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Behavioral effects in individual decisions of network formation: Complexity reduces payoff orientation and social preferences

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Abstract

Network formation constitutes an important part of many social and economic processes, but relatively little is known about how individuals make their linking decisions in networks. This article provides an experimental investigation of behavioral effects in individual decisions of network formation. Our findings demonstrate that the inherent complexity of the network setting makes individuals' choices systematically less payoff-guided and also strongly reduces their social orientation. Furthermore, we show that specific network complexity features aggravate the former effect. These behavioral effects have important implications for researchers and managers working in areas that involve network formation.

JEL Classification: A14, C91, D85

Keywords: network formation, individual decision making, behavioral effects, network complexity, payoff orientation, social preferences, choice experiments, mixed logit

1 Introduction

Network formation among individuals is an important phenomenon in many social and economic contexts, ranging from word-of-mouth communications among consumers (e.g., Iacobucci and Hopkins 1992) and social structure (e.g., Granovetter 1995) to perceived organizational support (e.g., Zagenczyk et al. 2010) and virtual communities (e.g., Wellman et al. 1996).

There exists a recent and increasing literature in which researchers experimentally investigate the network formation process. One stream in this literature is involved with testing integral game-theoretical models of network formation. They include variants of Bala and Goyal's (2000) noncooperative network formation model (e.g., Berninghaus et al. 2006, Callander and Plott 2005), Jackson and Wolinsky's (1996) pairwise cooperative network formation model (e.g., Deck and Johnson 2004), and fully cooperative network formation models like Jackson and Van den Nouweland's (2005) (e.g., Charness and Jackson 2007). This research identifies several conditions under which theoretically stable network structures are reproduced in the laboratory and addresses these networks' efficiency. Another stream of experimental studies examines the role of network formation as endogenously emerging in other relevant settings of cooperative decision making (e.g., Brown et al. 2004, Corbae and Duffy 2008, Hauk and Nagel 2001, Kirchsteiger et al. 2005). This research shows that cooperation decisions are considerably influenced when individuals are allowed to choose their partners versus when an interaction structure is imposed.

A common factor in this previous empirical investigation of the network formation process is that individual benefits and costs are induced to be given by a payoff function tailored to the specific game-theoretical setting. Therefore, an issue that has been largely ignored is that the complexity of the network formation decisions that individuals face may cause errors or simplifications in their evaluation of different link formation options and hence in their choice process. Although previous research acknowledges the mere existence of errors (e.g., Charness and Jackson 2007), these errors are typically simply modeled as random and the underlying process remains undisclosed. The objective of the current paper is to systematically investigate what behavioral shifts occur in individual decision making in network formation as a function of network complexity, like in previously studied choice contexts (e.g., Johnson and Payne 1985).

We perform an individual decision making experiment in which we vary three complexity features that are relevant in the context of network formation, i.e., opacity of choice consequences, transferability of value in the network, and social tradeoff between own payoff and others' payoff. These properties complicate the choices that individuals make about creating and maintaining links in the network. We examine whether these choices therefore become systematically less payoff-driven, i.e., also guided by behavioral decision cues, and furthermore whether they become less socially oriented, i.e., less guided by the payoff generated for other individuals.

In order to test our hypotheses, we confront participants in the lab with multiple static, non-interactive network situations in which they can choose to create or delete one link or to do nothing. Such a network situation constitutes the simplest network linking decision context, which allows us to study the effects of network complexity under highly controlled experimental conditions. In even more complex network tasks, like the strategic situations as commonly studied in the existing experimental network formation literature, the proposed complexity effects are also supposed to play a significant role, but it is not possible to disentangle each component's separate effect.

The participants' choices have a direct impact on their monetary rewards in the experiment and differ with respect to three complexity factors (payoff opacity, value transferability, social tradeoff), leading to different treatments. We perform a comprehensive parametric test of the hypotheses by estimating a mixed (i.e., random parameters) logit model (McFadden 2001, Hensher et al. 2005). This allows us to investigate the impact of complex network properties on individuals' decisions, while allowing for heterogeneity of the decision makers.

In Section 2, we present our theoretical framework, leading to hypotheses on behavioral effects in network linking decision making that differ from prior predictions based on full rationality. Section 3 describes the experimental design and the approach used for the mixed logit estimations. The results of our experiment and hypotheses tests are reported in Section 4. Section 5 concludes the paper with a discussion.

2 Theoretical framework

The objective of this section is to present our hypotheses about behavioral effects in individual decisions of network formation and compare them to predictions on individual choice behavior underlying the previous experimental network formation literature. After a description of our setting, the predictions based on prior theories are reviewed in Section 2.1 and our hypotheses are presented in Section 2.2.

The focus of our research is to investigate individuals' behavioral decision response to variations in network complexity. We address the elementary case of single link formation decisions by individuals. Doing so allows us to investigate complexity effects in a tightly controlled yet relevant setting of network formation decisions. To prevent possible confounding effects that do not originate from network complexity but from strategic interaction among individuals, we focus on individual one-period decisions.

