98 (5544, 9)	91.94 (186, 7)
risk dominant action	95.91 (171, 5)	100.00 (1929, 5)
(b) Treatment II-NC		
<i>Own Action round t</i>	<i>Other's Action round t-1</i>	
	payoff dominant action	risk dominant action
payoff dominant action	98.52 (5927, 9)	58.72 (453, 8)
risk dominant action	95.25 (463, 9)	98.58 (987, 8)
(c) Treatment I-C		
<i>Own Action round t</i>	<i>Other's Action round t-1</i>	
	payoff dominant action	risk dominant action
payoff dominant action	40.81 (5435, 8)	5.11 (665, 8)
risk dominant action	39.07 (645, 8)	25.58 (215, 7)

Note: The first number in the parentheses correspond to the total number of times this particular case has occurred. The second number corresponds to the number of groups this particular case has occurred in.

Table 3.7: Interaction proposals related to action choices

In all treatments, the lowest frequency of interaction proposals are made by subjects choosing the payoff dominant action to subjects who chose the risk dominant action in the previous round. In treatment I-NC, not proposing such an interaction can only serve as a signal that the behavior of the other subject is disapproved upon. Furthermore, in this treatment any interaction is beneficial. Still, we observe that such an interaction is proposed less frequently than other

interactions.

In treatment II-NC, it is always beneficial to propose an interaction to a subject who plays the risk dominant action. However, in 41 percent of the possible cases subjects who chose the payoff dominant action in the previous round, chose the dominated action of refusing to interact with a subject whose choice in the previous round was the risk dominant action. This strongly suggests the existence of efficiency enforcing exclusion by subjects choosing the payoff dominant action towards those subjects choosing the risk dominant action in the previous round.

The frequency of interactions proposed by subjects playing the payoff dominant action to a subject who played the risk dominant action in the previous round is lowest in treatment I-C. Recall that proposing such an interaction would lead to sure losses for the proposer of the interaction, given that the other subject keeps playing the risk dominant action.

In all treatments, subjects playing the payoff dominant action have a significantly higher inclination to propose interactions to subjects who chose the payoff dominant action rather than to subjects who chose the risk dominant action in the previous round (I-NC (Wilcoxon, $n=7$, $p=0.0250$, one-sided), II-NC (Wilcoxon, $n=8$, $p=0.0070$, one-sided), and I-C (Wilcoxon, $n=8$, $p=0.0059$, one-sided)).

Subjects playing the risk dominant action also have a strong tendency to propose interactions to subjects who chose the payoff dominant action in the previous round. In all treatments, proposing such interactions never induces losses. In treatment I-C, this interaction proposal is even the only interaction proposal for a subject choosing the risk dominant action that can lead to gains. Therefore, in this treatment, we expect to find more interaction proposals from subjects who play the risk dominant action to subjects playing the payoff dominant than to subjects playing the risk dominant action.

As can be seen in Table 3.7 this is indeed the case, 39.07% – 25.58%, although this difference is not significant (Wilcoxon, $n=8$, $p=0.1553$, one-sided). In the costless treatments, we do not expect to find any significance. In treatment I-NC, the previous action choice of the opponent indeed has no significant effect on the amount of interactions proposed by a subject who chooses the risk dominant action. Interestingly, in treatment II-NC, we do observe a strong tendency of subjects playing the risk dominant action to propose an interaction less often to subjects who played the payoff dominant action in previous round (Wilcoxon, $n=8$, $p=0.00553$, one-sided). This interaction though, if accepted, would induce the highest gains possible. One reason for this behavior might be that subjects expect that the other party will not accept such a proposal.

While in both treatment I-NC and I-C the frequency of established interactions

coincide with the frequency of proposed interactions shown in Table 3.7, this is not the case in treatment II-NC. Table 3.8 shows the frequency of *proposed* interactions that were actually established for treatment II-NC. Note that this frequency can be interpreted as the consent rate of the proposed interactions in Table 3.7. For example, 96.78 percent of the interactions proposed by a subject choosing the payoff dominant action in a given round to a subject who played the payoff dominant action in the previous round has also been proposed by the latter.¹⁰

Own Action round t	Other's Action round t-1	
	payoff dominant action	risk dominant action
payoff dominant action	96.78 (5736, 9)	56.73 (257, 9)
risk dominant action	72.35 (335, 9)	95.44 (942, 8)

Note: The first number in the parentheses correspond to the total number of times this particular case has occurred. The second number corresponds to the number of groups this particular case has occurred in.

Table 3.8: Established Interactions in Treatment II-NC

In cases where subjects play different actions than their counterpart in the previous round, the percentage of established interactions is much lower (56.73 and 72.35 percent) than in situations where subjects play the same action as their counterpart in the previous round (around 96 percent). The fact that only 72.35 percent of the interactions proposed by a subject choosing the risk dominant action to a person who chose the payoff dominant action in the previous round is established, is as expected. The vast majority, 78 percent, of the subjects proposing this interaction, chose the risk dominant action in the previous round as well. Refusing this interaction, can thus be seen as an efficiency enforcing act.

The underlying reason for the relatively low establishment rate of interactions proposed by a subject choosing the payoff dominant action to a person who chose the risk dominant action in the previous round is less straightforward. Recall that for a subject choosing the risk dominant action, interacting is most beneficial with subjects choosing the payoff dominant action. The data shows that in 82 percent of the cases where a subject choosing the payoff dominant action proposes an interaction to a subject choosing the risk dominant action in the previous round, no interaction between these two subjects took place in the previous round. A possible explanation for the low acceptance rate could, therefore, be that subjects choosing the risk dominant action in the previous round infer wrongly that an interaction will not be proposed as the interaction did not take place in the previous round, and therefore also do not propose an interaction. As a result, the interaction

¹⁰Thus $0.9678 * 5927 = 5736$, where the number 5927 has been retrieved from Table 3.7.

proposal in the current round is rejected.

Overall, the previous action choice of the opponent thus has a significant effect on the acceptance rate of interactions when one's own action in the current round is the payoff dominant action (Wilcoxon, $n=9$, $p=0.0061$, one-sided), as well as when one's own action in the current round is the risk dominant action (Wilcoxon, $n=8$, $p=0.0391$, one-sided).

3.6.5 Indegree

Further insight into the relation of received interaction proposals and the action choice in the coordination game can be gained by examining the average indegree a person has, given the consecutive amount of times he has chosen the payoff dominant and risk dominant action, respectively. Note that when a player plays 10 consecutive times the payoff dominant action, his observation is also counted as a data point with a consecutive play of 1, 2, ..., 9 of the payoff dominant action. The indegree is defined as the number of interaction proposals received. From the subject's point of view, the optimal indegree of a subject is in each treatment 5, irrespective of the action chosen by this subject. However, if we use a group perspective this need not be the case. In treatment II-NC the efficient indegree is 5. In treatment I-NC the efficient indegree can be between 0 and 5 as long as all interactions take place. In treatment I-C the efficient indegree lies between 0 and 5 as long as no interaction is proposed by both involved subjects and as long as all interactions take place. However, as in treatment I-C subjects face the additional coordination game on who will play for the interaction costs, fairness motives might play a role in deciding how this additional coordination problem should be resolved. From a fairness point of view, on average, all subjects should pay the same amount of interactions costs. The efficient average indegree is, therefore, 2.5.

In case a subject chooses the payoff dominant action, we expect to find generally high average indegree levels, as it is always beneficial to propose an interaction to someone who is playing the payoff dominant action. For low consecutive numbers of payoff dominant actions one might expect a lower average indegree. If a player has only just started to play the payoff dominant strategy, this action choice is not yet proven to be consistent. In treatment I-C, we expect to find lower average indegree levels due to the additional coordination problem that arises with respect to whom will have to pay the interaction costs. In this treatment, the optimal number of interactions a subject is involved in, is still 5. The average efficient indegree however, is such that on average all subjects pay the same amount of interactions costs. The efficient average indegree is therefore 2.5.

If the risk dominant action is chosen, we generally expect to find a lower average indegree, as playing with someone whose action choice is the risk dominant action is the least favorable outcome in terms of payoffs. In treatment I-NC and II-NC, we expect that the average indegree will still be positive as it is beneficial to interact. In case of treatment I-NC, subjects can only signal to subjects playing the risk dominant action that this behavior is unwanted by not proposing an interaction. In case of treatment II-NC, subjects can exclude these other subjects, as a punishment for this unwanted behavior, by not proposing such an interaction. In case of treatment I-C, subjects will incur losses if they make an interaction proposal to someone choosing the risk dominant action. In this treatment, we, therefore, expect an average indegree of 0 for a subject choosing the risk dominant action.

Figure 3.5(a) and (b) shows the results for both action choices, whereas (c) and (d) graphically shows the number of observations behind each point depicted in the figures.

Figure 3.5: Relation between consecutive action choice and the indegree

Figure 3.5(a) shows that in treatment I-NC and II-NC the indegree is almost constant and optimal irrespective of how often this subject has chosen the payoff dominant action. This result is driven by the fact that interacting with a subject who plays the payoff dominant action is always more beneficial than playing with someone who chooses the risk dominant action, irrespective of one's own action choice. In treatment I-C, similar results are found. On average 2 interactions are proposed to a payoff dominant playing subject, which is only slightly less than the average optimal indegree of 2.5. Furthermore, the indegree is quite stable.

In Figure 3.5 (b) we observe that the average indegrees of subjects playing the risk dominant action vary across treatments. In treatment I-NC, the average indegree almost immediately reaches the optimal number of 5.

In treatment II-NC, in contrast, there is an initial decrease in the average indegree, which is consistent with the idea of efficiency enforcement. Interestingly, as the number of consecutive choices of the risk dominant action increases, the average indegree increases again. This is likely to be related to the costs that are incurred by the excluder. It seems that subjects who exclude subjects that are consistently choosing the risk dominant action, at some point, prefer the gains of interacting rather than a payoff of zero. Note, however, that the number of observations behind these figures are relatively small.

In treatment I-C where interaction is costly, the average indegree is low and quickly decreases to the expected indegree of 0, as maintaining an interaction with a subject who plays the risk dominant action will lead to losses.

3.7 Individual data

In this section, we will examine in how far the individuals' characteristics and their individual behavior can explain the results presented in the previous sections. As a trade-off between efficiency considerations on the one hand and strategic uncertainty on the other hand are inherent to the coordination game, we expect that subjects' attitudes towards risk and efficiency will play a role in explaining subjects' behavior. Furthermore, we expect to find a relationship between subjects' risk and social preferences and the interactions subjects propose. Recall that in treatment II-NC, we observe behavior that is consistent with the idea of efficiency enforcement. We, therefore, investigate whether such behavior is correlated with preferences over efficient outcomes. In treatment I-C, there is an additional coordination problem of who will pay the costs of interacting. In this treatment, risk aversion might play an important role in the number of interactions proposed.

We first will examine subjects' risk attitudes, and afterwards their attitude towards efficiency. We end this section by analyzing the data using logit regressions.

3.7.1 Risk attitudes

In the Holt and Laury ten-paired lottery choice decisions, subjects are faced with ten paired lotteries and have to choose their most preferred lottery for each pair. The earlier a subject switches from the safe option to the risky option, the less risk averse this subject is. The risk neutral choice is such that in the first four consecutive choices the safe option is chosen and from that moment onwards the risky option is chosen. Consistent behavior thus requires only one switching point. In total only 9 out of 210 subjects switched more than once. These subjects are excluded in the analysis on risk attitudes and they are excluded in the regression.

Overall subjects are slightly risk averse. Rather than choosing the risk neutral switching point of 4, subjects switch to the risky choice either after the fourth or sixth paired lottery. Subjects in treatment I-NC appear slightly less risk averse, however, only in comparison to subjects in treatment B (MWU, $n=103$, $p=0.0321$, two-sided). All other comparisons do not reveal any significant difference, indicating that differences in risk attitudes are unlikely to explain the low interaction density in treatment I-C nor are they likely to explain the difference in behavior observed in the coordination game across the different treatments.

3.7.2 Efficiency attitudes

Another possible determinant of the behavior observed in a coordination game is an individual's attitude towards efficiency. When comparing our efficiency attitude measure across treatments ¹¹, we observe that only subjects in treatment II-NC show more concern for efficiency than subjects in treatment B (MWU, $n=108$, $p=0.0259$, two-sided).

However, there is no strong evidence for any systematic difference in the levels of concern about efficiency across the treatments. Differences in subjects' behaviors towards efficiency are therefore unlikely to explain the differences in behavior in the coordination game observed across the different treatments.

3.7.3 Regression analysis

In order to find variables that can explain the results found in the network game, we examine a subject's current action choice with a logit regression clustered at

¹¹Details on the exact procedure of measurement can be found in the Appendix.

the group level. We estimate the following model:

$$\text{logit}(b_{i,t}) = \log \frac{b_{i,t}}{1 - b_{i,t}} = a + I_i + N_{i,t-1} + E + \varepsilon_{i,t}.$$

The dependent variable $b_{i,t}$ equals 1 if subject i chooses the payoff dominant action in round t , and 0 otherwise. The independent variables can be categorized into three groups. The first group, I , consists of variables that measure individual attitudes towards risk and efficiency, which we obtained from the paired lottery test and the ellipse test. Subjects which are more risk averse and subjects which show less concern for efficiency are expected to be more likely to choose the risk dominant action.

The second category, N , consists of variables describing the action choices and the dynamics of the network game itself. All variables refer to the previous round, $t - 1$. First, a subject's action choice might exhibit some inertia, i.e., a positive dependence on his previous choice. Second, we expect that the number of interactions with subjects playing the payoff dominant action in the previous round has a positive effect on choosing the payoff dominant action in the current round. The action choices of all other subjects within the group in the previous round are also expected to have an impact. The more persons playing the payoff dominant action within the group, the more inclined subject i will be to do so as well. The indegree in the previous round might also affect the likelihood of playing the payoff dominant action. We split up the indegree into two categories: interaction proposals from subjects playing the payoff and risk dominant action, respectively. In the former case we expect to find a positive relation with the likelihood of choosing the payoff dominant action, whereas in the latter we expect to find a negative relation.

The existence of efficiency enforcement is examined with the following two variables. First, we introduce a dummy variable taking value 1 if subject i chose the payoff dominant action in the previous round *and* proposed at least one interaction to a person who chose the risk dominant action in round $t - 1$, and 0 otherwise. In treatment II-NC, this situation reflects the exclusion possibility in the current round. As in this treatment we observed behavior consistent with efficiency enforcement in the form of exclusion by subjects playing the payoff dominant action, we expect to see a nonnegative relationship between the likelihood of choosing the payoff dominant action and the dummy variable. In treatment I-NC and I-C, where exclusion is impossible, we expect to find a negative relation between the likelihood of choosing the payoff dominant action and the dummy variable. Subjects might be induced through best response dynamics to switch to the risk

dominant action rather than not propose the interaction and remain playing the payoff dominant action.

Second, we introduce a variable taking value 1 if there is an exclusion possibility in round t , *and* the interaction is no longer proposed by subject i in round t . Note that in treatment I-NC and I-C, the interaction still can take place, as no mutual consent is needed in order for the interaction to take place. In these treatments, subjects can thus only signal that this behavior is unwanted, and not actually exclude persons with such behavior. In case of treatment II-NC, this variable indicates the actual efficiency enforcement of a player. In all cases we expect to find a positive relation to choosing the payoff dominant action.

The final group of independent variables, E, controls for the endgame effect, which occurs in the last three rounds. We introduce a variable that takes the value 0 until round 28, whereas from round 28 onwards, it takes the value of the actual round.

The evenly numbered columns of Table 3.9 show the results for this logit regression.

Three general conclusions can be drawn from Table 3.9. First, the individual characteristics risk aversion and efficiency have explanatory power in the neighborhood treatments, whereas this is not the case in treatment B. In treatment I-NC and I-C, the results are as expected. Subjects that are more risk averse are less likely to choose the payoff dominant action. In treatment II-NC, the opposite is marginally significant. Recall, however, that in this treatment, subjects playing the payoff dominant action choice can exclude others. Hence in the presence of such exclusion, playing the risk dominant action is also risky. If subjects fear the possibility of being excluded, they may rather choose the payoff dominant action. Second, in all neighborhood treatments, subjects that are more driven by efficiency are more likely to play the payoff dominant action choice. Third, inertia is present in all treatments, i.e., subjects are likely to choose the same action in two consecutive rounds.

The effects of the actual coordination and network game will be discussed separately for each treatment as the interpretation of the independent variables describing these effects are treatment dependent.

In treatment B, variables (6) and (7) are not used in the regression as all subjects have to interact with all other subjects. Variables (4) and (5) are therefore identical, hence variable (5) is dropped. The results show that the total number of other subjects choosing the payoff dominant action in the previous round has a positive influence on the subject's choice of the payoff dominant action. Furthermore, the endgame effect is strongly significant.