Thus a typical decision task as we study would be described as follows. An individual ("you" in the example of Figure 1) is connected with several other individuals in a network and is facing the one-shot choice problem to change at most one link: her options are to delete one of her existing links ("a" or "d" in the example), to create a link with one individual that she is currently not directly connected to ("b" or "c" in the example), or not to change anything. This results in a new network structure that generates value for "you" as well as for "a" through "d" according to a function that is varied in complexity.

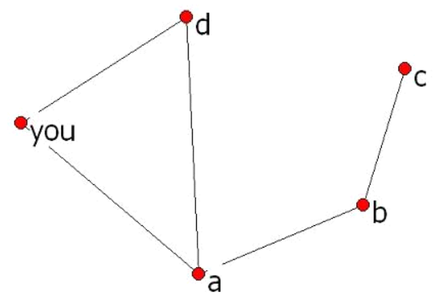


Figure 1: Example of network formation setting

2.1 Prior decision models

Economic theory (e.g., Varian 1992, Ch. 7) models experienced utility, i.e., utility on which actual decisions are based, as follows. The experienced utility that individual i derives from choosing alternative j is given by:

$$U_j^i = f^i\left(\text{Payoff}_j\right),$$

where Payoff_j is the payoff (i.e., benefits (functional, hedonic) minus costs (time, money)) obtained by i when she chooses j and f^i is a strictly increasing function. We refer to this as the normative payoff-based model.

Social preferences theory (for an overview see Fehr and Schmidt 2003) augments this model by explicitly allowing for the fact that in addition to their own payoff, individuals may take the payoff for other individuals into account when making their decisions. In this case, the experienced utility that individual i derives from choosing alternative j is given by:

$$U_j^i = f^i\left(\text{OwnPayoff}_j, \left(\text{OthersPayoff}_j^h\right)_{h\neq i}\right),$$

where OwnPayoff_j is the payoff personally obtained by i when she chooses j, OthersPayoff_j^h is the payoff obtained by another individual h when i chooses j, and $f^i(.)$ is a function reflecting how i holds others-oriented payoff components in mind (e.g., inequity aversion, efficiency preferences, etc.). We refer to this as the normative payoff-based model with social preferences.

2.2 Hypotheses

Our anticipation is that these prior utility models are not sufficient to explain link choice behavior in the presence of network complexity. This complexity arises due to network effects (Katz and Shapiro 1994): an individual's payoff is not only determined by her own choices, but also by those of other individuals in the network. Therefore, she finds it an inherently complex task to determine the precise payoff of linking choice alternatives.

As humans have bounded rationality (Camerer 1998), they cope with complexity in decision making by simplification, which commonly involves assessing a judgment object (e.g., linking choice alternative) using only the subset of properties of the object that are most accessible, i.e., that come most readily to mind, rather than using all relevant properties (Gigerenzer et al. 1999). This is clearly illustrated in the literature about the effects of task complexity in several other contexts, like audit judgment (e.g., Bonner 1994) and consumer choice (e.g., Swait and Adamowicz 2001), but no empirical research to date has addressed such effects in making complex network formation decisions.

We propose two main types of behavioral shifts: (i) the complexity in the network formation setting makes individuals' choices systematically less payoff-guided since they are additionally driven by other behavioral cues (Section 2.2.1) and (ii) it makes them less socially oriented (Section 2.2.2). Furthermore, we examine whether these effects are stronger under even more complex network decision making conditions (Section 2.2.3).

2.2.1 Payoff orientation

In the network formation setting the decision maker's payoff depends on the network structure after completion of her choice, where having more connections is on the one hand beneficial, since they provide access to additional resources, and on the other hand costly, for it takes time and effort to maintain them. Because of network effects, it is typically a complex task for individuals to judge the exact payoff consequences of link choice alternatives and we examine whether therefore individuals systematically deviate from payoff orientation.

A psychological process of judgment simplification is encountered in the literature about Conjunctive Probability Assessment, which shows that individuals make predictions based on a correlation they assume to exist between the assessment variable and some other variable (e.g., Broniarczyk & Alba 1994). Accordingly, individuals could partly substitute the normative payoff value of a link choice alternative by descriptive attributes that can be determined more easily and that are qualitatively related to it. Consequently, they could shift their orientation from exact payoff to (i) whether a link choice alternative involves actively deleting or creating a link or rather doing nothing, and (ii) how many direct links the individual of the choice alternative has in the network. This is in line with Qualitative Process Theory, which suggests that human reasoning is more likely to depend on qualitative rather than quantitative relations (Forbus 1993). Therefore, in our model we allow for individuals' use of the type of action or individual as behavioral cues in addition to the precise expected payoff.

We hypothesize:

Hypothesis 1 (reduction of payoff maximization) *Due to network complexity an individual's link formation choices are affected less strongly by their payoff consequences than predicted by the normative payoff-based model (Section 2.1), since they are also based on behavioral cues.*

Pursuing the above line of reasoning, we formulate the experienced utility that individual i may derive from choosing alternative j with the following behavioral cues:

$$U_j^i = f^i \left(\text{Payoff}_j, \text{Formation}_j, \text{Degree}_j\right), \tag{1}$$

where Formation_j is a dummy variable indicating by 0 that j involves sticking to the status quo and by 1 that it involves link deletion or creation, and Degree_j is the number of direct links of an individual with whom i deletes or creates a link in j.