Likelihood to choose the payoff dominant action in t	B		I-NC			Treatment I-NC			I-C	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		
(1) Risk aversion	0.8980 (0.160)	0.8980 (0.160)	0.6703 (0.000)***	0.7077 (0.000)***	1.1070 (0.093)*	1.1063 (0.099)*	0.8355 (0.002)***	0.8433 (0.006)***		
(2) Efficiency	1.000 (0.406)	1.000 (0.406)	1.0003 (0.097)*	1.0004 (0.079)*	0.9998 (0.017)**	0.9998 (0.017)**	1.0001 (0.000)***	1.0001 (0.000)***		
(3) Playing PD action, in t-1	27.1554 (0.000)***	27.1554 (0.000)***	287.57 (0.000)***	292.9697 (0.000)***	39.372 (0.000)***	38.2192 (0.000)***	19.90641 (0.000)***	18.959 (0.000)***		
(4) Interactions with subjects playing PD action in t-1	2.5148 (0.000)***	2.5148 (0.000)***	3.6175 (0.000)***	1.5469 (0.201)	1.4941 (0.108)	1.1478 (0.757)	1.2771 (0.142)	1.1592 (0.468)		
(5) Total number of other subjects playing PD action in group, in t-1	-	-	-	-	1.6260 (0.032)**	1.7334 (0.000)***	1.3576 (0.042)**	1.3004 (0.048)**		
(6) Indegree received from subjects playing PD action, in t-1	-	-	-	0.6324 (0.017)**	-	1.3261 (0.500)	-	1.2241 (0.121)		
(7) Indegree received from subjects playing RD action, in t-1	-	-	-	0.2676 (0.016)**	-	1.0870 (0.783)	-	0.8600 (0.366)		
(8) Playing PD action and proposing interaction to a subject who played RD action, in t-1	0.741 (0.702)	0.741 (0.702)	0.9641 (0.183)	0.0882 (0.156)	0.6530 (0.498)	.66847 (0.517)	0.2139 (0.010)***	0.2195 (0.009)***		
(9) Signalling/ excluding unwanted behavior in (8) by not proposing an interaction in t	-	-	-	-	-	-	4.43576 (0.016)**	4.5330 (0.007)***		
(10) End game effect	0.96890 (0.000)***	0.96890 (0.000)***	0.98549 (0.026)	.9874 (0.686)	0.9232 (0.000)***	0.9236 (0.000)***	0.9665 (0.000)***	0.9667 (0.000)***		
Observations	1566	1566	1560	1560	1525	1525	1392	1392		
Pseudo R^2	(0.7310)	(0.7310)	(0.9105)	(0.9115)	(0.6866)	(0.6868)	(0.3969)	(0.3998)		

Notes: (1) The first numbers correspond to the associated odd ratios, whereas the numbers in parentheses are the corresponding p-values.
(2) In treatment I-NC, variable(5) is dropped due to collinearity. In this treatment all interactions take place. As a result variable (4) and variable (5) are identical.
(3) In treatment I-NC and I-NC variable (9) predicts success perfectly and is hence not reported.
(4) Significant at: * 10 percent; ** 05 percent; *** 01 percent

Table 3.9: Regression Results

In treatment I-NC, both variables describing a person's indegree have a significantly negative influence on choosing the payoff dominant action as the current action. The more interaction proposals an individual receives from subjects playing the risk dominant action choice, the more likely one is to play the risk dominant action choice in the current round. This behavior is in line with myopic best response dynamics. The effect of having interaction proposals from individuals who choose the payoff dominant action on a subject's own action choice is unexpected, however. The higher a subject's indegree from subjects playing the payoff dominant action choice in the previous round, the *less* likely he is to play the payoff dominant action choice himself. However, recall that in this treatment all interactions are almost always proposed. Furthermore, groups quickly converge to one of the two equilibria. This means that the independent variables (4)-(7) are highly correlated. We, therefore, also ran the regressions without variable (5) and (6). The odd numbered columns of Table 3.9 show the results for this logit regression. There is only one difference between the two regressions, and that is exactly in treatment I-NC. In this treatment, the higher the number of interactions a subject had with subjects playing the payoff dominant action in the previous round, the more likely this subject is to choose the payoff dominant action in the current round.

In treatment II-NC, the visual aspect of seeing which subjects in the whole group chose the payoff dominant action in the previous round, has a significant positive effect on choosing the payoff dominant action choice in the current round. Moreover, in this treatment there is a strong endgame effect.

As expected, in treatment I-C, if in the previous round a subject chose the payoff dominant action and proposed an interaction with someone who played the risk dominant action, then in the current round this subject is more likely to switch to the risk dominant action. At the same time, subjects that signal that playing the risk dominant action is unwanted by not proposing an interaction, are likely to continue choosing the payoff dominant action in the current round. Furthermore, in this treatment we observe a strong endgame effect.

3.8 Results Network Game: *Block 2*

After thirty rounds, the groups are randomly reshuffled and these groups play the network game for another thirty rounds. The results for this second block serve as a test for the robustness of our previous findings.

Figure 3.6 shows the development of the frequencies of outcomes in the coor-

dination game over rounds.

Figure 3.6: Dynamics of Coordination Game

If we only compare the first round of block 1 and block 2 respectively, we observe that only in treatment II-NC subjects coordinate significantly more often on the payoff dominant action in block 2 (Wilcoxon, $n=9$, $p=0.042$, one-sided). Furthermore, the general picture is that for both treatments, the trends observed in block 1 are even more profound in block 2.¹² In comparison to block 1, in all treatments subjects coordinate relatively more often on the payoff dominant action in block 2. In treatments I-NC and II-NC, *all* subjects quickly learn to coordinate on the payoff dominant actions. Subjects seem to have learned that interacting is always beneficial and that the optimal action to coordinate on is the payoff dominant action, and, more importantly, they behave accordingly. In treatment I-C, subjects are less miscoordinating, and rather coordinate on the payoff dominant action. However, we do not observe more interactions in comparison to block 1. Subjects have thus learned that coordinating on the payoff dominant action is

¹²We cannot test the significance as we only have 3 independent observations.

optimal, but they still cannot overcome the additional coordination problem with respect to the interaction costs. In treatment B, we observe that over time, subjects coordinate more on the risk dominant outcome.

As we observe more coordination on the payoff dominant outcome in block 2, the actual welfare levels will also be closer to optimal welfare levels. Figure 3.7 confirms this statement.

Figure 3.7: Welfare Levels

Furthermore, we see that in all neighborhood treatments, except treatment I-C, the actual welfare level quickly approaches the optimal welfare level. Although in treatment I-C the actual welfare level falls short of the optimal level, the welfare level if all subjects would interact is close to the optimal level.

3.9 Conclusion

In this chapter we examined the implications of endogenous neighborhood choice on coordination problems. Whereas in most previous research subjects could not

decide with whom they would like to play the coordination game, in our experiment they can. Our results clearly show that the mere fact that subjects can decide with whom they *would like to* interact, induces subjects to choose the payoff dominant action significantly more often, thereby increasing efficiency. Not proposing an interaction to a subject is used as a signal that the behavior of that subject is disapproved. In case of treatment II-NC, this signal becomes an act of punishment in the form of exclusion. The subjects whose behavior is disapproved change their action choice, resulting in more subjects choosing the payoff dominant action.

In case of costless interaction, subjects learn to choose the payoff dominant action and over time, exclusion and signaling becomes less necessary. Furthermore, over time, more subjects interact with each other. As a result the welfare level increases. When interactions are both required to be one-sided and costly, subjects face an additional coordination problem with respect to whom will pay the costs for the interaction. This additional coordination problem is not resolved over time. Even though the vast majority of subjects learn to choose the payoff dominant actions, not all interactions take place, which results in substantial welfare losses.

Our results are robust. Subjects' behavior in the second block, where they are playing the same coordination game only in different groups, is similar to the subjects' behavior in the first block of the coordination game. In the costless neighborhood treatments, subjects fully coordinate on the payoff dominant outcome and all interactions take place. As a result, the actual welfare level approaches its optimal level. In treatment I-C, subjects are still not able to coordinate on the interaction costs.

An interesting avenue for future research is to investigate the role of feedback by introducing varying feedback information conditions. One possible scenario would be to give subjects only information about the action chosen by the subjects they interact with. Groups may become fragmented as more risk is involved in interacting with subjects with whom one did not interact before. Another possible avenue would be to restrict the number of interactions a subject can engage in.

3.10 Appendix

Instructions Circle and Ellipse Test

Introduction

Welcome to this experiment on decision-making. In this experiment you can earn money. How much you earn depends on your decisions and the decisions of other participants.

The experiment consists of four independent parts. In each part you can earn points. Your earnings in each part are independent of your earnings in the other part. At the end of the experiment you get paid your earned points privately in cash, according to the exchange rate:

$$\begin{array}{ll} \mathbf{100 \text{ points} = 8 \text{ eurocent}} & \text{in treatments } B, I\text{-}NC, \text{ and } II\text{-}NC \\ \mathbf{100 \text{ points} = 14 \text{ eurocent}} & \text{in treatment } I\text{-}C. \end{array}$$

First you receive the instructions for the first part. You will get the instructions for the following part only after the preceding part finished. At the end of the experiment you will be asked to fill in a short questionnaire. Thereafter you will be paid your earnings.

During the whole experiment, you are not allowed to communicate with other participants in any other way than specified in the instructions.

If you have a question, please raise your hand. We will then come to you to answer it.

Instructions part I

In part I of the experiment you are asked to make three decisions. These decisions concern the assignment of an amount (of points) to yourself and an amount to another, arbitrarily chosen participant.

You received a print-out of the computer screen for part I from us. Please take this print-out in front of you. We shall explain your choice options with the help of the print-out.

On the first screen you see a **circle**. The second and third screen will show **ellipses**. By choosing a point on the circle and ellipses you decide about the assignment of an amount of points to yourself and an amount of points to another participant in this experiment. This other participant will be chosen completely randomly by the computer.

Note: In each of these three decision rounds you will be linked to another participant. Furthermore, you will never meet a person who has already made, is making or who will, in the future, make a decision that affects your earnings.

Each point on the circle and ellipses represents an amount that is added to your earnings (+) or is subtracted from your earnings (-) and an amount that is added to the earnings of the other participant (+) or is subtracted from his or her earnings (-). Hence, with your decision you can increase or decrease your earnings and the earnings of the other participant.

You can click on any point of the circle with the help of your mouse. You will then see an arrow that shows you the decision you made. Additionally, you will see the corresponding amounts (points) in the window ‘decision’, at the right of the circle/ ellipse. In the ‘**for you**’ field you will see the amount that you assigned to yourself, and in the ‘**for the other**’ field the amount you assigned to the other participant. To change your decision you can click on another point of the circle. You may also use the buttons below the circle. With these buttons you can refine your decision: you can move the arrow a little bit in the clockwise direction (left button) or in the counter-clockwise direction (right button). If you are satisfied with your decision you have to confirm it by clicking on the button ‘**Confirm**’. An ‘**Are you sure?**’ window will appear then. Click on yes if you do not want to change your choice anymore.

Your earnings in one decision round will depend on your own decision **and** the decision of one other, randomly chosen, participant you are paired with. This other participant has to make a similar decision as you made. **Note:** In each of these three decision rounds you will be linked to another participant. Furthermore, you will **never** meet a person who has already made, is making or who will, in the future, make a decision that affects your earnings. Your earnings in this part of the experiment are therefore equal to the sum of the amounts you assign to yourself and the amounts that the three randomly chosen other participants assign to you.

Note: these amounts can be positive but also negative. In the latter case the amount will be subtracted from the earnings of the respective recipient.

During the whole experiment, you will receive no information about the decisions of the other participants you are paired with. Only after the end of the experiment you will get informed about the amount these other participants have assigned to you. Similarly, the other participants will get informed about the amount you assign to her or him only after the end of the experiment.

Part I of the experiment will begin shortly. **There is no practice round.**

If you have any questions now, please raise your hand. If you do not have any questions any more, please click on **‘READY’**.

(a) Circle

(b) Ellipse 1

(c) Ellipse 2

Figure 3.8: Computer Screens

Explanation Calculations Circle and Ellipse Test

Each point on the circle and ellipses corresponds to a certain allocation of points to the person making the decision (S) and to another anonymous individual (O) to which the decision maker is matched according to the perfect stranger protocol. The horizontal dimension represents the allocation to yourself, whereas the vertical dimension determines the allocation to the other.

By a proper choice of coordinate system, the three ellipses can be described by the following equations

$$\begin{aligned} \text{Circle:} & \quad \frac{S^2}{2^2} + \frac{O^2}{2^2} = 1, \\ \text{Ellipse 1:} & \quad \frac{S^2}{1^2} + \frac{O^2}{3^2} = 1 \\ \text{Ellipse 2:} & \quad \frac{S^2}{3^2} + \frac{O^2}{1^2} = 1. \end{aligned}$$

The maximum number of points a decision maker can allocate to himself and the other anonymous individual can be found in the table below.

Treatment	Circle		Ellipse 1		Ellipse 2	
	S	O	S	O	S	O
B	816	816	1224	408	408	1224
I-NC	816	816	1224	408	408	1224
II-NC	816	816	1224	408	408	1224
I-C	446	446	698	234	234	698

Table 3.10: Maximum Allocations for the Different Treatments

Each point corresponds to a certain angle, which makes it possible to quantify people's disposition to others by determining the willingness of individuals to help or hurt others at a cost to themselves. In order to find a measure for efficiency we first calculate the optimal angle with respect to efficiency and the ellipses. In case of the circle we know the optimal angle is 45 degrees. The optimal angles for efficiency in ellipse 1 and ellipse 2 are 83.66 and 6.34 degrees, respectively.

Furthermore, we calculate the angles of the actual choices made. This gives us three angles for actual choices and three angles for the corresponding optimal choices. We take the negative of the Euclidean distance between these vectors as a measure of efficiency.

Instructions Network Game

Treatment B

Instructions part II

In this part of the experiment every participant is in a **group of six** with five other participants. Before part II begins, these groups of six will be formed arbitrarily with the help of the computer. The group you are in will not change during this part of the experiment. You will not get information about the identity of the persons in your group, neither during the experiment, nor after the experiment. Other participants will also not receive any information about your identity. Each person in your group is indicated by a letter. The other five persons in your group will be indicated by the letters **A**, **B**, **C**, **D** and **E**. You will receive the name **Me**. The same letter always refers to the same person. For your convenience we will call these participants **your neighbors**.

This part of the experiment consists of 30 rounds. In each round you can earn points. Your total earnings in this part of the experiment is the sum of your earnings in each of the 30 rounds. In each round, you - and each other person in your group - has to make one decision. You have to make a **decision** called **color**. This decision is explained in detail below.

Note: during all 30 rounds the other participants in your group will stay the same persons.

Decision (in one single round)

Decision: color

Each person in your group has to choose between two colors: **blue** and **green**. As explained above, you interact with each of your neighbors. In these interactions you can earn points. The color chosen by you and the color chosen by your neighbors determine how much you and your neighbors earn in these interactions.

Your earnings and the earnings of one of your neighbors are determined as follows:

your color	color of your neighbor	your earnings	earnings of your neighbor
blue	blue	95 points	95 points
blue	green	5 points	90 points
green	blue	90 points	5 points
green	green	75 points	75 points

In each round you will interact with **each** participant in your group. Therefore, your total earnings in a round is the sum of all points you earn in each of the interactions. **Note:** you can not choose different colors for different participants. You can, however, choose different colors in different rounds.

You get now information about the computer screen that you will see during this part of the experiment. You received a print-out of the computer screen (Example screen 1) from us. Take this print-out in front of you. The screen consists of five windows: **round**, **decision**, **decision: color**, **information** and **short explanation**.

- **Round:** This window holds information about past round(s). At the beginning of a new round you will automatically receive information in this window about decisions in the previous round, (In the example, this is round 6; see upper left corner). In the window there are 6 little squares, named **Me**, **A**, **B**, **C**, **D** and **E**. **Me** always refers to you. The letters refer to the other five persons in your group. This window also shows the interaction structure. This structure remains fixed throughout all 30 rounds.
 - The squares are either **blue** or **green**. This gives you information about the color choices of the persons in your group. (In the example: persons **A**, **B** and **D** have chosen the color **green**, while the persons **Me**, **C** and **E** have chosen the color **blue**)
 - At the bottom of this window you find two buttons called **previous** and **next**. You can use these buttons to look at the decisions in all previous rounds. Between the buttons you can find your **earnings** (in points) in the corresponding round.
- **Decision:** This windows has no importance in the experiment.
- **Decision: color:** This window is located in the lower right corner. In this window you choose between the two colors **blue** and **green**. You make your decision by clicking in the empty button to the left of **Blue** or **Green**.

When you are satisfied with your decision you have to confirm these decisions by clicking on the button ‘**Confirm**’.

- **Information:** In this window you find information on the current round and on your **total earnings** up until this round.
- **Short explanation:** If this window turns yellow you have to make your decision. After you made and confirmed your decision this window will turn grey. You then have to wait until all participants are ready. Only then a new round will begin.

Information: After each round, you will receive information about the choices of all persons in your group. All other persons in your group will also receive information about all your decisions.

This is the end of the instructions of part II. You will now have to answer a few questions to make sure that you understood the instructions properly. Thereafter, there will be one practice round in which you cannot yet earn any money. Your decisions in this practice round will not be revealed to other participants. Only after the practice round is over part II of the experiment will begin.

If you have any questions please raise your hand. If you have no questions any more, click on ‘**Next**’.

Figure 3.9: Example screen 1

Treatment I-NC

Instructions part II

In this part of the experiment every participant is in a **group of six** with five other participants. Before part II begins, these groups of six will be formed arbitrarily with the help of the computer. The group you are in will not change during this part of the experiment. You will not get information about the identity of the persons in your group, neither during the experiment, nor after the experiment. Other participants will also not receive any information about your identity. Each person in your group is indicated by a letter. The other five persons in your group will be indicated by the letters **A**, **B**, **C**, **D** and **E**. You will receive the name **Me**. The same letter always refers to the same person.