2.2.2 Social preferences

The presence of social tradeoff is a further complicating factor in the network setting, implying that an individual's choices not only affect her own value, but also the value for her neighbors, her neighbors' neighbors, etcetera (e.g., Bala and Goyal 2000, Jackson and Wolinsky 1996). This aspect of network formation choices makes it more complex for individuals with social preferences to judge the exact value of link choice alternatives, because besides their own payoff they also have to consider the payoff of (possibly many) other individuals.

We investigate whether individuals deal with the complexity of social tradeoff by focusing on the payoff aspect that can be determined most easily (Gigerenzer et al. 1999). Therefore, we examine whether individuals tend to focus more strongly on their own payoff and will pay relatively less attention to others' payoff due to the greater complexity of evaluating this social payoff. In the past, behavioral economists have found empirical evidence for social preferences. Recently, Falk and Kosfeld (2003), Goeree et al. (2008) and Van Dolder and Buskens (2008) found social motives in network formation, but this was in lab environments where choice complexity was largely mitigated by explicit payoff information, which presented participants with the numerical payoff consequences of their choice options. Thus, we propose the following hypothesis:

Hypothesis 2 (reduction of social preferences) *Due to network complexity an individual's link formation choices are affected less strongly by their payoff consequences for other individuals than predicted by the normative payoff-based model with social preferences (Section 2.1), since they become systematically more socially oriented when the complexity is removed.*

We include this behavioral effect in the experienced utility that individual i derives from choosing alternative j as follows:

$$U_j^i = f^i\left(\text{OwnPayoff}_j, \left(\text{OthersPayoff}_j^h\right)_{h \neq i}, \text{Formation}_j, \text{Degree}_j\right), \tag{2}$$

where f^i is a function less increasing in $\left(\text{OthersPayoff}_j^h\right)_{h \neq i}$ when i does not receive an explicit payoff overview than when she does.

2.2.3 Reinforcing complexity conditions

Finally, we hypothesize that in addition to the general opacity of choice consequences in this context, specific complexity aspects of networks may strengthen individuals' tendency to deviate from payoff orientation and to focus on their own payoff.

Value transferability The first network feature regarded here is value transferability, which refers to the fact that an individual derives value not only from her direct neighbors, but also indirectly from her neighbors' neighbors, etcetera. This network property makes it even more complex for individuals to judge the exact payoff of link choice alternatives, because it requires additional cognitive work to be forward-looking over indirect links. This leads to the following hypotheses:

Hypothesis 3 (moderating effects of value transferability)

Hypothesis 3.1 *The presence of value transferability in a network decreases the impact of payoff on an individual's link formation choices.*

Hypothesis 3.2 *The presence of value transferability in a network decreases the impact of others' payoff on an individual's link formation choices.*

Social tradeoff Another complexity property we consider is social tradeoff, implying that an individual's choices not only affect her own value, but also the value for her neighbors, her neighbors' neighbors, etcetera (cf. Section 2.2.2). This network property makes it more complex for individuals with social preferences to judge the exact value of link choice alternatives, because besides their own payoff they have to consider the payoff of (possibly many) other individuals, which requires extra cognitive effort. Therefore, the presence of social tradeoff will not only cause a shift of orientation from others' to own payoff (Hypothesis 2), but we also expect it to have a strengthening effect on the deviation from payoff orientation. This can be formulated in the following hypothesis:

Hypothesis 4 (moderating effect of social tradeoff) *The presence of social tradeoff in a network decreases the impact of payoff on an individual's link formation choices.*

We include these moderating effects of complexity factors in the experienced utility that individual i derives from choosing alternative j as follows:

$$\begin{aligned} U_j^i \; = \; & f^i \Big(\text{OwnPayoff}_j, \big(\text{OthersPayoff}_j^h \big)_{h \neq i}, \text{Formation}_j, \text{Degree}_j, \\ & \text{Complexity} \times \Big(\text{OwnPayoff}_j, \big(\text{OthersPayoff}_j^h \big)_{h \neq i}, \text{Formation}_j, \text{Degree}_j \Big) \Big), \end{aligned} \tag{3}$$

where Complexity is the network choice complexity condition that i is facing and f^i is a function in which the hypothesized interaction effects with Complexity are included. Note that the behavior we predict shows a positive association with the behavior predicted by prior normative decision models (Section 2.1). Therefore, although people do not base their decisions on exact payoff, they may still maximize their utility by saving effort (cf. Gigerenzer et al. 1999).

3 Methods

In this section we describe the experimental design as well as the parametric approach used for testing our hypotheses.