This part of the experiment consists of 30 rounds. In each round you can earn points. Your total earnings in this part of the experiment is the sum of your earnings in each of the 30 rounds. In each round, you - and each other person

in your group - has to make one decision. You have to make a **decision** called **connections** and a **decision** called **color**. These decisions are explained in detail below.

Note: during all 30 rounds the other participants in your group will stay the same persons.

Decision (in one single round)

Decision: connections

You have to decide with whom you want to make a connection. You can make a connection with any other person in your group and you can make as many connections as you want. These choices - together with the choices of the other persons in your group - determine with whom you **interact** (in the respective round) as explained below:

- You will interact with a person with whom you made a connection.
- You will interact with a person who made a connection with you.
- You will not interact with a person if neither of you made a connection with each other.

For your convenience we will call those persons in your group with whom you **interact: your neighbors**. Your neighbors are therefore those persons with whom you made a connection and those persons who made a connection with you.

Decision: color

Each person in your group has to choose between two colors: **blue** and **green**. As explained above, you **interact with all your neighbors**. In these interactions you can earn points. The color chosen by you and the color chosen by your neighbors determine how much you and your neighbors earn in these interactions.

Your earnings and the earnings of one of your neighbors are determined as follows:

your color	color of your neighbor	your earnings	earnings of your neighbor
blue	blue	95 points	95 points
blue	green	5 points	90 points
green	blue	90 points	5 points
green	green	75 points	75 points

In each round you will **interact with all your neighbors**. Therefore, your total earnings in a round from the interactions with your neighbors is the sum of all points you earn in each of the interactions. For each person in your group with whom you do not interact (i.e., all persons who are not your neighbors) you earn 0 points. For example, if you have no neighbors in a round, then you earn 0 points in this round.

Note: you can not choose different colors for different participants. You can, however, choose different colors in different rounds.

You get now information about the computer screen that you will see during this part of the experiment. You received a print-out of the computer screen (Example screen 1) from us. Take this print-out in front of you. The screen consists of five windows: **round**, **decision**, **connection**, **decision**, **color**, **information** and **short explanation**.

- **Round:** This window holds information about past round(s). At the beginning of a new round you will automatically receive information in this window about decisions in the previous round, (In the example, this is round 6; see upper left corner). In the window there are 6 little squares, named **Me**, **A**, **B**, **C**, **D** and **E**. **Me** always refers to you. The letters refer to the other five persons in your group.
 - A line between two persons (letters or ‘Me) indicates that these two persons were neighbors in the previous round, that is they had an interaction with each other.
 - A thick full line between two persons indicates that they both connected to each other. (See, e.g., the line between **Me** and **C** on the example screen).
 - A thin line between two persons indicates that only one of them made a connection: such a line is full on the side of the person that made the connection, and broken on the side on the side of the person that did not made the connection. (See, e.g., the line between **Me** and **B** on the example screen: **Me** made a connection with **B**, but **B** did not make a

connection with Me.)

- No line between two persons indicates that neither of them made a connection.
- The squares are either **blue** or **green**. This gives you information about the color choices of the persons in your group. (In the example: persons **A**, **B** and **D** have chosen the color **green**, while the persons **Me**, **C** and **E** have chosen the color **blue**.)
- At the bottom of this window you find two buttons called **previous** and **next**. You can use these buttons to look at the decisions in all previous rounds. Between the buttons you can find your **earnings** (in points) in the corresponding round.

- **Decision: connections** In this window you can choose with whom you want to make a connection. Again, there are five squares named **A**, **B**, **C**, **D** and **E** and the square **Me**. You can make a connection with another person in your group by clicking on the corresponding square. A non-broken grey line will appear to indicate that you made a connection. To remove a connection you made, click on the corresponding square again. (On the example screen: **Me** made a connection with persons **A**, **B**, **C** and **D**.)

Note: At the beginning of each round you will always see the connections that you made in the previous round. If you want, you can remove these connections in the way described above.

- **Decision: color:** This window is This window is located precisely underneath the window, just described. In this window you choose between the two colors **blue** and **green**. You make your decision by clicking in the empty button to the left of **Blue** or **Green**.

When you are satisfied with all your decisions (that is, with **both**: the **connections** you made and the chosen **color**), you have to confirm these decisions by clicking on the button ‘**Confirm**’.

- **Information:** In this window you find information on the current round and on your **total earnings** up until this round.
- **Short explanation:** If this window turns yellow you have to make your decision. After you made and confirmed your decision this window will turn

grey. You then have to wait until all participants are ready. Only then a new round will begin.

Information: After each round, you will receive information about the choices of all persons in your group. All other persons in your group will also receive information about all your decisions.

This is the end of the instructions of part II. You will now have to answer a few questions to make sure that you understood the instructions properly. Thereafter, there will be one practice round in which you cannot yet earn any money. Your decisions in this practice round will not be revealed to other participants. Only after the practice round is over part II of the experiment will begin.

If you have any questions please raise your hand. If you have no questions any more, click on ‘Next’.

Figure 3.10: Example screen 1

Treatment II-NC

Instructions part II

In this part of the experiment every participant is in a **group of six** with five other participants. Before part II begins, these groups of six will be formed arbitrarily with the help of the computer. The group you are in will not change during this part of the experiment. You will not get information about the identity of the persons in your group, neither during the experiment, nor after the experiment. Other participants will also not receive any information about your identity. Each person in your group is indicated by a letter. The other five persons in your group will be indicated by the letters **A**, **B**, **C**, **D** and **E**. You will receive the name **Me**. The same letter always refers to the same person.

This part of the experiment consists of 30 rounds. In each round you can earn points. Your total earnings in this part of the experiment is the sum of your earnings in each of the 30 rounds. In each round, you - and each other person in your group - has to make one decision. You have to make a **decision** called **connections** and a **decision** called **color**. These decisions are explained in detail below.

Note: during all 30 rounds the other participants in your group will stay the same persons.

Decision (in one single round)

Decision: connections

You have to decide with whom you want to make a connection. You can make a connection with any other person in your group and you can make as many connections as you want. These choices - together with the choices of the other persons in your group - determine with whom you **interact** (in the respective round) as explained below:

- You will interact with a person with whom you made a connection *and* who made a connection to you. So **mutual consent** is needed for interaction.
- You will not interact if either only you or only the other person made a connection.

- You will not interact with a person if neither of you made a connection with each other.

For your convenience we will call those persons in your group with whom you **interact: your neighbors**. Your neighbors are therefore those persons with whom you made a connection and who at the same time also made a connection with you.

Decision: color

Each person in your group has to choose between two colors: **blue** and **green**. As explained above, you **interact with all your neighbors**. In these interactions you can earn points. The color chosen by you and the color chosen by your neighbors determine how much you and your neighbors earn in these interactions.

Your earnings and the earnings of one of your neighbors are determined as follows:

your color	color of your neighbor	your earnings	earnings of your neighbor
blue	blue	95 points	95 points
blue	green	5 points	90 points
green	blue	90 points	5 points
green	green	75 points	75 points

In each round you will **interact with all your neighbors**. Therefore, your total earnings in a round from the interactions with your neighbors is the sum of all points you earn in each of the interactions. For each person in your group with whom you do not interact (i.e., all persons who are not your neighbors) you earn 0 points. For example, if you have no neighbors in a round, then you earn 0 points in this round.

Note: you can not choose different colors for different participants. You can, however, choose different colors in different rounds.

You get now information about the computer screen that you will see during this part of the experiment. You received a print-out of the computer screen (Example screen 1) from us. Take this print-out in front of you. The screen consists of five windows: **round**, **decision: connection**, **decision: color**, **information** and **short explanation**.

- **Round:** This window holds information about past round(s). At the beginning of a new round you will automatically receive information in this window

about decisions in the previous round, (In the example, this is round 6; see upper left corner). In the window there are 6 little squares, named **Me**, **A**, **B**, **C**, **D** and **E**. **Me** always refers to you. The letters refer to the other five persons in your group.

- A thick full line between two persons (letters or Me) indicates that they both made a connection with each other, that is they had an interaction with each other. See, e.g., the line between **Me** and **C** on the example screen).
 - A thin line between two persons indicates that only one of them made a connection: such a line is full on the side of the person that made the connection, and broken on the side on the side of the person that did not made the connection. (See, e.g., the line between **Me** and **B** on the example screen: **Me** made a connection with **B**, but **B** did not make a connection with **Me**.)
 - No line between two persons indicates that neither of them made a connection.
 - The squares are either **blue** or **green**. This gives you information about the color choices of the persons in your group. (In the example: persons **A**, **B** and **D** have chosen the color **green**, while the persons **Me**, **C** and **E** have chosen the color **blue**.)
 - At the bottom of this window you find two buttons called **previous** and **next**. You can use these buttons to look at the decisions in all previous rounds. Between the buttons you can find your **earnings** (in points) in the corresponding round.
- **Decision: connections** In this window you can choose with whom you want to make a connection. Again, there are five squares named **A**, **B**, **C**, **D** and **E** and the square **Me**. You can make a connection with another person in your group by clicking on the corresponding square. A non-broken grey line will appear to indicate that you made a connection. To remove a connection you made, click on the corresponding square again. (On the example screen: **Me** made a connection with persons **A**, **B**, **C** and **D**.)
Note: At the beginning of each round you will always see the connections that you made in the previous round. If you want, you can remove these connections in the way described above.
 - **Decision: color:** This window is This window is located precisely underneath the window, just described. In this window you choose between the

two colors **blue** and **green**. You make your decision by clicking in the empty button to the left of **Blue** or **Green**.

When you are satisfied with all your decisions (that is, with **both**: the **connections** you made and the chosen **color**), you have to confirm these decisions by clicking on the button '**Confirm**'.

- **Information:** In this window you find information on the current round and on your **total earnings** up until this round.
- **Short explanation:** If this window turns yellow you have to make your decision. After you made and confirmed your decision this window will turn grey. You then have to wait until all participants are ready. Only then a new round will begin.

Information: After each round, you will receive information about the choices of all persons in your group. All other persons in your group will also receive information about all your decisions.

This is the end of the instructions of part II. You will now have to answer a few questions to make sure that you understood the instructions properly. Thereafter, there will be one practice round in which you cannot yet earn any money. Your decisions in this practice round will not be revealed to other participants. Only after the practice round is over part II of the experiment will begin.

If you have any questions please raise your hand. If you have no questions any more, click on '**Next**'.

Figure 3.11: Example screen 1

Treatment I-C

Instructions part II

In this part of the experiment every participant is in a **group of six** with five other participants. Before part II begins, these groups of six will be formed arbitrarily with the help of the computer. The group you are in will not change during this part of the experiment. You will not get information about the identity of the persons in your group, neither during the experiment, nor after the experiment. Other participants will also not receive any information about your identity. Each person in your group is indicated by a letter. The other five persons in your group will be indicated by the letters **A**, **B**, **C**, **D** and **E**. You will receive the name **Me**. The same letter always refers to the same person.

This part of the experiment consists of 30 rounds. In each round you can earn points. Your total earnings in this part of the experiment is the sum of your earnings in each of the 30 rounds. In each round, you - and each other person

in your group - has to make one decision. You have to make a **decision** called **connections** and a **decision** called **color**. These decisions are explained in detail below.

Note: during all 30 rounds the other participants in your group will stay the same persons.

Decision (in one single round)

Decision: connections

You have to decide with whom you want to make a connection. You can make a connection with any other person in your group and you can make as many connections as you want. These choices - together with the choices of the other persons in your group - determine with whom you **interact** (in the respective round) as explained below:

- You will interact with a person with whom you made a connection.
- You will interact with a person who made a connection with you.
- You will not interact with a person if neither of you made a connection with each other.

Note: Making a connection is costly. The cost of making a connection will be 80 points.

For your convenience we will call those persons in your group with whom you **interact**: **your neighbors**. Your neighbors are therefore those persons with whom you made a connection and who at the same time also made a connection with you.

Decision: color

Each person in your group has to choose between two colors: **blue** and **green**. As explained above, you **interact with all your neighbors**. In these interactions you can earn points. The color chosen by you and the color chosen by your neighbors determine how much you and your neighbors earn in these interactions.

Your earnings and the earnings of one of your neighbors are determined as follows:

your color	color of your neighbor	your earnings	earnings of your neighbor
blue	blue	95 points	95 points
blue	green	5 points	90 points
green	blue	90 points	5 points
green	green	75 points	75 points

Note: The cost of making a connection is not subtracted from these earnings. For each connection you make you have to subtract 80 points from the earnings from decision: color.

In each round you will **interact with all your neighbors**. Therefore, your total earnings in a round from the interactions with your neighbors is the sum of all points you earn in each of the interactions. For each person in your group with whom you do not interact (i.e., all persons who are not your neighbors) you earn 0 points. For example, if you have no neighbors in a round, then you earn 0 points in this round.

Note: you can not choose different colors for different participants. You can, however, choose different colors in different rounds.

You get now information about the computer screen that you will see during this part of the experiment. You received a print-out of the computer screen (Example screen 1) from us. Take this print-out in front of you. The screen consists of five windows: **round**, **decision**, **connection**, **decision**, **color**, **information** and **short explanation**.

- **Round:** This window holds information about past round(s). At the beginning of a new round you will automatically receive information in this window about decisions in the previous round, (In the example, this is round 6; see upper left corner). In the window there are 6 little squares, named **Me**, **A**, **B**, **C**, **D** and **E**. **Me** always refers to you. The letters refer to the other five persons in your group.
 - A line between two persons (letters or Me) indicate that these two persons were neighbors in the previous round, that is they had an interaction with each other.
 - A thick full line between two persons (letters or Me) indicates that they both made a connection with each other, that is they had an interaction with each other. See, e.g., the line between **Me** and **C** on the example

screen). This also means that **both** persons have to **pay** the **cost** of making the connection.

- A thin line between two persons indicates that only one of them made a connection: such a line is full on the side of the person that made the connection, and broken on the side of the person that did not make the connection. (See, e.g., the line between **Me** and **B** on the example screen: **Me** made a connection with **B**, but **B** did not make a connection with **Me**. In this example **Me** has to **pay** the **cost** of making the connection)
 - No line between two persons indicates that neither of them made a connection.
 - The squares are either **blue** or **green**. This gives you information about the color choices of the persons in your group. (In the example: persons **A**, **B** and **D** have chosen the color **green**, while the persons **Me**, **C** and **E** have chosen the color **blue**.)
 - At the bottom of this window you find two buttons called **previous** and **next**. You can use these buttons to look at the decisions in all previous rounds. Between the buttons you can find your **earnings** (in points) in the corresponding round.
- **Decision: connections** In this window you can choose with whom you want to make a connection. Again, there are five squares named **A**, **B**, **C**, **D** and **E** and the square **Me**. You can make a connection with another person in your group by clicking on the corresponding square. A non-broken grey line will appear to indicate that you made a connection. To remove a connection you made, click on the corresponding square again. (On the example screen: **Me** made a connection with persons **A**, **B**, **C** and **D**.)
Note: At the beginning of each round you will always see the connections that you made in the previous round. If you want, you can remove these connections in the way described above.
 - **Decision: color:** This window is This window is located precisely underneath the window, just described. In this window you choose between the two colors **blue** and **green**. You make your decision by clicking in the empty button to the left of **Blue** or **Green**.

When you are satisfied with all your decisions (that is, with **both**: the **connections** you made and the chosen **color**), you have to confirm these

decisions by clicking on the button ‘**Confirm**’.

- **Information:** In this window you find information on the current round and on your **total earnings** up until this round.
- **Short explanation:** If this window turns yellow you have to make your decision. After you made and confirmed your decision this window will turn grey. You then have to wait until all participants are ready. Only then a new round will begin.

Information: After each round, you will receive information about the choices of all persons in your group. All other persons in your group will also receive information about all your decisions.

This is the end of the instructions of part II. You will now have to answer a few questions to make sure that you understood the instructions properly. Thereafter, there will be one practice round in which you cannot yet earn any money. Your decisions in this practice round will not be revealed to other participants. Only after the practice round is over part II of the experiment will begin.

If you have any questions please raise your hand. If you have no questions any more, click on ‘**Next**’.

Figure 3.12: Example screen 1

Instructions part III

Explanation part III

This part of the experiment is exactly the same as the previous part except for the fact that **new groups** of six will arbitrarily be formed with the help of the computer. That is, the composition of the group you are in differs from the composition of the group you were in, in the previous part. During this part of the experiment, the group you are in will not change. This part of the experiment consists of thirty rounds.

Instructions Ten-paired Lottery-Choice Decisions

In this part of the experiment you will be asked to make ten decisions on lotteries.

You received a print-out of the computer screen for part IV from us. Please take this print-out in front of you. We shall explain your choice options with the help of the print-out.

The print-out shows ten decisions. Each decision is a paired choice between “Option A” and “Option B.” You will make ten choices, but only one of them will be used in the end to determine your earnings. These choices will affect your earnings, in the following way. After you have made all of your choices, that is after selecting Option A or Option B in each decision row, you will have to click on the button “confirm”. Thereafter, a button “start computer” arises. This button starts the procedure in which the computer randomly selects one of the ten decisions that will be relevant for your earnings. Thereafter, you will see a new screen where the actual lottery, that is the choice option associated with the selected decision row, will take place. When you press the button “start counting” the computer will randomly pick a number between 1 and 10 which will determine your payoff for the option you chose, Option A or Option B, for the particular decision selected.