3.1 Experimental design

Our experiment presented participants with six network formation link choice problems similar to that in Figure 1. In these problems a participant was allowed to change at most one direct link, i.e., to delete a link that already exists between her and another individual, to create a link between her and another individual if there is not yet one, or to change nothing. The choice problems are illustrated in Tables 6 and 7, Appendix B. They were created such that they represent a variety of network linking decisions while enabling mutual comparison. The number of individuals was kept constant in all six choice problems. Pilot studies conducted by the authors before the experiment indicated that most other structural complexity features like the total number of links and the number of visual crossings between links did not affect participants' choices. An exception was whether the decision maker was connected to the rest of the network at the moment of choice or not. Therefore, three of the six choice problems involved a connected position and the other three an isolated position for the participant. Furthermore, to avoid unanticipated biases due to other structural factors, the order of choice problems was rotated among participants.

To test for the hypothesized shifts in behavior due to value transferability and social tradeoff, we employed four experimental treatments where these two characteristics were between-subjects factors. Thus, each participant faced one of four particular complexity conditions (see Section 2.2.3). The experimental design is summarized by Table 1. A within-subject manipulation for the treatments *social* and *both* will be discussed later in this section.

		social tradeoff	
		NO	YES
value	NO	*none*	*social* (part 1, part 2)
transferability	YES	*transfer*	*both* (part 1, part 2)

Table 1: Experimental design

Each participant was confronted with a payoff function matching her condition. This function reflected the benefits and costs of link formation according to a typical situation as observed in communication networks with high cost of link maintenance and was explained in words to the participants in the instructions (see Appendix A). For a participant i in treatment *none* or *social* there was no value transferability, so value was derived from direct neighbors only. The payoff function was then given by:

$$\Pi_i = \begin{cases} \sum\limits_{j \in N_i} \frac{1}{\mu_i \mu_j} & \text{if} \quad \mu_i > 0 \\ 0 & \text{if} \quad \mu_i = 0, \end{cases}$$

where N_i is the set of individuals with whom i has a direct link, individual j is a neighbor of i if $j \in N_i$, and $\mu_i = |N_i|$ is the number of neighbors of i, i.e., the degree of i.

For treatments *transfer* and *both* there was value transferability, so value was derived from direct as well as indirectly connected individuals. The payoff function was then given by:

$$\Pi_i = \begin{cases} \sum_{j \in \bar{N}_i} \sum_{p \in \mathcal{P}_{i,j}} \frac{1}{\mu_i \mu_j \prod_{k \in \breve{p}} (\mu_k)^2} & \text{if} \quad \mu_i > 0 \\ 0 & \text{if} \quad \mu_i = 0, \end{cases}$$

where $\bar{N}_i$ is the set of individuals with whom i has either a direct or an indirect link, $\mathcal{P}_{i,j}$ is the set of paths between i and j, where a path is defined as a sequence of consecutive links without repeated individuals, $\breve{p}$ is the set of individuals on path p between i and j excluding i and j themselves, and μ_i is the degree of i. In the instructions, these payoff functions were not presented in formulas but in easy verbal descriptions, illustrated by an example (see Appendix A).

For treatments *none* and *transfer* there was no social tradeoff. The participants were informed that nobody else was affected by their choices. For treatments *social* and *both* there was social tradeoff. The participants were informed that the payoffs for the other individuals in the choice problems were determined analogously to their own payoff, and that the total payoffs created for these other individuals due to their choices would be divided equally among the other participants in the room. Thus, a simple form of social preferences, not involving distributional issues, was evoked. No information or feedback about the tasks and choices of the other participants was provided during the experiment in order to underline that strategic motivations are ineffective, since the choices of other participants do not influence the payoffs in the decision problems.

To control for individual differences in social preferences, for participants in treatments *social* and *both* where payoff for other participants had to be considered, an additional part was added to the experiment. This was exactly the same as the first part, but for each choice option the payoff for the participant as well as for the others were mentioned explicitly. This is illustrated in Figure 2, Appendix B. Charness et al. (2004) showed that providing participants with such a comprehensive payoff table is an effective way to systematically reduce complexity. The objective of this extra manipulation was to test in how far participants take others' payoff into account when the complexity of doing so is removed. The payoffs for all choice problems are given in Table 8 in the same appendix. Thus, for the treatments *social* and *both*, whether or not numerical payoff information was provided was incorporated as a within-subjects factor.

The experiment took place in a computer lab with students and employees of various faculties of Maastricht University, the Netherlands. The 48 male and 66 female participants from diverse nationalities were randomly assigned to the four between-subject treatments. Participants were informed how the payoffs they would earn in the experiment would be converted into cash euros afterwards, see Sections A.1 and A.2, Appendix A for details. After each choice, feedback was given to the participant about the payoff she earned for herself and if relevant for the other participants in the room, and the maximum and minimum payoff that could have been earned in the specific choice problem. They could only start the experiment after answering a number of control questions correctly to make sure the instructions were understood correctly and after two really paid-out practice rounds with only three choice alternatives, see Table 5, Appendix B. At the end of the experiment they were asked to comment on their motives and the way they made their choices in a debriefing part. Average earnings were €6.03 and the post-hoc correlations between payoffs and behavioral cues as well as between own and others' payoffs were below 0.31.

3.2 Mixed logit estimations

We perform a comprehensive parametric test of our hypotheses by estimating a mixed (i.e., random parameters) logit model (Hensher et al. 2005). This estimation approach enables us to establish the roles of several attributes of link alternatives in the network formation process, while allowing for heterogeneity across individuals. The total potential experienced utility that individual i under treatment t derives from choosing alternative j in choice problem c is affected by both payoff and other factors as well as the complexity condition she is facing, and is formalized as follows:

$$\begin{aligned} U^i_{cj} = & \sum_{k\in K} \beta^i_k P^t_{kcj} + \sum_{m\in M} \gamma^i_m C_{mcj} + \sum_{k\in K} \varphi_k T^t P^t_{kcj} + \sum_{m\in M} \chi_m T^t C_{mcj} \\ & + \theta S^t P^t_{1cj} + \sum_{m\in M} \xi_m S^t C_{mcj} + \zeta T^t S^t P^t_{1cj} + \sum_{m\in M} \eta_m T^t S^t C_{mcj} \\ & + \sum_{k\in K} \psi_{1k} I^t_c P^t_{kcj} + \sum_{m\in M} \psi_{2m} I^t_c C_{mcj} + \sum_{k\in K} \psi_{3k} I^t_c T^t P^t_{kcj} + \sum_{m\in M} \psi_{4m} I^t_c T^t C_{mcj} \\ & + \varepsilon^i_{cj}, \end{aligned}$$

where:

K is the set of payoff indices $\{1, 2\}$,

P^t_{1cj} is the own payoff generated for i under t when in c she chooses j,

P^t_{2cj} is the payoff generated for the other participants,

M	is the set of control variable indices $\{1, 2\}$,
C_{1cj}	is a control dummy variable indicating deviation from the status quo,
C_{2cj}	is a control variable indicating the number of direct links of an individual with whom a link is deleted or created,
T^t	is a dummy variable indicating the presence of value transferability, i.e., treatment *transfer* or *both*,
S^t	is a dummy variable indicating the presence of social tradeoff, i.e., treatment *social* or *both*,
I^t	is a dummy variable indicating the presence of numerical payoff information (within-subject manipulation), and
ε^i_{cj}	is a stochastic variable drawn from a standard Gumbel distribution.[1]

In random parameter β^i_k, superscript i allows for heterogeneity due to individuals' personal preferences as follows:

$$\beta^i_k = \beta_k + \nu^i_k,$$

where ν^i_k is a stochastic variable drawn from a normal distribution. Analogously, random parameters are included for the main effects of the control variables on choice (γ^i_m).

Then, under the usual assumptions, the unconditional probability that individual i will choose alternative j equals the expected value of the logit probability over all possible values of the random parameters. The model is estimated by Maximum Likelihood with NLOGIT 3.0, Econometric Software, Inc., implementing 500 Halton draws in the Monte Carlo simulation.

[1] Notice that interactions between S and P_2 or between S, T and P_2 do not provide additional information to P_2 or the interaction between T and P_2 respectively, and therefore are not included, and that interactions including both I and S do not provide additional information to interactions only including S and therefore are not incorporated either.

4 Results

4.1 Some illustrative descriptive results

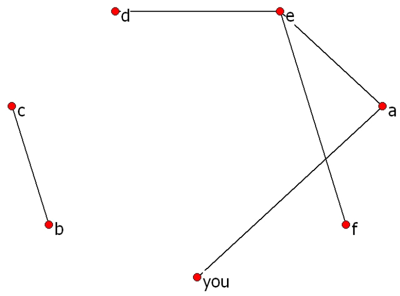
Before turning to a more formal analysis, we first present some illustrative results for the choices made in the different conditions. Hereby the focus is on choice problem 5 (Table 2; above this table with choice percentages in the different conditions, the respective choice problem and its payoffs are replicated for the reader's comfort).

In complexity condition *none* (first row Table 2), without value transferability and social trade-off, all participants choose one of the normatively optimal alternatives, i.e., nothing, b, c, d, or f. However, in condition *transfer*, where value transferability is included, only 67.8% of the respective participants chooses one of the normatively optimal alternatives, i.e., b or c. This is in line with Hypothesis 3.1.

In complexity condition *social* (second row Table 2), where social tradeoff is included, even though changing nothing involves the status quo and was listed first in the description of choice options, only 10.7% of the respective participants turns out to opt for this, which would reveal social preferences in the sense that it maximizes the payoffs for the other participants, given maximum own payoff. All these participants still maximize their own payoff though. However, in the second part of the experiment, when payoff information is given, thus eliminating network complexity, 53.6% of the same participants prefers this option. This pattern corresponds with Hypothesis 4.

In complexity condition *both* (third row Table 2), with both value transferability and social tradeoff, only 42.9% of the respective participants chooses one of the options with optimal own payoff, i.e., b or c, whereas the rest seems to reveal social preferences in the sense that they reduce their own payoff in order to increase others' payoffs. Note that 21.3% even chooses a Pareto inferior option, i.e., a, d, e, or f. However, in the second part of the experiment, when payoff information is given, thus eliminating network complexity, the proportion with optimal own payoff increases to 71.4%. Also, only 3.6% chooses a Pareto inferior option. This result is in line with Hypothesis 4.