Note: Even though you will make ten decisions, only one of these will end up affecting your earnings, but you will not know in advance which decision will be used. Obviously, each decision has an equal chance of being used in the end.

Now, please look at Decision 1 at the top. Option A pays x points if the randomly chosen number by the computer is 1, and it pays y points if the randomly chosen number by the computer is 2-10. Option B yields w points if the randomly chosen number by the computer is 1, and it pays z points if the randomly chosen number by the computer is 2-10. In Decision 2, Option A pays x points if the randomly chosen number by the computer is 1-2, and it pays y points if the randomly chosen number by the computer is 3-10. Option B yields w points if the randomly chosen number by the computer is 1-2, and it pays z points if the randomly chosen number by the computer is 3-10. The payments are determined in a similar manner for the other rows.

If you have any questions please raise your hand. If you have no questions any more, press ‘**ready**’.

Treatment	x	y	w	z
B	2000	1600	3850	100
I-NC	2000	1600	3850	100
II-NC	2000	1600	3850	100
I-C	1144	916	2200	58

Table 3.11: Values for the different treatments

MainForm

	Option A	Option B
Decision 1	☐ 2000 with 10% chance and 1600 with 90% chance	☐ 3850 with 10% chance and 100 with 90% chance
Decision 2	☐ 2000 with 20% chance and 1600 with 80% chance	☐ 3850 with 20% chance and 100 with 80% chance
Decision 3	☐ 2000 with 30% chance and 1600 with 70% chance	☐ 3850 with 30% chance and 100 with 70% chance
Decision 4	☐ 2000 with 40% chance and 1600 with 60% chance	☐ 3850 with 40% chance and 100 with 60% chance
Decision 5	☐ 2000 with 50% chance and 1600 with 50% chance	☐ 3850 with 50% chance and 100 with 50% chance
Decision 6	☐ 2000 with 60% chance and 1600 with 40% chance	☐ 3850 with 60% chance and 100 with 40% chance
Decision 7	☐ 2000 with 70% chance and 1600 with 30% chance	☐ 3850 with 70% chance and 100 with 30% chance
Decision 8	☐ 2000 with 80% chance and 1600 with 20% chance	☐ 3850 with 80% chance and 100 with 20% chance
Decision 9	☐ 2000 with 90% chance and 1600 with 10% chance	☐ 3850 with 90% chance and 100 with 10% chance
Decision 10	☐ 2000 with 100% chance and 1600 with 0% chance	☐ 3850 with 100% chance and 100 with 0% chance

Please look carefully at the decision rows above. For each decision row you have to choose between option A and option B by clicking on the appropriate 'radiobutton'.

Confirm

Figure 3.13: Example Ten-paired Lottery-Choice Decisions

4

MAXIMUM EFFORT IN THE NEIGHBORHOOD MINIMUM EFFORT GAME

Many situations where coordination plays a crucial role have a weakest link characteristic, i.e. the weakest player determines the outcome for all involved parties. These situations can be modeled by the minimum effort game. Each subject chooses an effort level and obtains a payoff which is determined by the lowest effort in the group. In this chapter, we examine the impact of endogenous interaction choice on behavior and welfare in the minimum effort game. In the experimental treatment, subjects play the minimum effort game within their self chosen neighborhood. A subject will be part of the neighborhood only if there is mutual consent on being a part of it. In the control treatment, the minimum effort game has to be played with all group members. The results show that the choice of interaction partners leads to unanimous coordination on the payoff dominant equilibrium. The exclusion possibility, apparently, induces subjects to increase their effort level towards the highest effort possible. At the same time, subjects seem to understand that from an efficiency point of view it is most beneficial to interact with all other group members. As a result, over time, all subjects interact with each other and choose the maximum effort level.

4.1 Introduction

Societies continuously face incidents in which coordination plays a crucial role. Many of these situations have a weakest link characteristic, i.e. the weakest player determines the outcome for all involved parties. Maintaining financial stability within the Euro zone is a prominent example in the European Monetary Union. Member states have to take measures for having a sound national financial system. The integrity of the whole European financial system and the stability of the Euro, is dependent on the member state with the weakest national financial market. The

country with the greatest economic difficulties and the weakest national financial system, determines the chances of a crisis to occur and the depth of a crisis, which subsequently affects countries with sound national financial systems. At the same time, all countries benefit from having a sound national financial market. Currently, Greece is the weakest link in the Euro-area, with a deficit of 12.7 percent of GDP last year. Other member states see Greece as such a large threat to financial instability that German Chancellor Angela Merkel even suggested that “In the future, we need an entry in the Lisbon Treaty that would make it possible, as a last resort, to exclude a country from the Euro zone if the conditions are not fulfilled again and again over the long term” (March 17th, 2010).

Another example that has attracted attention of the media, is the fight against infectious diseases such as SARS, avian influenza, swine influenza, or AIDS. To prevent the diseases from breaking out or spreading, involved parties have to invest into precautionary means.¹ The party which exerts the lowest effort determines to a large extent the chances of outbreak or eradication of a disease. To minimize the chances of an outbreak, all parties should choose the highest precaution level. The same reasoning can be applied to computer networks. Hackers or viruses try to enter weakly protected computers and use them as stepping stones to move further into the network.

In all examples, players face the problem to coordinate on high efforts, which is maximizing both, welfare as well as individual payoffs. Hence, in contrast to typical social dilemma situations, providing high effort is an equilibrium strategy but it is characterized by high strategic uncertainty. One single player deviating downwards is sufficient to cause substantial losses for each individual as well as for the whole group.

The two examples differ with respect to the interaction structure. Currently, the Euro-zone member states are bound to their interaction partners by the Lisbon Treaty. Now that the Euro zone faces a crisis, countries suggest to extend the treaty to allow for exclusion of countries, which continuously have the weakest financial system. In contrast, the actors in the disease and computer network example, be it countries or individuals, have the possibility to choose their interaction partners. If, for example, a network is repeatedly hacked via the same weakly protected computer, system administrators of other computers might deny access from this specific computer to theirs. Similarly, governments may restrict, or at least discourage, free travel from and to countries with repeated outbreaks

¹Involved parties could be individual persons or countries. Precautionary means could be for example vaccination on the individual level or the provision of medication or health education on the country level.

of infectious diseases.

The sketched difference between endogenously chosen and exogenously given neighborhoods opens up a new perspective on coordination problems and might turn out to be a crucial determinant in solving coordination problems. In this chapter, we investigate coordination on effort levels within both exogenous and endogenous interaction frameworks.

For the case of exogenously given neighborhoods, an appropriate game-theoretic model is the so-called minimum effort game which was introduced by Bryant (1983).² Van Huyck, Battalio and Beil (1990, VHBB henceforth) were the first to examine this minimum effort game experimentally. Subjects in their experiments repeatedly chose an effort level between 1 and 7 and received round payoffs that decreased in their own chosen level, but more strongly increased in the minimum level of the group. Any strategy profile where players play the same effort level constitutes a Nash equilibrium. Moreover these equilibria can be ranked according to the criteria of risk dominance and payoff dominance (see Harsanyi and Selten, (1988)).³ VHBB were interested whether subjects could in the course of several rounds tacitly coordinate on high efforts.⁴ The results were rather disappointing from the efficiency perspective. Only in very small groups of two participants and in the case of costless effort (i.e. high effort was riskless) subjects were able to coordinate on the payoff dominant equilibrium.

These results have led to a wave of experiments in which the robustness of the VHBB results was tested and conditions for the emergence of Pareto-efficient behavior were explored (see Devetag and Ortmann (2007) for an excellent overview). Almost all attempts focus on the reduction of strategic uncertainty. Brandts and Cooper (2006) showed that increasing the potential efficiency gains mitigates the tendency to coordinate on inefficient equilibria. Other ways to reduce strategic uncertainty and to induce higher effort levels are the admission of cheap talk before the game (Blume and Ortmann, (2007)), the reduction of exploration costs by an increase of the number of rounds (Berninghaus and Ehrhart, (1998)), or common knowledge, and unanimous “positive” advice of previous subjects (Chaudhuri et al., (2009)).

²Bryant suggested the game as a simple, parsimonious micro-foundation to describe how coordination failure in macroeconomics could lead to bad equilibria.

³Although the concept of risk dominance is not transitive in general, it turns out to be for this particular type of game.

⁴VHBB separated two types of coordination problems. Firstly, players may fail to predict the effort levels of other players and therefore fail to coordinate on any equilibrium (individual coordination problem). Secondly, as the equilibria can be Pareto ranked, players might coordinate but coordinate on a low payoff equilibrium (collective coordination problem).

Mixed evidence was found with respect to feedback information. While Berninghaus and Ehrhart (2001) found that average effort increases if subjects do not only get feedback about the minimum effort but also about its distribution, other studies like the original VHBB or Engelmann and Normann (2009) do not confirm this.

Another determinant which plays a role in improving efficiency is the group size. VHBB already showed that small groups more easily coordinate on high efforts than large groups. The results have been proven to be very robust (see Table 2 in Weber, (2006), and Van Huyck, Battalio and Rankin, (2007)).

Based on these results, Weber (2006) showed that starting out from small groups and adding participants one by one also enables coordination on high effort levels in larger groups, although coordination eventually collapsed in many larger groups.

By and large, although some studies provide gleams of hope, coordination on the payoff-dominant equilibrium is hardly observed. Moreover, if Pareto-efficient behavior does occur, it turns out to be quite fragile over time.

Endogenous neighborhood choice might change the picture because it introduces the possibility of punishment. Instead of adjusting the effort level to the low efforts provided by some neighbors, players have the alternative to exclude them from their neighborhood. Excluding players forgo the benefits from interaction with the excluded players but they also reduce their strategic uncertainty. Moreover, the threat of being excluded might counterbalance strategic uncertainty and, therefore, induces subjects to play higher effort levels. Hence, endogenous neighborhood choice may serve as a powerful device to achieve coordination on the payoff dominant equilibrium.

In our experiment we set out to test whether endogenizing the neighborhood choice indeed has this effect. Therefore, we extend the minimum effort game and allow players to simultaneously choose their neighborhood together with their effort level. We run two treatments, a baseline treatment with an exogenously given complete network, which is comparable to the standard minimum effort game, and a neighborhood treatment with endogenous neighborhood choice.

We indeed find that in the long run outcomes of the neighborhood treatment converge to the maximum effort and complete neighborhoods, i.e. everybody interacts with everybody else, while providing the highest effort. This is in sharp contrast to the result of the baseline treatment where most of the groups converge to the lowest effort equilibrium. The effect turns out to be remarkably stable with respect to group size. Even in groups of 24 subjects, all subjects' behavior quickly converges to complete networks with highest effort provision.

In the remainder of the chapter we will formally introduce the minimum effort game and its neighborhood choice extension in Section 4.2. Then we describe our experimental design and procedure in Sections 4.3 and 4.4. In Sections 4.5 and 4.6 we report on the results of the experiments and in Section 4.7 we conclude. Appendix A provides the formal derivation of the theoretical benchmarks as well as the experiment instructions.

4.2 The Minimum Effort Game

For our baseline treatment we use the same minimum effort game as in VHBB. We call it the baseline minimum effort game. For the treatment with endogenous neighborhood choice we extend the players' strategy set to include the choice of desired neighbors. A player does not play the minimum effort game against the entire group but only against his neighborhood. Furthermore, we adjust the payoff function in order to take the neighborhood size into account. We call this the neighborhood minimum effort game.

4.2.1 The baseline minimum effort game

Let $N = \{1, 2, 3, \dots, n\}$ be a finite set of players and let $E = \{1, 2, \dots, 7\}$ be a set of effort levels. Each player chooses a strategy, i.e. an effort level $s_i = e_i \in E$. Let $s = (s_i)_{i \in N}$ be a strategy profile of all players in the group. Further, let b denote the constant marginal cost of effort, let a be the constant marginal return on the lowest group effort, and let $a > b > 0$. The payoff of player i is then determined by

$$\pi_i(s) = a \min_{j \in N} \{e_j\} - be_i + c \quad (4.1)$$

where $c > 0$ ensures non-negative payoffs for all strategy profiles.⁵

Since $a > b > 0$, every player has the incentive to choose his effort level equal to the minimum level of the other players. Therefore, all profiles $s^{\tilde{e}} = (\tilde{e})_{i \in N}$ where all players play the same effort $\tilde{e}$ are pure strategy Nash equilibria.⁶ In equilibrium, higher effort levels yield higher payoffs. The Nash equilibria can therefore be Pareto ranked, where $s^7 = (7)_{i \in N}$ is the Pareto-dominant equilibrium. Furthermore, $s^1 = (1)_{i \in N}$ is the risk-dominant, i.e. s^1 pairwise risk-dominates any other pure strategy equilibrium.

⁵Negative payoffs are problematic from a practical point of view as it is difficult to enforce payments from subjects.

⁶We concentrate on pure strategy equilibria. Equilibria in mixed strategies exist, however.

4.2.2 The neighborhood minimum effort game

As in the baseline minimum effort game, let $N = \{1, 2, 3, \dots, n\}$ be a finite set of players and let $E = \{1, 2, \dots, 7\}$ be a set of effort levels. Each player i chooses a strategy which consists of two elements: $s_i = (e_i, I_i)$. Additionally to the effort level e_i , player i chooses a set of players with whom he would like to interact: $I_i \subseteq N \setminus \{i\}$.⁷ An interaction requires mutual consent, i.e. i and j interact if and only if $i \in I_j$ and $j \in I_i$. For strategy profile $s = (s_1, s_2, \dots, s_n)$, the neighborhood of player i is defined by $N_i(s) = \{j | j \in I_i \wedge i \in I_j\}$, where $|N_i(s)|$ denotes the number of i 's neighbors.

In reality, having more interactions also implies higher potential payoffs. The number of neighbors, however, also increases the chance of facing a low effort level in the own neighborhood. In our model, players should face the same tradeoff between the size of the neighborhood and the strategic uncertainty which goes along with it. The simplest and most natural extension of the payoff function of the baseline minimum effort game is to determine the minimum effort only with respect to the neighborhood, including oneself, and account for the effect of the neighborhood size. We, therefore, introduce the factor $\frac{|N_i(s)|}{n-1}$ into the payoff function of the neighborhood minimum effort game:

$$\pi_i(s) = \frac{|N_i(s)|}{n-1} \left[a \left(\min_{j \in N_i(s) \cup \{i\}} \{e_j\} \right) - be_i + c \right]. \quad (4.2)$$

For the case of the maximum neighborhood ($N_i(s) = N \setminus \{i\}$) the payoff function and the degree of strategic uncertainty in the neighborhood minimum effort game and the baseline minimum effort game coincide. Moreover, it is always beneficial to increase one's neighborhood if the minimum effort does not decrease.

4.2.3 Theoretical benchmarks

Games involving network formation may go along with a multiplicity of Nash equilibria. This is also the case in our neighborhood minimum effort game as we require mutual consent for interactions to take place. For example, any fragmentation of the network where in each component the same effort is played and none of the players wants to interact with players from other components, is a Nash equilibrium. Pairwise stability predicts the complete network given equal effort levels, but does not solve the multiplicity problem with respect to the effort levels.

⁷The words interaction and play can be used interchangeably. In the context of endogenous neighborhood choice we use the term interaction since whether or not to interact is a choice rather than an exogenously given fact.

Consequently, many actions can be justified as part of an equilibrium strategy by some appropriate beliefs. We address this problem of equilibrium selection by using the techniques of stochastic stability (Young 1993, 1998), which reveals the relative dynamic stability of the equilibria. Details and proofs can be found in Appendix A.

Proposition 4.1 *In both the baseline and the neighborhood minimum effort game, the unique stochastically stable equilibrium is the complete network with every player playing the lowest effort.*

Note that in equilibrium, in both games the network is complete. While this is due to construction in the baseline minimum effort game, it emerges from the stochastic dynamics in the neighborhood minimum effort game.

4.3 Design and hypotheses

Our experiment comprises two treatments; the baseline treatment and the neighborhood treatment. In each treatment subjects play the corresponding game repeatedly for 30 rounds in fixed matching groups of eight. To assure anonymity, subjects do not get to know the identity of the other group members. They refer to themselves as “me” and to the others with the capital letters “A” to “G”. For each subject, these identifiers remain fixed throughout the experiment. The parameters of the payoff function are set in the same way as in VHBB, i.e. $a = 20$, $b = 10$, and $c = 60$ (see the payoff table in the instructions in Appendix B). When making their decision, subjects have access to the complete history of their own and all other group members’ previous actions.

4.3.1 Baseline treatment

In the baseline treatment, the full neighborhood is exogenously enforced, i.e. in each round each subject has to interact with all group members and only chooses an effort level. The only notable difference to the standard minimum effort game (VHBB) is the provision of information of all previous decisions. Moreover, to have the appearance of the screen most similar to the neighborhood treatment (see next section for details), in each round the baseline subjects receive a graphical representation of the complete network.⁸

The major problem subjects face is strategic uncertainty. Doubts in high effort ambitions of other subjects may induce playing safe, i.e. playing a low effort.

⁸A screenshot can be found in the instructions in Appendix B.

Doubts can also be of a more subtle higher order: a subject might not doubt another's willingness to coordinate on high efforts, but might believe that another subject doubts. As soon as more subjects follow a safe strategy, low-effort outcomes are self-confirming and very difficult to overcome.

This reasoning is confirmed by the prevailing evidence from the literature. Subjects do not manage to coordinate on the payoff-dominant equilibrium but rather converge to the lowest effort over time (Devetag and Ortmann 2007), irrespective of the level of feedback received on the distribution of effort levels (VHBB, Engelmann and Normann, (2009)). Even in the extended feedback condition of Berninghaus and Ehrhart (2001) in which higher than usual effort levels are found, these levels deteriorate over time. Therefore, we expect to find support for the following hypothesis

Hypothesis 4.2 *In the baseline treatment (minimum effort game with fixed exogenously given neighborhoods), subjects behavior will converge to the minimum effort.*

4.3.2 Neighborhood treatment

In the neighborhood treatment, neighborhoods are endogenous, i.e. in each round subjects do not only choose their effort level but also indicate with whom they want to interact.

After all subjects have made their effort and interaction decisions, each subject's neighborhood and corresponding payoff is individually determined according to equation 4.2 in Section 4.2.2). Thereafter, on a separate screen, subjects receive feedback about the size of their neighborhood, the minimum effort in their neighborhood, including themselves, and their payoff.

Unlike in the baseline treatment, where subjects could only react by changing their effort level, a subject now has an alternative way of reacting to low effort levels of other subjects. Rather than adjusting his own effort downwards, he can exclude subjects playing low effort from his neighborhood.

Since the payoffs are proportional to the size of the subject's neighborhood, an excluded subject loses money. Therefore, a possible response of such an excluded subject is to increase his effort level in consecutive rounds. This gives the excluder an incentive to re-include the excluded subject into his neighborhood. This basic mechanism of efficiency enforcement might lead to maximum effort and a complete network in the group. Weber (2006) shows that starting out from pairs and adding subjects one by one fosters high effort levels up to a certain size of the group. We expect that a similar but endogenous process takes place in our neighborhood

treatment. Small subgroups coordinating on high effort levels will form and only admit others to their neighborhood if they choose high effort too. Compared to Weber (2006), this process may even be more robust as deviators can be excluded any time. We, therefore, put forward

Hypothesis 4.3 *In the neighborhood treatment (minimum effort game with endogenously chosen neighborhoods), subjects' behavior converges to the complete network with every subject playing the highest effort.*

4.4 Experimental Procedure

All experimental sessions were conducted at the Behavioral and Experimental Economics Laboratory Maastricht (BEELab) with students from Maastricht University. The vast majority of subjects were from economics and business administration. The others were from law, cultural sciences and from the University College Maastricht. They were recruited through email announcements and announcements on students' intranet. Subjects were not allowed to participate more than once in the experiment. The experiment was computerized and programmed in Z-tree (Fischbacher, 2007). For each session, 16 subjects were recruited and randomly divided into two independent groups of 8 students. Subjects got written instructions which they could study at their own pace (see Appendix B). Additionally they could ask questions privately.⁹ Before the game started subjects had to answer some control questions correctly. In total, we conducted 9 sessions: 5 with endogenous neighborhood choice and 4 baseline sessions. Subjects collected their payoffs in points which were exchanged to euro at the rate of 2 points = € 0.01, and paid confidentially in cash immediately after the experiment. On average participants earned € 11.82 in the baseline treatment and € 17.17 in the neighborhood treatment. A typical session in the neighborhood treatment lasted about 80-90 minutes whereas a typical session in the baseline treatment lasted around 50-60 minutes.

To check the robustness of our results, we ran additional sessions with large groups of 24 subjects, three sessions with the baseline treatment (large baseline) and three sessions with the neighborhood treatment (large neighborhood). The sessions took roughly 30 minutes longer than their small groups counterparts. Participants in the large baseline treatment earned € 14.35 on average while participants in the large neighborhood treatment earned € 20.32 on average.

⁹We did only answer questions about the instructions. No answer was given if it had influenced the subjects expectation or strategy choice.

4.5 Results

4.5.1 Effort levels

In the experiment we collected data from 8 groups for the baseline treatment and 10 groups for the neighborhood treatment. Each group forms an independent observation and if not stated differently statistical tests are based on aggregated measures of these independent groups.

We begin the analysis with the effort choices over time. Figures 4.1(a) and 4.1(b) show the cumulative distribution of effort levels for the baseline treatment and the neighborhood treatment, respectively. In the first round, we observe only

Figure 4.1: Cumulative Distribution of Efforts across Rounds

small differences. Regarding the effort level as cardinal and applying a MWU-test on individual first round effort levels across treatments yields no significant difference (MWU, $n=144$, $p=0.8919$, two-sided).¹⁰ However, behavior exhibits completely different dynamics in the consecutive rounds. In the baseline treatment, the lowest effort becomes more frequent and is ultimately chosen more often than all other effort levels together. On the other hand, in the neighborhood treatment, the highest effort level becomes very quickly the dominant choice, while the frequencies of the other levels dwarf to a negligible size. To test this difference in trends we calculate each group's Spearman rank correlation coefficient between round and effort level chosen. The coefficients in the neighborhood treatment are (marginally) significantly more positive than those of the baseline treatment (MWU, $n=18$, $p=0.0756$, two-sided).¹¹

¹⁰The distributions of effort levels are not identical though (Fisher exact test, $n=144$, $p=0.027$). There is more mass on the extreme effort levels 1 and 7 in the baseline treatment.

¹¹Stronger results can be achieved with a Kolmogorov-Smirnov test (KS, $n=18$, $p=0.012$).

In order to get a more detailed picture of how subjects' effort choices converge towards a certain effort level, we now focus on the average and minimum effort levels played within the group and within the neighborhoods. The results are reported in Figures 4.2(a) and 4.2(b), respectively.

Note: The average minimum effort in (a) ((b)) refers to the minimum effort levels played in the group (neighborhood) averaged across groups.

Figure 4.2: Average and Minimum Efforts over Time

Figure 4.2(a) shows that the average effort levels and the minimum effort levels in the baseline treatment are clearly below those of the neighborhood treatment (MWU on groups' average effort levels over all rounds, $n=18$, $p=0.001$, two-sided; MWU on groups' minimum effort levels averaged over rounds, $p=0.0033$, two-sided). Furthermore, the average effort level in the baseline treatment converges downwards to the minimum effort, indicating coordination on lower effort levels.

In the baseline treatment, three out of eight groups manage to coordinate on the highest effort during rounds 13 to 24. The average effort of the other five groups is approaching 1. Most subjects adapt their behavior to the minimum effort played in their groups in the previous round, leaving the minimum effort unchanged. Some subjects even overshoot, i.e. they play a lower level than the minimum level of the previous round. This behavior causes a decrease in the minimum effort level and is observed in the first 11 and the last 6 rounds. Towards the end we observe an end game effect in two of the three efficient groups (see Section 4.5.5 for possible explanations).

The baseline treatment results are in line with previous findings although they are more on the efficient end of the spectrum from the literature (Devetag and Ortmann 2007).

In the neighborhood treatment we observe a much higher effort level, which approaches 7 fairly quickly. In all but one group, all subjects converge to playing

this effort level, within the first ten rounds. One group remains unstable and does not converge to any common effort level. Nevertheless, also this group's average level is above 6 from round 10 onwards. Also in this treatment, we observe an end game effect in six of the ten groups which drags down the overall average (see Section 4.5.5).

Figure 4.2(b) shows the average and minimum effort, when aggregating on neighborhoods rather than on groups. We observe a slightly higher and less volatile minimum effort level when only taking neighborhoods into account instead of the whole group. Furthermore, the average effort level is also slightly higher in the neighborhoods. Apparently, subjects with low effort levels are excluded.¹²

4.5.2 Neighborhood formation

Next to the development of the effort levels, we are interested in the neighborhood formation process. To verify where exclusion takes place, we need to look at the interaction proposals made by the subjects. Depending on the subjects' interaction choices I_i and I_j , four different situations may result. Besides mutual consent ($j \in I_i$ and $i \in I_j$) and mutual exclusion ($j \notin I_i$ and $i \notin I_j$), subject i might be the sole proposer of an interaction ($j \in I_i$ and $i \notin I_j$) or the one to reject j 's interaction proposal ($j \notin I_i$ and $i \in I_j$). Figure 4.3 shows the frequencies of these situations over time.¹³ We see that the vast majority of subjects, namely 78

Figure 4.3: Interactions Proposals across Rounds

percent, interact from the beginning onwards. Moreover, there is a clear increase of the interaction frequency over time. This is confirmed by a Wilcoxon signed rank

¹²Subjects who are excluded by some neighbors appear in less neighborhoods and, therefore, their effort level enters the averaging over neighborhoods less often.

¹³Note that the frequencies to be a sole interaction proposer and a rejector of a proposal have to be equal by definition.

test applied to groups' Spearman rank correlation coefficients between frequency of mutual interaction and round number (Wilcoxon, $n=10$, $p=0.043$, two-sided). An interesting fact to mention is that the few interactions that do not take place after round 10 are caused by only one group, which is the same group that also showed unstable behavior with respect to the effort choices. The remaining groups approach the complete network by round 10.

4.5.3 Exclusion

The frequencies of highest effort and interaction density seem to be in strong accordance. This suggests a relationship between both and puts another point on the hypothesis that low effort players are punished by exclusion and are forced back into the high effort equilibria.

To verify this exclusion hypothesis, we first analyze the consequences which arise for low effort players; do they face a higher risk of being excluded by others? The analysis is based on all dyadic relationships among all subject pairs i and j for a two round time interval ($t - 1$ and t). We categorize the dyadic relations by the behavior of subject i in round $t - 1$ into three distinct classes. The first class includes all cases where subject i 's effort was not only lower than subject j 's but also the minimum in j 's neighborhood ($e_i < e_j$ and $e_i = \min_{k \in N_j} \{e_k\}$). The second class includes all cases where i provided less effort than subject j but still more than the minimum in subject j 's neighborhood ($e_i < e_j$ but $e_i > \min_{k \in N_j} \{e_k\}$). The third class includes all remaining cases where subject i provided at least as much effort as subject j ($e_i \geq e_j$). We eventually investigate whether in round t subject j excluded i from his neighborhood.

Class	Effort level subject i , $t - 1$	Exclusion ratio, t	Exclusion rate, t
1	$e_i < e_j$ and $e_i = \min_{k \in N_j} \{e_k\}$	105/273	38.5 percent
2	$e_i < e_j$ and $e_i > \min_{k \in N_j} \{e_k\}$	21/89	23.6 percent
3	$e_i \geq e_j$	84/14738	0.6 percent

Table 4.1: Exclusion rate for the three different cases

The data in Table 4.1 shows that playing at least the effort of the other subject goes along with a very small risk of being excluded (0.6%).¹⁴ In contrast, the risk is quite high when playing a lower effort level than the other subject (23.6%) and it further increases if this effort level is the minimum of the other subject's neighborhood (38.5%). To test whether these differences are significant, we calculate

¹⁴Note this number includes the cases where subjects within a neighborhood coordinate on the same effort level. If we exclude these cases, the chances of being excluded raises to 4.2 %.

the exclusion rates for each independent group separately and apply a Wilcoxon signed rank test. All three pairwise comparisons are significant (Wilcoxon signed rank test, two-sided: case 1 vs. case 2, $n=8$, $p=0.017$; case 1 vs. case 3, $n=10$, $p=0.005$; case 2 vs. case 3, $n=8$, $p=0.036$). Low effort players thus face a significant risk of being excluded by high effort players.

The question remains whether excluded subjects change their behavior or not. Only by keeping their interaction proposal and increasing their effort level they give the excluding subject an incentive to re-establish the interaction. To investigate this issue in more detail, we extend the analysis of the dyadic relationships by another round $t + 1$. We investigate the behavior of a subject i in round $t + 1$ who have been excluded in round t by a subject j . Subject i may react in two dimensions. Firstly, he may keep the interaction proposal to j ($j \in I_i$) or sever the interaction proposal on his part ($j \notin I_i$). Secondly, he may keep ($e_i^{t+1} = e_i^{t-1}$), or change his effort level.¹⁵ In the latter case, we distinguish four possible changes in the effort level. First, subject i might decide to increase his effort level to at least the effort level of subject j , $e_i \uparrow$, $e_i^{t+1} \geq e_j^{t-1}$, or increase to an effort level below the effort level of subject j , $e_i \uparrow$, $e_i^{t+1} < e_j^{t-1}$. Similarly, subject i might decide to decrease his effort level above the effort level of subject j , $e_i \downarrow$, $e_i^{t+1} > e_j^{t-1}$, or decrease to an effort level to at least the effort level of subject j , $e_i \downarrow$, $e_i^{t+1} \leq e_j^{t-1}$. Table 4.2 reports the results.¹⁶

In general, we can say that most excluded subjects keep interaction proposals to subject j in round $t + 1$ (89.9%, 85.7%, and 78.8% for the different classes, respectively¹⁷). With respect to the effort level, excluded subjects make their decisions dependent on how much effort they provided in round $t - 1$. If subject i 's effort was at least as high as subject j 's effort, he keeps the same effort level as in round $t - 1$ (75.0%¹⁸). If the effort was lower than subject j 's effort, most subjects i increase their effort level in round $t + 1$ (71.7% and 80.9% for class 1 and 2, respectively¹⁹).

To make a more precise statement, we will now focus on the most popular strategies within each different class. In both class 1 and 2 where excluded subjects played an effort level below that of subject j , the most popular strategy for round $t + 1$ is to keep the interaction proposal and to increase the effort level to at least the

¹⁵The comparison of behavior is done over round $t - 1$ and round $t + 1$, as in round $t + 1$ subject i reacts to the exclusion by subject j in round t .

¹⁶Note that the sum of cases in round $t + 1$ might be lower than in round t because for $t = 30$ no further round exists.

¹⁷ $89.9 = 47.5 + 14.1 + 18.2 + 10.1$, $85.7 = 61.9 + 9.5 + 4.8 + 9.5$, and $78.8 = 17.3 + 59.6 + 1.9$

¹⁸ $75.0 = 59.6 + 15.4$

¹⁹ $71.4 = 47.5 + 14.1 + 6.1 + 4.0$, and $80.9 = 61.9 + 9.5 + 9.5$

$t-1$	Class 1: $e_i < e_j$ and $e_i = \min_{k \in N_j} \{e_k\}$					
$t+1$	$e_i \uparrow, e_i^{t+1} \geq e_j^{t-1}$	$e_i \uparrow, e_i^{t+1} < e_j^{t-1}$	$e_i^{t+1} = e_i^{t-1}$	$e_i \downarrow, e_i^{t+1} > e_j^{t-1}$	$e_i \downarrow, e_i^{t+1} \leq e_j^{t-1}$	
$j \in I_i$	47.5% (47)	14.1% (14)	18.2% (18)	n.a.	10.1% (10)	
$j \notin I_i$	6.1% (6)	4.0% (4)	0.0% (0)	n.a.	0.0% (0)	
$t-1$	Class 2: $e_i < e_j$ and $e_i > \min_{k \in N_j} \{e_k\}$					
$t+1$	$e_i \uparrow, e_i^{t+1} \geq e_j^{t-1}$	$e_i \uparrow, e_i^{t+1} < e_j^{t-1}$	$e_i^{t+1} = e_i^{t-1}$	$e_i \downarrow, e_i^{t+1} > e_j^{t-1}$	$e_i \downarrow, e_i^{t+1} \leq e_j^{t-1}$	
$j \in I_i$	61.9% (13)	9.5% (2)	4.8% (1)	n.a.	9.5% (2)	
$j \notin I_i$	9.5% (2)	0.0% (0)	4.8% (1)	n.a.	0.0% (0)	
$t-1$	Class 3: $e_i \geq e_j$					
$t+1$	$e_i \uparrow, e_i^{t+1} \geq e_j^{t-1}$	$e_i \uparrow, e_i^{t+1} < e_j^{t-1}$	$e_i^{t+1} = e_i^{t-1}$	$e_i \downarrow, e_i^{t+1} > e_j^{t-1}$	$e_i \downarrow, e_i^{t+1} \leq e_j^{t-1}$	
$j \in I_i$	17.3% (9)	n.a.	59.6% (31)	0.0% (0)	1.9% (1)	
$j \notin I_i$	3.8% (2)	n.a.	15.4% (8)	1.9% (1)	0.0% (0)	

Table 4.2: Reactions to being excluded

Note: The number in the parentheses corresponds to the number of times this particular case has occurred.

same effort as player j 's (47.5% and 61.9%, for class 1 and class 2, respectively). In class 3, where excluded subjects played a similar or higher effort level than subject j in round $t - 1$, around 60% of the excluded subjects does not alter its strategy in round $t + 1$. Exclusion of subjects who played a lower effort level than subject j 's in round $t - 1$ thus induces them to increase their effort levels to at least as high as subject's j effort level in round $t - 1$. In contrast, it does not induce excluded subjects who played at the least the effort level of subject j to alter their effort level.