Further descriptive results, primarily from the debriefing part, are given in Appendix C.



	value transferability NO			value transferability YES	
	you	others		you	others
nothing	5	41.67	nothing	6.39	47.5
a	0	40	a	0	46.67
b	5	31.67	b	6.94	40.45
c	5	31.67	c	6.94	40.45
d	5	38.33	d	6.25	44.17
e	3.75	36.25	e	5	40.94
f	5	38.33	f	6.25	44.17

none / payoff info NO		*transfer* / payoff info NO	
choice	%	choice	%
nothing	43.3	nothing	17.9
a	0.0	a	0.0
b	40.0	b	60.7
c	10.0	c	7.1
d	3.3	d	0.0
e	0.0	e	3.6
f	3.3	f	10.7
social / payoff info NO		*social* / payoff info YES	
choice	%	choice	%
nothing	10.7	nothing	53.6
a	0.0	a	0.0
b	39.3	b	21.4
c	7.1	c	7.1
d	17.9	d	7.1
e	0.0	e	3.6
f	25.0	f	7.1
both / payoff info NO		*both* / payoff info YES	
choice	%	choice	%
nothing	35.7	nothing	25.0
a	0.0	a	0.0
b	28.6	b	46.4
c	14.3	c	25.0
d	7.1	d	3.6
e	7.1	e	0.0
f	7.1	f	0.0

Table 2: Descriptive results choice problem 5

4.2 Mixed logit results

A comprehensive parametric test of the hypotheses is conducted by estimating a mixed logit model across all experimental conditions (Section 4.2.1). A p-value of 0.05 is taken as cut-off value for significance. In Section 4.2.2 several robustness checks are performed.

4.2.1 Hypothesized model

The estimation results for all experimental treatments including the interaction effects of an explicit payoff overview are given in Table 3.

In these results we find support for the reduction of payoff orientation in this complex setting (Hypothesis 1), since besides the own payoff, the degree of the individual involved in the choice alternative appears to be significantly influential on a linking decision, where individuals with many links are avoided in comparison with relatively isolated individuals (negative γ_2^i). This might be based on the qualitative notion that maintaining links is costly. For the conditions with social payoff, where the within-subjects factor of numerical payoff information was included, this is reconfirmed by the positively significant ψ_{11}-coefficient, indicating that when participants were provided with such a comprehensive payoff overview, the impact of payoff on their linking choices increased.

With respect to the expected reduction of social preferences in the network formation context (Hypothesis 2), we find very strong confirmation as the β_2^i-coefficient is not significant at all, whereas in the situation where participants were provided with numerical payoff information, the corresponding coefficient (ψ_{12}) is positively significant, showing that the same individuals were more willing to consider the consequences of their choices for others than they actually did in the first round of the experiment.

The hypothesized moderating effects of value transferability are supported with respect to the reduction of payoff orientation: the φ_1-coefficient of the payoff interaction term turns out to be negatively significant. We see that instead, participants sticked significantly more to the status quo (negative χ_1) and reversed their preference for isolated versus central individuals (χ_2). Since others' payoff were already completely ignored in the choices of the participants, it is not possible anymore for the additional complexity factor value transferability to significantly decrease their effect (Hypothesis 3.2).

The hypothesized moderating effect of social tradeoff on payoff orientation is corroborated as well, for the θ_1-coefficient is also significantly negative. Here, respondents had the tendency to deviate from the status quo (positive ξ_1).

Finally, respondents' simplifying behavior significantly varies among participants in several respects as can be concluded from the significant random parameter standard deviations in the last column of Table 3.

variable	**para-meter**	**estimated mean (p-value)**	**estimated st. dev. (p-value)**	**cf. hyp.**
own payoff	β_1^i	1.785 (0.000)	0.466 (0.000)	
others' payoff	β_2^i	-0.016 (0.680)	0.134 (0.000)	2
formation	γ_1^i	0.487 (0.243)	1.033 (0.000)	1
degree	γ_2^i	-0.845 (0.000)	0.118 (0.526)	1
transferability * own payoff	φ_1	-1.055 (0.003)		3
transferability * others' payoff	φ_3	-0.019 (0.729)		3
transferability * formation	χ_1	-1.451 (0.012)		3
transferability * degree	χ_2	1.500 (0.000)		3
social tradeoff * own payoff	θ_1	-1.128 (0.002)		4
social tradeoff * formation	ξ_1	1.420 (0.041)		4
social tradeoff * degree	ξ_2	-0.114 (0.727)		4
transferability * social tradeoff * own payoff	ζ	1.274 (0.002)		
transferability * social tradeoff * formation	η_1	-1.448 (0.116)		
transferability * social tradeoff * degree	η_2	0.042 (0.914)		
payoff info * own payoff	ψ_{11}	0.863 (0.002)		1
payoff info * others' payoff	ψ_{12}	0.136 (0.004)		2
payoff info * formation	ψ_{21}	-1.972 (0.010)		
payoff info * degree	ψ_{22}	0.477 (0.196)		
payoff info * transferability * own payoff	ψ_{31}	0.518 (0.202)		
payoff info * transferability * others' payoff	ψ_{32}	-0.097 (0.162)		
payoff info * transferability * formation	ψ_{41}	3.134 (0.002)		
payoff info * transferability * degree	ψ_{42}	-0.995 (0.041)		

Table 3: Mixed logit estimations

4.2.2 Robustness

In this section, we check whether our estimation results are robust for several control variables.