Until now we have not taken into account the fact that subjects who have not been excluded by any neighbor in round t might also change their effort levels. In order to make a stronger statement about whether it is the exclusion mechanism that induces subjects to increase their effort level, we have to compare our results to subjects who have not been excluded by any neighbor in round t . In class 1, there are five subjects who were not excluded by any neighbor. All subjects, except one, increased their effort level.²⁰ Interestingly, all subjects that increased their effort level were excluded in a round previous to round t . In class 2, we have seven subjects who have not been excluded by any neighbor in round t . Four of these subjects increased their effort level²¹. Three out of the four subjects increasing their effort level could not have been excluded before, due to the fact that round $t - 1$ was round 1. However, all these subjects in class 2 did observe exclusion of subjects who did not play the maximum effort level in round $t - 1$. The other subject increasing his effort level, could have been and actually was excluded in round previous to round t . All these subjects, in both class 1 and 2, thus observed the effects of exclusion, either by being excluded themselves in a round previous to t , or by observing exclusion of group members by their neighborhood. We can, therefore, conclude that exclusion indeed induces subjects to increase their effort levels.

4.5.4 Welfare

Failure of coordination can create large welfare losses. We have seen that the possibility of exclusion promotes coordination to higher effort levels. However, we do not know whether the exclusions take place at the expense of welfare. Exclusion might come at a cost and we do not know yet whether or not the gains from higher effort levels outweigh these costs. We therefore will now investigate the welfare levels.

²⁰This subject kept the same effort level

²¹Two subjects decreased their effort level, and one subject kept the same effort level.

We calculate a group's welfare level by the summation of payoffs of all group members. Additionally, we calculate two benchmark levels: firstly, the optimal welfare level where every group member plays maximum effort and interacts with all other group members, and secondly, a fictitious welfare level which had been obtained in the neighborhood treatment if all subjects would have interacted with all group members, given their effort level. Figure 4.4 depicts the development of the average welfare level over time for each treatment as well as the corresponding benchmarks. In both treatments average welfare levels increase over time. How-

Figure 4.4: Welfare Levels across Rounds

ever, the average welfare level of the neighborhood treatment significantly outperforms that of the baseline treatment (MWU on groups average welfare, $n=18$, $p=0.0129$, two-sided).

The difference between the fictitious benchmark and the actual welfare level of the neighborhood treatment provides us with a measure of the net costs of exclusion. As can be seen, it is small in the beginning and becomes negligible from round 10 onwards. Hence, exclusion does not come at a high cost to the welfare level. The possibility to exclude others induces subjects to increase their effort level towards the highest effort possible. At the same time, subjects seem to understand that from an efficiency point of view, it is most beneficial to interact with all other group members.

4.5.5 End game effect

As already briefly discussed in Section 4.5.1, we observe an end game effect in many groups. This end game effect happens in two out of three efficient groups in the baseline treatment. In one group it happened in the last round only, while in the other group, it started in round 25 already. In both groups, the effect is caused by *one* subject deviating from the highest effort.

In the neighborhood treatment an end game effect happened in six out of ten groups. In five out of the six groups, the effect is caused by *one* subject deviating from the highest effort, in the other group this was caused by *four* subjects. In four of the six groups, the end game effect occurred in the last round only, in two groups it started earlier (in rounds 28 and 29, respectively).

Why should one leave a “functioning” and efficient equilibrium? In the following we discuss three possible explanations and report the corresponding evidence in the data with respect to the neighborhood treatment.

A first possible reason is revenge. Subjects who played a high effort in the beginning and either by exclusion or by good example persuade others into the Pareto-efficient equilibrium earn a lower total payoff compared to their peers who started off with low effort. These efficiency minded subjects might use the last rounds to take revenge and to equalize total payoffs by playing a low effort.

Another reason only applies for the neighborhood treatment. Some subjects might lack the insight that high effort levels are beneficial for all. By exclusion they feel forced into a high effort equilibrium. Towards the end of the experiment, facing a diminishing threat of exclusion they fell back into their preferred behavior.

Neither pattern of behavior was frequent in the data. Only in two out of the nine cases, we find evidence that is consistent with the idea that the end game effect was driven by feelings of revenge. In the other seven cases, we cannot make such a statement as the subjects were both forced as well as forcing others to play higher effort levels. The third explanation is that for various reasons trust vanishes and some subjects start to doubt that others will continue to play the highest effort. As already mentioned in the introduction, these doubts may be of a higher order type.

Given that we did not ask subjects for their beliefs and our data is not clearly favoring one of the explanations we cannot draw any sharp conclusion. However, the threat of exclusion seems to play an important role, as in seven out of the nine cases, the end game effect only occurs in the last round where the threat of exclusion does not exist anymore.

4.6 Large groups

In this section, we investigate the robustness of the efficiency outcomes reported in the previous section. While there are several dimensions in which robustness can be checked, we focus on group size, because of the following two reasons. Firstly, group size has a strong impact on strategic uncertainty. Each additional group

member decreases the chance of efficient coordination as it increases the chance of facing a low effort level within the group. Secondly, the existing literature acknowledges group size as an important factor on efficient coordination (VHBB, Weber, (2006), and Van Huyck, Battalio, and Rankin, (2007). Small groups more easily coordinate on high efforts than large groups.

We conducted six additional sessions, where each session consisted of one large group of 24 subjects. In three sessions the baseline treatment was implemented, whereas in the other three sessions the neighborhood treatment was implemented. For convenience we will call them large baseline treatment and large neighborhood treatment. Besides examining whether our results are robust with respect to group size, we were also interested in whether the group gets fragmented into separate neighborhoods coordinating on different effort levels.

Figure 4.5 shows the distributions of effort levels and their development over time. The distributions are similar to the distribution found in the small group treatments. One difference to the small group treatments is that the effort levels in the first round differ between the large baseline and the large neighborhood treatment. Subjects in the large neighborhood treatment choose significantly higher efforts in round 1 than subjects in the large baseline treatment (MWU, $n=144$, $p=0.0238$, two-sided).

Figure 4.5: Distribution of Efforts in Groups across Rounds

Like in the small group treatments, we find opposite dynamics with respect to the efforts development. In the large baseline treatment, the absolute majority of subjects converges towards playing the lowest possible effort level, whereas in the large neighborhood treatment, subjects converge towards the highest effort level (MWU, $n=6$, $p=0.10$, two-sided).²²

²²Note, this is the strongest significance level one can get in a MWU-test with 6 observations.

Figure 4.6 shows the average effort level and the average minimum effort level in the large treatments. Despite the small number of independent observations, the differences are significant (MWU on groups average effort level, $n=6$, $p=0.10$, two-sided; MWU on average minimum effort level, $n=6$, $p=0.10$, two-sided).

Figure 4.6: Average and Minimum Efforts across Rounds

In each of the large neighborhood sessions, we observe an end game effect in the last round. In different sessions, it was triggered by one, two and four subjects, respectively. It is noteworthy that all downward movements of the average as well as minimum effort, except for the last round, are caused by *one* single group where *one* single individual played lower effort levels recurrently. In the other two groups all members played the highest effort level after ten rounds.

As we observe that all but one subject play the highest effort level, we expect to find almost full interaction over time. The proposed and the actual interactions are depicted in Figure 4.7.

Figure 4.7: Interactions across Rounds

In the very beginning, all groups form an almost complete network, but quickly the interaction frequency drops down to only a bit more than 0.5, before recovering

to almost full interaction by round 12. From then onwards, all cases of non-interaction involve the one single subject who repeatedly deviated from the highest possible effort.

Similarly to the small groups, we find that in the large neighborhood treatment, exclusion is triggered by playing the minimum effort within the other subject's neighborhood. In each case where a subject played an effort below the maximum, this person was excluded by at least one other person. In the most extreme case, a person who played a lower effort level got excluded completely. After being excluded subjects increased their effort level to the maximum. After this increase was observed by the other subjects, they were included again by all other subjects. It is interesting to note that for the one subject who repeatedly decreased the effort level, other subjects became more and more reluctant to interact with this person. As a result, on average, this person only received five interaction proposals per round, whereas the remaining subjects received 21 proposals per round on average.

4.7 Conclusions

With the real live examples of the minimum effort game we pointed out a major difference between situations where players are bound to their neighborhood and others where players may freely choose with whom to interact. In line with these examples, we extended the minimum effort game by endogenous neighborhood choice and conducted an experiment with two treatments: a baseline treatment, where the neighborhood was fixed and a neighborhood treatment, where subjects could endogenously determine their neighborhood. We have proven that, given our parameters, in both the baseline and the neighborhood minimum effort game, the unique stochastically stable equilibrium is the complete network with every player playing the lowest effort.

The results show that endogenous neighborhood choice solves the coordination problem and ensures efficient outcomes. The basic mechanism is quite simple. In standard minimum effort games, subjects do not have the means to force others into the payoff dominant equilibrium. Consequently, as soon as there exists subjects unwilling to exert the highest effort or doubting that others will exert high efforts, efficient coordination fails. In such a situation, the only way to ensure reasonable payoffs is to also provide low effort. This process is self-confirming and mires the outcome into the risk dominant equilibrium.

Endogenous neighborhood choice gives subjects the possibility to exclude those who display unwanted behavior. It turns out that exclusion is used by high ef-

fort players against low effort players. Moreover, exclusion works, i.e. low effort players quickly realize that they have to increase effort in order to be included again by other subjects. This behavior persuaded all subjects of the neighborhood treatments into the efficient equilibrium.²³

Our data show that the inefficiency results of VHBB and successors do not necessarily apply for the type of situations where individual subjects are able to choose with whom they would like to interact. In consequence, for such situations, regulatory means seem not be necessary. However, we do not want to stretch our results too far. Our neighborhood treatments give efficient coordination a good shot. Our subjects played the game for many rounds; they had full information about others' past strategies; and eventually the costs of exclusion were rather moderate. We consider our experiment to provide a benchmarks that show what is possible with endogenous networks. What remains unexplored is where the border between efficient and inefficient coordination with endogenous interactions runs. In our view there are several interesting avenues to proceed to check the robustness of the results. We have already shown that results are remarkably robust with respect to group size. Other dimensions like feedback information have to be tested still. For example, coordination on the payoff dominant equilibrium may have a harder stand if subjects only receive information about those subjects' actions whom they interacted with. A fragmentation of the group into different sub-groups is perceivable as interacting with "unknown" subjects involves risk. A further avenue is to vary the characteristics of interactions, e.g. add interaction costs or allow for interactions that only require one-sided interaction proposals. While interaction costs might lead to an increase of efficiency in the minimum effort game due to a forward induction argument, one-sided interactions completely offsets the exclusion power and may likely lead to inefficient outcomes as in the baseline minimum effort game experiments. Further interesting variations may include non-linear exclusion costs or a limited amount of links.

²³Only one subject in the large neighborhood treatment repeatedly fell back on playing low effort levels.

4.8 Appendix A: Theoretical benchmarks

Theoretical benchmarks

We show that for our parameter setting the fully interlinked network with every player playing the lowest effort is the unique stochastically stable equilibrium for the minimum effort game with neighborhood choice. Thereafter we show that this also holds for the restricted case of the minimum effort game without neighborhood choice.

The game

The analysis rests on a one-shot game where each player simultaneously chooses an effort level and the set of other players whom he or she wants to interact with. The basic elements of the game are:

- $N = \{1, 2, 3, \dots, n\}$ is a finite set of players.
- $E = \{1, 2, \dots, m\}$ is a set of effort levels.
- $s_i = (e_i, I_i)$ is the strategy of player i with $e_i \in E$ is the player's chosen effort level and $I_i \subseteq N \setminus \{i\}$ is the set of players with whom i wants to interact with.
- $s = (s_1, \dots, s_n) = ((e_j, I_j))_{j \in N}$ is a strategy profile. Later we will interpret it as a state in a Markovian chain. With $s^{\tilde{e}}$ we denote the strategy profile where every player wants to interact with every other player and all play the same effort $\tilde{e}$, i.e. $s^{\tilde{e}} = ((\tilde{e}, N \setminus \{j\}))_{j \in N}$.
- $s_{-i} = (s_1, \dots, s_{i-1}, s_{i+1}, \dots, s_n) = ((e_j, I_j))_{j \in N \setminus \{i\}}$ is the vector of strategies of all players except i .
- Given a strategy profile s , players i and j are linked if both want to interact with each other, i.e. $j \in I_i$ and $i \in I_j$. If an interaction wish of i with j is not reciprocated, i.e. $j \in I_i$ but $i \notin I_j$ then j is called a dangling link of i .
- Given a strategy profile s , the neighborhood of a player i is the set of all players i is linked to, i.e. $N_i(s) = \{j | j \in I_i \wedge i \in I_j\}$. With $|N_i(s)|$ we denote the cardinality of $N_i(s)$, in other words the size of the neighborhood.

- For a given s players i 's payoff is

$$\pi_i(s) = \frac{|N_i(s)|}{n-1} \left[a \left(\min_{j \in N_i(s) \cup \{i\}} \{e_j\} \right) - be_i + c \right]$$

with $a > b > 0$ and $c > 0$.

- Our specific experimental settings are $m = 7$, $a = 20$, $b = 10$ and $c = 60$ for $n = 8$ and $n = 24$, respectively.

The process

We follow a variant of the approach of Young (1993, 1998). Assume discrete and successive time rounds ($t = 1, 2, \dots$). Each round t every player may play a myopic best response to the other players' strategies of round $t - 1$ with some positive probability σ . This construction constitutes a Markov chain with the state space being the set of all strategy profiles and the transition probabilities depending on σ and the payoffs π . We will show that only states with the complete network and everybody playing the same effort are absorbing states and that no other recurrent class of states exist. Thereafter we take the parametrization of our experimental design and calculate the number of errors which are necessary to get from one absorbing state to the other. We use the method introduced by Young (1993, 1998) to show that the state with the complete network and the minimum effort played by all players is the only stochastically stable one.

Some useful observations

To start, we state some almost trivial propositions. We will use them later. The corresponding proofs are straightforward.

Proposition A. 1 *Given an outcome $s = ((e_i, I_i), s_{-i})$. Then the players i 's payoff is independent of dangling links, i.e. $\pi_i((e_i, I_i), s_{-i}) = \pi_i((e_i, I'_i), s_{-i})$ with $I'_i = \{j | j \in I_i \wedge i \in I_j\}$.*

Proof: Dangling links are not decisive for the neighborhood of a player, i.e. $N_i((e_i, I_i), s_{-i}) = N_i((e_i, I'_i), s_{-i})$. Hence, neither the removal nor the addition of dangling links change payoffs. As a corollary we get that any best response remains a best response if dangling links are removed or added. ■

Proposition A. 2 *For $N_i(s) \neq \emptyset$ the condition $e_i = \min_{j \in N_i(s)} \{e_j\}$ is necessary for $s_i = (e_i, I_i)$ being a best response to $s_{-i} = ((e_j, I_j))_{j \in N \setminus \{i\}}$.*

Proof: Assume $N_i(s) \neq \emptyset$ and that the condition does not hold, then i can improve his payoff by adjusting e_i to $\min_{j \in N_i(s)} e_j$ while holding I_i constant. ■

Absorbing states and recurrent classes

Proposition A. 3 *A state $s^{\tilde{e}}$ with $s_i^{\tilde{e}} = (\tilde{e}, N \setminus \{i\})$ for each player $i \in N$ and some $\tilde{e} \in E$ is an absorbing state.*

Proof: We have to show that $s_i = (\tilde{e}, N \setminus \{i\})$ is the only best response to $s_{-i} = (s_j)_{j \in N \setminus \{i\}}$ with $s_j = (\tilde{e}, N \setminus \{j\})$.

Removing players from I_i strictly decreases $|N_i(s)|$ and therefore strictly decreases π_i . The marginal payoff change with respect to e_i is $-a + b$ (< 0) if i decreases e_i and $-b$ (< 0) if i increases e_i . Any combination of changes in effort and interaction also leads to negative payoff consequences. It follows that s_i is the only best response to s_{-i} . This holds for each player. ■

Each of the absorbing states forms a recurrent class. In the following we will show that no other recurrent class exists.

Proposition A. 4 *No other recurrent class than those defined by the absorbing states in proposition A.3 exists.*

Proof: We introduce a hierarchy of sets of states into the state space. Let

S be the set of all possible states.

S' be the subset of S for which in any state s' players who are linked play the same effort level and no dangling link exists. This means that the network induced by s' consists of one or more components with all players within a component are playing the same effort level.

S'' be the subset of S' where in any state s'' the link relation is transitive, i.e. if i is linked to j and j to k then also i is linked to k . This means that the network induced by s'' consists of one or more fully interlinked components without dangling links and with all players within a component are playing the same effort level.

S^a be the set of the absorbing states.

It is obvious that $S \supset S' \supset S'' \supset S^a$. The last inclusion follows from Proposition A.3, an absorbing state is characterized by the complete network with every player playing the same effort.

The proof comprises three steps. We will show that for each state in the supersets S , S' , and S'' a finite path of best responses into the subsets S' , S'' , and S^a exists which the players follow with positive probability.

Step $s \in S \rightarrow s' \in S'$

Assume state $s \in S$. The following algorithm generates a finite sequence of best responses that occurs with a positive probability and leads to a state $s' \in S'$. Assume that players update their strategies one by one.

1. Sort the players into a two lists A and B .²⁴

List A contains players that do not have any dangling link in their strategy and whose effort level is at most the minimum effort level of their neighborhood.

List B contains the other players.

2. Take the first player i from list B and calculate all best responses to s_{-i} . There exists a best response s_i without dangling links and $e_i = \min_{j \in N_i(s)} \{e_j\}$ (see propositions A.1 and A.2). Update player i 's strategy to such a best response and put him at the end of list A . The update of s_i may cause some players in A to violate the A -conditions. Put them at the end of list B .
3. If there are players left in B then continue with step 2.

The generated sequence is finite because for each application of step 2 there is exactly one player moving from B to A . A move of a player i from A to B can only happen if a neighbor j moves from B to A and breaks up a link or decreases his effort level such that $e_j < e_i$. In the first case the link between i and j will be irreversibly deleted.²⁵ In the second case i updates by keeping the link and lowering e_i or by breaking the link. Since E is finite, lowering e_i can only happen a finite number of times before the link has to be broken. Because the breaking of a link is irreversible and there is only a finite number of links to be broken, there can only be a finite number of moves from A to B .

²⁴We chose to have lists rather than sets because list B must enable an order for processing the elements (first in first out principle).

²⁵Note that only players moving from B to A may change their strategy. Player j who is now in A can only reestablish the link to i , after he has been moved back to B . Since he will be put at the end of the list, i will have deleted the dangling link before j 's next turn.

Step $s' \in S' \rightarrow s'' \in S''$

Assume state $s' \in S'$, i.e. N is subdivided into several disjoint components $C_1, C_2, \dots, C_k$. Each component is (not necessarily fully) linked and is free of dangling links. Each player within a component is playing the same effort level. Consider a component C_l in which effort level $\tilde{e}$ is played. Consider further a player $i \in C_l$ who plays strategy $s_i = (\tilde{e}, I_i)$ with $I_i \subseteq C_l$. Then strategy $s_i = (\tilde{e}, C_l \setminus \{i\})$ is a best response to s_{-i} because adding dangling links do not change payoffs (see Proposition A.1). There is a positive probability that each player is playing this best response and that this happens in each component. This means that we reach a state $s'' \in S''$ where components are fully connected.

Step $s'' \in S'' \rightarrow s^a \in S^a$

Assume state $s'' \in S''$. Assume two disjoint components $\underline{C}, \overline{C} \subset N$ and that each components is fully connected. Each player in $\underline{C}$ and $\overline{C}$ plays effort $\underline{e}$ and $\bar{e}$, respectively. Without loss of generality assume that $\bar{e} \geq \underline{e}$.

By the condition

$$\frac{|\underline{C}| + |\overline{C}| - 1}{n - 1} (a\underline{e} - b\underline{e} + c) > \frac{|\overline{C}| - 1}{n - 1} (a\bar{e} - b\bar{e} + c) \quad (4.3)$$

we distinguish two cases:

If condition (4.3) holds, then a player $i \in \overline{C}$ prefers to play $\underline{e}$ and to link up to all players in both components rather than to stay with component $\overline{C}$. Because of Proposition A.1 it happens with positive probability that all players in $\underline{C}$ will create a dangling link to all players in $\overline{C}$. Once this happens it becomes a best response for each player from $\overline{C}$ to connect to all players from $\underline{C}$ and switch to effort level $\underline{e}$.

If the converse of condition (4.3) holds, then

$$\frac{|\underline{C}| + |\overline{C}| - 1}{n - 1} (a\underline{e} - b\underline{e} + c) < \frac{|\overline{C}|}{n - 1} (a\bar{e} - b\bar{e} + c) \quad (4.4)$$

follows. This means that player $i \in \underline{C}$ prefers to join $\overline{C}$, to switch the effort level to $\bar{e}$ and to break up all links to his neighbors from $\underline{C}$, rather than being connected to both components and to play an effort level of $\underline{e}$. Because of Proposition A.1 it will happen with positive probability that all players in $\overline{C}$ will offer to establish a link with all players in $\underline{C}$. Once this happens it becomes a best response for all players from $\underline{C}$ to connect to all players from $\overline{C}$, switch the effort level to $\bar{e}$ and break the links with their old neighborhood. The resulting component is not completely

connected but connects completely with positive probability and within finitely many steps (for the proof see step $s' \in S' \rightarrow s'' \in S''$).

The previous paragraphs show that regardless of the result of condition 4.3 there is a positive probability that two components merge to one fully interlinked component $\underline{C} \cup \overline{C}$ where each player plays the same effort level (either $\underline{e}$ or $\bar{e}$). A repeated application of this part of the proof shows that with finitely many steps and positive probability we reach a single fully interlinked component with all players playing the same effort level; i.e. we reach a state $s^a \in S^a$. ■

Stochastically stable equilibria

So far we showed that the best reply dynamic almost surely converges to one of the absorbing states, making them the only candidates for stochastically stable equilibria. We continue by determining the number of mistakes that is necessary to reach from one absorbing state to a basin of attraction of another absorbing state. First, note that mistakes in the form of breaking links only, cannot lead to a different absorbing state unless players are excluded completely from their neighborhood. This requires at least $n - 1$ mistakes. Fewer mistakes are necessary if players change their effort level as well. Note further that a number of uncoordinated deviations does never create a higher temptation for other players to change their strategies than the same number of coordinated deviations to another effort level. Therefore it is sufficient to look at the cases where with a subgroup's joint deviation to another effort level we can reach the basin of attraction of another absorbing state.

Consider the system to be in an absorbing state s^a with N fully interconnected and $e_i = \bar{e}$ for all players i . Assume that $d_\downarrow$ players deviate to $\underline{e} < \bar{e}$. The following condition must hold to make other players switching to $\underline{e}$ instead of breaking the links to the deviators:

$$a\underline{e} - b\underline{e} + c \geq \frac{n - 1 - d_\downarrow}{n - 1} (a\bar{e} - b\bar{e} + c).$$

This resolves to

$$d_\downarrow \geq \frac{(n - 1)(\bar{e} - \underline{e})}{\bar{e} + \frac{c}{a - b}}.$$

Consider $d_\uparrow$ players who deviate to $\bar{e} > \underline{e}$. The following condition must hold to make players switching to $\bar{e}$ and cutting all the links to the players of the lower effort level, instead of not changing the strategy:

$$\frac{d_\uparrow}{n - 1} (a\bar{e} - b\bar{e} + c) \geq a\bar{e} - b\bar{e} + c.$$

This resolves to

$$d_{\uparrow} \geq \frac{(n-1) \left(\bar{e} + \frac{c}{a-b} \right)}{\tilde{e} + \frac{c}{a-b}}.$$

In the remainder we focus on our parameter settings of the experiment. In short this means: $a = 20, b = 10, c = 60, E = \{1, 2, \dots, 7\}$, and $N = \{1, 2, \dots, 8\}$ or $N = \{1, 2, \dots, 24\}$, respectively.²⁶ The following tables show the resistances between the absorbing states, i.e. the number of deviations needed to move from an absorbing state (row entry) to a basin of attraction of another absorbing state (column entry).

For the case of 8 players we get:

$r(s^i, s^j)$	s^1	s^2	s^3	s^4	s^5	s^6	s^7
s^1	0	7	6	5	5	5	4
s^2	1	0	7	6	6	5	5
s^3	2	1	0	7	6	6	5
s^4	3	2	1	0	7	6	6
s^5	3	2	2	1	0	7	6
s^6	3	3	2	2	1	0	7
s^7	4	3	3	2	2	1	0

For the case of 24 players we get:

$r(s^i, s^j)$	s^1	s^2	s^3	s^4	s^5	s^6	s^7
s^1	0	21	18	17	15	14	13
s^2	3	0	21	19	17	16	15
s^3	6	3	0	21	19	18	16
s^4	7	5	3	0	21	20	18
s^5	9	7	5	3	0	22	20
s^6	10	8	6	4	2	0	22
s^7	11	9	8	6	4	2	0

Proposition A. 5 *For both, the 8-player case and the 24-player case s^1 is the only stochastically stable equilibrium of the minimum effort game with endogenous neighborhood choice.*

²⁶There are more general results achievable. For example all absorbing states may be stochastically stable for some appropriate parameter settings. These results are however not important for our central goal, the calculation of the theoretical benchmark for our experimental settings.

Proof: We have to show that s^1 is the state with the minimum stochastic potential. This means that among all rooted trees, those with the minimum total resistance (sum of all resistances among the edges) have the root s^1 .

Consider a rooted tree T^m with root $s^m \neq s^1$ and total resistance $r(T^m)$. Then we can construct a new rooted tree T^{m-1} with root s^{m-1} by connecting s^m to s^{m-1} and removing the edge from s^{m-1} to state s^k on the path to s^m . The new tree has total resistance

$$r(T^{m-1}) = r(T^m) + r(s^m, s^{m-1}) - r(s^{m-1}, s^k) \leq r(T^m).$$

The last inequality holds because $r(s^m, s^{m-1}) \leq r(s^{m-1}, s^k)$ as can be verified from the tables.

We can iterate this process till we construct T^1 with root s^1 and total resistance

$$r(T^1) = r(T^2) + r(s^2, s^1) - r(s^1, s^k) < r(T^2).$$

The last inequality holds because $r(s^2, s^1) < r(s^1, s^k)$ as can be verified from the tables.

Hence, for any rooted tree T^m we find a chain of rooted trees such that $r(T^1) < r(T^2) \leq \dots \leq r(T^m)$. Therefore the root of the tree with the minimum total resistance must be s^1 . ■

The case without neighborhood choice

For the case without neighborhood choice I_i is restricted to $I_i = N \setminus \{i\}$. A strategy is therefore $s_i = e_i$. Furthermore $N_i(s) = N \setminus \{i\}$ and hence $|N_i(s)| = n - 1$. This reduces the payoff function to

$$\pi_i(s) = a \min_{j \in N} \{e_j\} - be_i + c$$

Proposition A. 6 *A state s with $s_i = \tilde{e}$ for each player $i \in N$ and some $\tilde{e} \in E$ is an absorbing state in the minimum effort game without neighborhood choice and no other recurrent class exists.*

Proof: This follows immediately from the restriction $I_i = N \setminus \{i\}$ and Proposition A.2. ■

The resistance table for the case of 8 players is:

$r(s^i, s^j)$	s^1	s^2	s^3	s^4	s^5	s^6	s^7
s^1	0	7	7	7	7	7	7
s^2	1	0	7	7	7	7	7
s^3	1	1	0	7	7	7	7
s^4	1	1	1	0	7	7	7
s^5	1	1	1	1	0	7	7
s^6	1	1	1	1	1	0	7
s^7	1	1	1	1	1	1	0

For the case of 24 players we get:

$r(s^i, s^j)$	s^1	s^2	s^3	s^4	s^5	s^6	s^7
s^1	0	23	23	23	23	23	23
s^2	1	0	23	23	23	23	23
s^3	1	1	0	23	23	23	23
s^4	1	1	1	0	23	23	23
s^5	1	1	1	1	0	23	23
s^6	1	1	1	1	1	0	23
s^7	1	1	1	1	1	1	0

Proposition A. 7 *For both, the 8-player case and the 24-player case s^1 is the only stochastically stable equilibrium of the minimum effort game without endogenous neighborhood choice.*

The proof is identical to the proof of Proposition A.5.

4.9 Appendix B

Instructions treatment B

Introduction

Welcome to this decision-making experiment. In this experiment you can earn money. How much you earn depends on your decisions and the decisions of other participants. During the experiment your earnings will be counted in points. At the end of the experiment you get your earned points paid out privately and confidentially in cash, according to the exchange rate:

$$\mathbf{2 \text{ points} = 1 \text{ eurocent.}}$$

It is important that you have a good understanding of the rules in the experiment. Therefore, please read these instructions carefully. In order to check that the instructions are clear to you, you will be asked a few questions at the end of the instructions. The experiment will start only after everybody has correctly answered the questions. At the end of the experiment you will be asked to fill in a short questionnaire. Thereafter you will receive your earnings.

During the whole experiment, you are not allowed to communicate with other participants in any other way than specified in the instructions.

If you have a question, please raise your hand. We will then come to you and answer your question in private.

Explanation Experiment

During the experiment every participant is in a **group of eight**, that is in a group with seven other participants. The group you are in will not change during the experiment. You will not receive any information about the identity of the persons in your group, neither during the experiment, nor after the experiment. Other participants will also not receive any information about your identity.

Each person in your group is indicated by a letter. You will receive the name “**me**”. The other seven persons in your group will be indicated by the letters **A**, **B**, **C**, **D**, **E**, **F** and **G**. The same letter always refers to the same person.

The experiment consists of 30 rounds. In each round you can earn points. Your total earnings in this experiment is the sum of your earnings in each of the 30 rounds.

In each round, you - and each other person in your group - will have to make one decision called “**Which number do you choose?**”. Your decision and the decisions of the other participants in your group will influence your earnings (as well as the earnings of the other group members). These decisions are explained in detail below.

Note: During the whole experiment, during all 30 rounds the other participants in your group will stay the same persons

Decision (in one single round)

Decision: “Which number do you choose?”

In each round, each person in your group has to choose one number from 1 to 7; i.e. either 1, 2, 3, 4, 5, 6, or 7. Your earned points in each round depend on

1. your **own choice of number**
2. the **smallest number** chosen the other persons in the group *and* yourself

Note: Here is the payoff table:

		Smallest number chosen by your group including yourself						
		7	6	5	4	3	2	1
Your chosen number	7	130	110	90	70	50	30	10
	6	-	120	100	80	60	40	20
	5	-	-	110	90	70	50	30
	4	-	-	-	100	80	60	40
	3	-	-	-	-	90	70	50
	2	-	-	-	-	-	80	60
	1	-	-	-	-	-	-	70

Since one’s choice can be a number from 1 to 7, the smallest number can range from 1 to 7. Your payoff is determined by the cell in the row of “your chosen

number” and the column of the “smallest number chosen by your neighbors and yourself”. An example is given below.

In the table there are cells with “-”. This indicates that such a combination of “your chosen number” and the “smallest number chosen by your neighbors and yourself” is not possible. For example, if “your chosen number” is 4, the smallest number chosen by your neighbors and yourself cannot be 7, 6, or 5.

Examples:

Suppose you chose 3 and the smallest number chosen by the other persons in your group and yourself was 3, you earn 90 points.

Suppose you chose 5 and the smallest number chosen by the other persons in your group and yourself was 3, you earn 70 points.

Suppose you chose 5 and the smallest number chosen by the other persons in your group and yourself was 4, you earn 90 points.

Suppose you chose 7 and the smallest number chosen by the other persons in your group and yourself was 4, you earn 70 points.

Information about Computer Screen (in one single round)

You now get information about the computer screen that you will see during the experiment. You received a print-out of the computer screen (**Example screen 1**) from us. Take this print-out in front of you. The screen consists of two windows: **History** and **Decision**.

- **History:** This window holds information about past round(s). At the beginning of a new round you will automatically receive information in this window about decisions made in the previous round, (In the example, this is round 2; see upper part of the screen). In the window there are 8 circles, named **me, A, B, C, D, E, F** and **G**. **Me** always refers to you. The letters refer to the other seven persons in your group.
 - Next to the letters you see numbers between 1 and 7. These numbers indicate the chosen numbers of the persons in your group. The number

next to letter A shows the chosen number of A. The number next to letter B shows the chosen number of B and so forth. (For example, in screen 1 persons **D** and **G** chose number 6, while person **F** chose number 5.)

- At the bottom of this window you find two buttons called **Previous Round** and **Next Round**. You can use these buttons to look at the decisions in all previous rounds. The button **Most Recent Round** brings you back to the last round played.
- Your **earnings** (in points) in the corresponding round can be found just above the graph next to **Round Earnings**.
- **Decision:** In this window you see which round you are in and here you have to make your decisions.
 1. **Which number do you choose?** In the small window next to **My Number** you type in the number you want to choose.

When you are satisfied with all your decisions (that is, with **both** the proposals (not) to interact and your chosen number), you have to confirm these decisions by clicking on the button **“Ok”**.

Note: After each round you will receive information about all the decisions made (that is, all interaction proposals made and the number choices) by all persons in your group. All other persons in your group will also receive information about all your decisions. This is the end of the instructions. You will now have to answer a few questions to make sure that you understood the instructions properly. If you have any questions please raise your hand. After you have answered all questions please raise your hand. We will then come to you to check your answers. The experiment will begin only after everybody has correctly answered all questions.

If you are ready please remain seated quietly.

Figure 4.8: Example Screen 1

Instructions treatment E

Introduction

Welcome to this decision-making experiment. In this experiment you can earn money. How much you earn depends on your decisions and the decisions of other participants. During the experiment your earnings will be counted in points. At the end of the experiment you get your earned points paid out privately and confidentially in cash, according to the exchange rate:

$$\mathbf{2 \text{ points} = 1 \text{ eurocent.}}$$

It is important that you have a good understanding of the rules in the experiment. Therefore, please read these instructions carefully. In order to check that the instructions are clear to you, you will be asked a few questions at the end of the instructions. The experiment will start only after everybody has correctly answered the questions. At the end of the experiment you will be asked to fill in a short questionnaire. Thereafter you will receive your earnings.

During the whole experiment, you are not allowed to communicate with other participants in any other way than specified in the instructions.

If you have a question, please raise your hand. We will then come to you and answer your question in private.

Explanation Experiment

During the experiment every participant is in a **group of eight**, that is in a group with seven other participants. The group you are in will not change during the experiment. You will not receive any information about the identity of the persons in your group, neither during the experiment, nor after the experiment. Other participants will also not receive any information about your identity.

Each person in your group is indicated by a letter. You will receive the name “**me**”. The other seven persons in your group will be indicated by the letters **A**, **B**, **C**, **D**, **E**, **F** and **G**. The same letter always refers to the same person.