Order and learning effects The model is re-estimated for the first part of the experiment only (without numerical payoff information)[2] where the variance of the error term is allowed to linearly depend on a control variable tracking the position of the respective alternative in the list of choice options, to check for robustness against order effects. Furthermore, the variance of the error term is allowed to linearly depend on a control variable measuring experience by tracking how many problems the participant already solved at the respective moment of choice, to check for robustness against learning effects. We find that all previously found behavioral effects remain and that the order effects turn out not to be significant. The simplification effects turn out to be stronger for more experienced individuals, since they deviate significantly more from payoff orientation by systematically deviating from the status quo and avoiding individuals with many links, so the behavioral effects in network formation decisions as explored in the current paper are definitely not transitory.

Error shift effects Finally, we compare our model to a more restricted model where instead of including separate interaction effects for the complexity conditions, we only allow the variance of the error term to linearly depend on them, to check whether the effects are possibly merely due to shifts in choice precision (see Salisbury and Feinberg 2010). This rival model turns out to perform significantly worse in terms of model fit (loglikelihood decreases from -1541.201 to -1626.358), strengthening our claim of more systematic effects of complexity on link choice behavior. Hereby we follow the recent call by Hutchinson et al. (2010) to find deterministic sources of behavioral effects.

[2] For the second part of the experiment, when payoff tables are provided to the same participants, it is not straightforward how to extend the definition of the experience variable.

5 Discussion

5.1 Conclusions

This study shows (see Table 4) that network complexity influences individual link choice behavior in a systematic way, since individuals' choices are guided less by payoff, where the attention appears to be shifted to factors only qualitatively related to payoff, and moreover, their social orientation is strongly reduced. Furthermore, we demonstrate that the specific network complexity features value transferability and social tradeoff aggravate the former effect. In Section 4.2.2 it was confirmed that these changes in behavior cannot accurately be captured by models only allowing for differences in choice precision among complexity conditions.

hypothesis	**result**
behavioral effects of network complexity on linking choice	
1: reduction of payoff orientation	supported (isolated individual as behavioral cue)
2: reduction of social preferences	supported (numerical payoff necessary to consider other individuals' payoff at all)
moderating effects of specific network complexity features	
3: value transferability	supported for reduction of payoff orientation (central individual & sticking to status quo as behavioral cues); social preferences could not be further reduced
4: social tradeoff	supported (deviating from status quo as behavioral cue)

Table 4: Summary experimental results

5.2 Implications

The current research pioneers empirical research into the issue of behavioral effects in individual decisions of network formation. Our results should raise interest in future research into this realm, for they have important implications for experimental research as well as application areas of network formation.

For instance, experimental research practice is often disposed to make the payoff consequences of choices as transparent as possible for participants to prevent biased findings due to their wrong understanding of the instructions. However, we claim that this explicit information modifies participants' behavior in a systematic way, since it eliminates complexity that they otherwise would handle by simplification.

Furthermore, in many practical applications of network formation such as social structure (e.g., Granovetter 1995) and perceived organizational support (e.g., Zagenczyk et al. 2010), it matters to be aware of behavioral effects as found in this study. For example, with regard to word-of-mouth communication among consumers (e.g., Iacobucci and Hopkins 1992) or virtual communities (e.g., Wellman et al. 1996), for the supplier of the respective product or service it is interesting to know that consumers have a tendency to talk with isolated peers and that they neglect benefits that peers derive from their communication decisions. Also, suppliers can exploit the finding that this simplifying behavior is dependent on the complexity of the network environment, e.g., by facilitating information about social payoffs.

In order to prevent interference of complexity types that are not the focus of the current research, we studied a relatively simple network linking decision that is only one-shot and involves only one active participant changing at most one link. Also, the payoff information is complete and certain. Future research could study whether and in how far these additional complexity types strengthen the behavioral effects shown by the current paper.

Another direction that follow-up studies could take concerns the question in how far the complexity types and behavioral effects we considered are specific for the network context. For example, in how far does complexity reduce social preferences in other choice settings? Moreover, future experiments could generate further insights in the linking choice process of individuals by concentrating on specific effects from the rich range of simplifying tendencies explored here.

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A Instructions

A.1 Social tradeoff NO Value transferability NO *YES*[3]

In this experiment you are asked to respond to eight choice problems. You can earn points depending on the choices you make in these problems. The total number of points that you have at the end of the experiment determines your monetary payoff.