The experiment consists of 30 rounds. In each round you can earn points. Your total earnings in this experiment is the sum of your earnings in each of the 30 rounds.

In each round, you - and each other person in your group - will have to make two decisions which will influence your earnings. You have to make a **decision** called “**With whom would you like to interact?**” and a **decision** called “**Which number do you choose?**” Your decisions and the decisions of the other participants in your group will influence your earnings (as well as the earnings of the other group members). These decisions are explained in detail below.

Note: During the whole experiment, during all 30 rounds the other participants in your group will stay the same persons

Decisions (in one single round)

Decision: “With whom would you like to interact?”

You have to decide with whom you would like to interact. You can **propose** an interaction to any other person in your group and you can make as many proposals as you want. (You can also decide not to make any proposal.) Your interaction proposals - together with the proposals of the other persons in your group - determine with whom you actually interact (in the respective round) as explained below:

- You will interact with a person to whom you proposed to interact only if the other person also proposed to interact with you. That is, **mutual consent** is needed for an interaction to actually take place.
- You will not interact with another person if either only you or only the other person proposed to interact.
- You will not interact with another person if neither of you proposed to interact with each other.

For convenience we will call those persons in your group with whom you **interact: your neighbors**. Your neighbors are therefore those persons to whom you proposed to interact and who at the same time also proposed to interact with you.

Decision: “Which number do you choose?”

In each round, each person in your group has to choose one number from 1 to 7; i.e. either 1, 2, 3, 4, 5, 6, or 7. Your earned points in each round depend on

1. your **own choice of number**
2. the **smallest number** chosen by your neighbors ***and*** yourself
3. the number of neighbors you have

Note: You can not choose different numbers for different neighbors. You can, however, choose different numbers as well as different persons to interact with in the different rounds.

Here is the payoff table:

		Smallest number chosen by your group including yourself						
		7	6	5	4	3	2	1
Your chosen number	7	130	110	90	70	50	30	10
	6	-	120	100	80	60	40	20
	5	-	-	110	90	70	50	30
	4	-	-	-	100	80	60	40
	3	-	-	-	-	90	70	50
	2	-	-	-	-	-	80	60
	1	-	-	-	-	-	-	70

Since one's choice can be a number from 1 to 7, the smallest number can range from 1 to 7. Your payoff is determined by the cell in the row of "your chosen number" and the column of the "smallest number chosen by your neighbors and yourself". An example is given below.

In the table there are cells with "-". This indicates that such a combination of "your chosen number" and the "smallest number chosen by your neighbors and yourself" is not possible. For example, if "your chosen number" is 4, the smallest number chosen by your neighbors and yourself cannot be 7, 6, or 5.

Your earned points in a round will be the payoff as given in the table multiplied by

$$\frac{\text{number of neighbors}}{7}.$$

For each person in your group with whom you do not interact (i.e. all persons who are not your neighbors) you earn 0 points. For example, if you have no neighbors in a round, then you earn 0 points in that round.

Examples:

Suppose you have four neighbors. You chose 3 and the smallest number chosen by your neighbors and yourself was 3, you earn $4/7 * 90 = 51 \frac{3}{7}$ points.

Suppose you have three neighbors. You chose 5 and the smallest number chosen by your neighbors and yourself was 3, you earn $3/7 * 70 = 30$ points.

Suppose you have four neighbors. You chose 5 and the smallest number chosen by your neighbors and yourself was 4, you earn $4/7 * 90 = 51 \frac{3}{7}$ points.

Suppose you have three neighbors. You chose 7 and the smallest number chosen by your neighbors and yourself was 4, you earn $3/7 * 70 = 30$ points.

Information about Computer Screen (in one single round)

You now get information about the computer screen that you will see during the experiment. You received a print-out of the computer screen (**Example screen 1**) from us. Take this print-out in front of you. The screen consists of two windows: **History** and **Decision**.

- **History:** This window holds information about past round(s). At the beginning of a new round you will automatically receive information in this window about decisions made in the previous round, (In the example, this is round 2; see upper part of the screen). In the window there are 8 circles, named **me**, **A**, **B**, **C**, **D**, **E**, **F** and **G**. **Me** always refers to you. The letters refer to the other seven persons in your group.
 - A **thick complete** line between two persons (letters or 'me') indicates that they both proposed to interact with each other, that is they were neighbors and, hence, did actually interact with each other. (See, e.g., the line between **me** and **D** on the example screen).
 - A **thin incomplete** line between two persons indicates that only one of them proposed to interact. That is, they were not neighbors and, hence, did not interact with each other. Such a line starts on the side of the person that proposed to interact, and stops just before the circle of the person that did not want to interact. (See, e.g., the line between

me and **F** on the example screen: **me** proposed to interact with **F**, but **F** did not propose to interact with **me**.)

- No line between two persons indicates that neither of them proposed to interact. That is, they were not neighbors and hence, did not interact with each other.
 - Next to the letters you see numbers between 1 and 7. These numbers indicate the chosen numbers of the persons in your group. The number next to letter A shows the chosen number of A. The number next to letter B shows the chosen number of B and so forth. (For example in screen 1, persons **A** and **G** have chosen number 5, while the persons **me** and **E** have chosen number 7.)
 - At the bottom of this window you find two buttons called **Previous Round** and **Next Round**. You can use these buttons to look at the decisions in all previous rounds. The button **Most Recent Round** brings you back to the last round played.
 - Your **earnings** (in points) in the corresponding round can be found just above the graph next to **Round Earnings**.
- **Decision:** In this window you see which round you are in and here you have to make your decisions.
 1. **With whom would you like to interact?** Below this question you see the seven letters which refer to the seven other participants in your group. You can propose to interact with another person in your group by clicking the button “yes” (the first button), that is the first button to the right of that person’s letter. If you do not want to interact with a person or if you want to remove a proposal to interact, you activate the button “no”, that is the second button to the right of that person’s letter. **Note:** At the beginning of each new round the buttons (i.e. proposals) you have chosen in the previous round will be activated. In each new round you can change your choices, i.e., proposals (not) to interact in the way described above.
 2. **Which number do you choose?** In the small window next to **My Number** you type in the number you want to choose.

When you are satisfied with all your decisions (that is, with **both** the proposals (not) to interact and your chosen number), you have to confirm these decisions by clicking on the button “**Ok**”.

Note: After each round you will receive information about all the decisions made (that is, all interaction proposals made and the number choices) by all persons in your group. All other persons in your group will also receive information about all your decisions. This is the end of the instructions. You will now have to answer a few questions to make sure that you understood the instructions properly. If you have any questions please raise your hand. After you have answered all questions please raise your hand. We will then come to you to check your answers. The experiment will begin only after everybody has correctly answered all questions. If you are ready please remain seated quietly.

History

Round: 2
Round Earnings: 30.00

me: 7

Decision

Round 4

With whom would you like to interact?

with A: Yes ☐ No ☐

with B: Yes ☐ No ☐

with C: Yes ☐ No ☐

with D: Yes ☐ No ☐

with E: Yes ☐ No ☐

with F: Yes ☐ No ☐

with G: Yes ☐ No ☐

Which number do you choose?

My Number:

Figure 4.9: Example screen 1

Large Networks

The instructions are similar to the instructions in the small networks. In the window there are 24 circles, named **me**, **N1**, **N2**,..., **N23**. The label **Me** always refers to you. The letters refer to the other twenty-three persons.

Figure 4.10: Example screen 1 Treatment B

Figure 4.11: Example screen 1 Treatment E

NEDERLANDSE SAMENVATTING

(SUMMARY IN DUTCH)

Risico's zijn inherent aan het leven. Al sinds de eerste mensachtigen een paar miljoen jaar geleden in Oost-Afrika rondzwierven, is ons lot bepaald door natuurlijke gebeurtenissen. Natuurrampen zoals aardbevingen, overstromingen en stormen, maar ook plagen hebben altijd ons bestaan bedreigd. Tegelijkertijd stonden onze levens op het spel door het tegenkomen van roofdieren gedurende onze zoektocht naar voedsel en onderdak. Angsten en risico's die zulke ontberingen oproepen, bepaalden ons gedrag jegens risico in het algemeen. Het vermijden van risico's speelde sinds de vroege mensheid een cruciale rol in het menselijk gedrag.

In de loop der tijd, ontwikkelden we een groot inzicht in de gevolgen van de risico's en in de mogelijkheden zulke risico's te vermijden door middel van bijvoorbeeld religieuze gedachten en handelingen, legendes en mythes, en schilderijen en tekeningen. Eén van de eerste voorbeelden is de paleolitische tekening die bekend staat als “de schacht van de dode of gewonde man” in de grotten van Lascaux, Frankrijk. Deze tekening toont een confrontatie tussen een prehistorische jager en een bizon die klaarblijkelijk de jager dood spietst. Zulke paleolitische tekeningen suggereren dat mensen zich inderdaad bewust waren van de risico's die hen omringden. De tekeningen worden tegenwoordig beschouwd als een poging een soort magische controle te krijgen over de verwoestende krachten van de natuur.

Na verloop van tijd groeiden samenlevingen door domesticatie en technologische vooruitgang van kleine samenlevingen van jagers-verzamelaars uit tot grote en complexe samenlevingen. Aangezien samenlevingen van jagers-verzamelaars gebaseerd waren op sterke familiebanden, was er in de samenleving geen drang naar andere instituties, en werd iedereen in de samenleving als gelijkwaardig beschouwd.

Hoe uitgebreider de samenlevingen werden, hoe ingewikkelder en hoe meer onderling verbonden de sociale interacties tussen de individuen werden. Er ontstond een complexe sociale hiërarchie en een drang naar institutioneel bestuur. Samenlevingen konden niet langer als geïsoleerd en homogeen worden gezien, maar waren eerder gebaseerd op een aantal subculturen en tegenculturen, waarvan individuen tegelijkertijd deel uit konden maken.

Daar de samenlevingen moderniseerden en meer vervlochten raakten, ontstond er een nieuw soort risico, dat het product was van menselijk handelen en menselijk contact. Aangezien mensen meer en meer met elkaar verbonden raakten, werden ze blootgesteld aan risico's als vervuiling, criminaliteit en terroristische daden. Samenlevingen pasten zich aan aan dit groot aantal risico's, door het veranderen van de sociale organisatie van de samenleving ten einde risico's te beheersen. We leven nu in wat sociologen de "risicosamenleving" of "risicomaatschappij" noemen. Volgens de wereldbekende socioloog Giddens (1999) is de risicosamenleving "een samenleving die meer en meer bezig is met de toekomst (en ook met veiligheid), waardoor het begrip van risico wordt bepaald." Een logische gevolgtrekking zou zijn dat de samenleving en de vervlechting binnen deze samenleving ook de houding van individuen jegens risico bepaalt.

In dit proefschrift wordt het effect van de sociale omgeving en haar structuur op de risicohouding van individuen onderzocht. In het eerste gedeelte van het proefschrift is de mate van het risico niet afhankelijk van de sociale omgeving, terwijl in het tweede gedeelte van het proefschrift de mate van het risico wel afhankelijk is van de sociale omgeving.

Risicohoudingen in een niet strategische sociale omgeving

Er is een overvloed aan bewijs dat individuen niet alleen hun eigen inkomsten belangrijk vinden maar ook de inkomsten van de mensen om hun heen. Dit bewijs suggereert dat de risicohoudingen van mensen gevormd worden door de inkomsten die anderen in hun omgeving hebben, en de risico's die deze anderen lopen. Tijdens het beslissen om al dan niet lid te worden van de Postcode loterij, spookt het scenario dat je burens wel lid zijn en dat jouw postcode per toeval getrokken wordt als winnende postcode door ieder's hoofd. In deze situatie kan de risicohouding zeer zeker beïnvloed worden door de sociale omgeving waarin iemand zich bevindt.

Tegelijkertijd, bevinden mensen zich soms in de positie waarin ze voor anderen het type en de grootte van risico moeten bepalen. Denk bijvoorbeeld aan het toewijzen van een donorlever. Op dit moment, zijn de criteria voor het krijgen van een donorlever, de bloedgroep, het gewicht van de donor, de urgentie en de wachttijd.

Al deze criteria zijn objectief. Maar zou de toewijzing van een donorlever niet ook afhankelijk moeten zijn van de levensstijl en de leeftijd van de persoon die de lever zal krijgen? Verdient een 60-jarige vrouw die er altijd een gezonde levensstijl op na heeft gehouden de lever meer dan een 35-jarige man die al 15 jaar alcoholist is? Of moeten ze een gelijke kans hebben op het krijgen van de lever?

In hoofdstuk 2 wordt de rol van sociale omgevingen op individueel keuze-gedrag onderzocht, vanuit zowel een theoretisch als experimenteel perspectief. Drie verschillende uitbreidingen op de sociale nutsfunctie van Fehr en Schmidt worden geïntroduceerd om risico een rol te kunnen laten spelen. Een nieuwe methodiek wordt geïntroduceerd waarin in dezelfde fase van het experiment de relatie tussen sociale interesse en risicohoudingen wordt getest, zonder dat dit leidt tot gedrag dat wordt aangespoord door wederkerigheid. De resultaten tonen aan dat sociale interesse een effect heeft op risicohoudingen. Eveneens wordt er getest of mensen een bepaalde voorkeur hebben voor bepaalde procedures met betrekking tot het toewijzen van uitkomsten. De focus ligt hier op moreel keuzegedrag. Onze bevindingen tonen aan dat mensen niet verantwoordelijk willen worden gehouden voor slechte uitkomsten voor anderen, en dat ze een voorkeur hebben voor eerlijke procedures waarin het lot de verdeling bepaalt. Interessant genoeg hebben mensen niet noodzakelijkerwijs een voorkeur voor verdelingen die leiden tot een gelijke distributie.

Risicohoudingen in een strategische sociale omgeving

Tegelijkertijd komen individuen in situaties terecht waarin strategische onzekerheid aanwezig is. Iemand's risicohouding wordt bepaald door zijn houding jegens strategische onzekerheid. Een mogelijke manier om zulke risico's te verminderen is door met anderen in de omgeving beslissingen en handelingen af te stemmen.

Een situatie die het afgelopen jaar veel aandacht heeft gekregen in de media is de verspreiding van influenza type H1N1, beter bekend als de mexicaanse griep. Toen eenmaal bekend werd dat er sprake zou zijn van een pandemie, troffen mensen uit alle lagen van de samenleving maatregelen om de gevolgen van zo'n uitbraak te minimaliseren. Overheden moesten beslissen welk advies te geven aan burgers die in aanraking zouden komen met de mexicaanse griep. Bovendien moesten ze beslissen over het aantal te bestellen vaccins, en of ze al dan niet vliegtuigpassagiers met griepklachten, of vliegtuigpassagiers uit landen waar niet gevaccineerd werd de toegang tot het land zouden moeten weigeren. Tegelijkertijd discussieerden mensen over het al dan niet in acht nemen van het advies om gevaccineerd te worden, en het advies thuis te blijven wanneer men de mexicaanse griep heeft.

Zou u een vriendschap met iemand die de mexicaanse griep heeft op een laag pitje zetten om het risico zelf besmet te worden en het risico dat u zelf anderen zou besmetten te verminderen? En wat nu als deze persoon nog niet besmet is maar niet gevaccineerd wil worden?

In het tweede gedeelte van het proefschrift, onderzoeken we door middel van experimenten het effect van het kunnen kiezen van de sociale omgeving op de houding jegens strategische onzekerheid.

In hoofdstuk 3 doen mensen een voorstel aan mensen met wie ze graag een standaard 2×2 coördinatiespel willen spelen, en besluiten tegelijkertijd welke actie ze zouden willen spelen in dit coördinatiespel. In één geval, zal het doen van een voorstel geld kosten. Of het coördinatiespel daadwerkelijk gespeeld wordt hangt af van de vereisten die gesteld worden aan de voorstellen. Mensen zullen alleen het coördinatiespel spelen met diegenen waarmee aan deze vereisten voldaan wordt. Deze mensen zullen burens genoemd worden. Onze resultaten tonen aan dat zolang het aantal en de samenstelling van de burens niet worden opgedrongen, het meest efficiënte evenwicht bereikt wordt. Bovendien, zolang er geen kosten aan de voorstellen verbonden zijn, zullen alle mensen met elkaar het coördinatiespel spelen.

Maar bij veel coördinatieproblemen, zoals het voorbeeld van de mexicaanse griep, bepaalt de zwakste speler de uitkomst voor alle betrokkenen. Daarom is er in zulke situaties sprake van maximale strategische onzekerheid. Het “minimum effort” spel is een speciale versie van het coördinatiespel, met exact deze eigenschap.

In hoofdstuk 4 introduceren we een aangepaste versie van het minimum effort spel. In deze aangepaste versie, kunnen mensen beslissen met wie ze graag het minimum effort spel zouden willen spelen, in plaats van opgelegd te krijgen met wie ze het spel moeten spelen. Het spel wordt alleen gespeeld als beide betrokkenen instemmen met het spelen van het spel. Dit geeft ruimte om mensen wiens gedrag in het minimum effort spel niet getolereerd wordt, buiten te sluiten. Ons belangrijkste resultaat is dat de mogelijkheid anderen buiten te sluiten, mensen motiveert de hoogste inspanning te leveren. Het is interessant te zien dat dit resultaat ook bij grote groepen wordt gevonden.

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SHORT CURRICULUM VITAE

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