In each problem, you see a picture of a network in which you and several other nodes are interconnected by links. In order to generate points, you are allowed to change at most one link. You have the following options to do this: (1) you can delete one link that already exists between you and any other node, (2) you can create one link between you and any other node if there is not yet any link between you and this node, or (3) you can choose not to change anything.

You can determine the number of points you receive due to your choice for a specific problem, as follows. **For each node you are directly linked with (we call such a node a neighbour) you obtain points.** *For each path that links you to some other node you obtain points.* However, there is also some cost associated with being connected: **the number of points you receive for each of your direct neighbours equals 10 divided by two components: (i) the number of direct neighbours you have, and (ii) the number of direct neighbours this neighbour has.** *the number of points you receive for each path that links you to some other node equals 10 divided by three components: (i) the number of direct neighbours you have in the network, (ii) the number of direct neighbours this other node has in the network, and (iii) the square of the number of direct neighbours that any of the further nodes on the path between you and the other node has in the network.*

[example, see Section A.3]

After each of the eight problems, the number of points that you earned will be reported.

Note that there are no real people behind the other nodes in a network: you are the only one able to change a link and earn points by this.

At the end of the experiment, points are exchanged for euros in the following way: amount in euros you receive = 4 + **0.4** *0.3* (total number of points that you earned - **33.68** *45.17*).

A.2 Social tradeoff YES Value transferability NO *YES*

In this first part you are asked to respond to eight choice problems. You can earn points depending on the choices you make in these problems. Moreover, your choices can also generate points for the other participants in the room. The total number of points that you have at the end of the experiment determines your monetary payoff.

In each problem, you see a picture of a network in which you and several other nodes are interconnected by links. In order to generate points, you are allowed to change at most one link. You have the following options to do this: (1) you can delete one link that already exists between you and any other node, (2) you can create one link between you and any other node if there is not yet any link between you and this node, or (3) you can choose not to change anything.

You can determine the number of points you receive due to your choice for a specific problem, as follows. **For each node you are directly linked with (we call such a node a neighbour) you obtain points.** *For each path that links you to some other node you obtain points.* However, there is also some cost associated with being connected: **the number of points you receive for each of your direct neighbours equals 10 divided by two components: (i) the number of direct neighbours you have, and (ii) the number of direct neighbours this neighbour has.** *the number of points you receive for each path that links you to some other node equals 10 divided by three components: (i) the number of direct neighbours you have in the network, (ii) the number of direct neighbours this other node has in the network, and (iii) the square of the number of direct neighbours that any of the further nodes on the path between you and the other node has in the network.*

[example, see Section A.3]

After each of the eight problems, the number of points that you earned will be reported.

The other nodes in the choice problems receive points in the same way as you do. There are no real people behind these nodes and you are the only one able to change a link in a network. However, the points that the other nodes receive due to your choices do have a consequence for the other participants in this room. In fact, these points will be divided equally among them.

[example continued, see Section A.3]

[3] Bold text was used in treatments without value transferability and italics text in treatments with value transferability.

The number of points that you generated for the other participants will also be reported after each problem.

At the end of the experiment, points are exchanged for euros in the following way: amount in euros you receive for this first part = 4 + **0.06** *0.07* (total number of points that you earned in this first part - **265.51** *320.63*).

The choices you made in the first part do not influence the payoffs in this part and the choices you will make in this part do not influence the payoffs in the previous part.

In this second part you are asked to respond to eight choice problems. You can earn points depending on the choices you make in these problems. Moreover, your choices can also generate points for the other participants in the room. The total number of points that you have at the end of the experiment determines your monetary payoff.

At the end of the experiment, points are exchanged for euros in the following way: amount in euros you receive for this second part = 0.5 + **0.03** *0.035* (total number of points that you earned in this second part - **265.51** *320.63*).

A.3 Example

A.3.1 Social tradeoff NO Value transferability NO

For example, in the above network [Figure 1] you have two direct neighbours: a and d. For neighbour a you get 10 points divided by 2 (since you have two direct neighbours) divided by 3 (since a has three direct neighbours). For neighbour d you get 10 points divided by 2 (since you have two direct neighbours) divided by 2 (since d has two direct neighbours). In total you therefore receive 10/6 + 10/4 = 25/6 points in this example.

A.3.2 Social tradeoff NO Value transferability YES

For example, in the above network [Figure 1] there are two paths between you and c. For the path via a and b you get 10 points divided by 2 (since you have two direct neighbours in the network) divided by 3 * 3 (since a has three direct neighbours in the network) divided by 2 * 2 (since b has two direct neighbours in the network) divided by 1 (since c has one direct neighbour in the network). For the path via d, a, and b you get 10 points divided by 2 (since you have two direct neighbours in the network) divided by 2 * 2 (since d has two direct neighbours in the network) divided by 3 * 3 (since a has three direct neighbours in the network) divided by 2 * 2 (since b has two direct neighbours in the network) divided by 1 (since c has one direct neighbour in the network). In total you therefore receive 10/72 + 10/288 = 25/144 points for the paths between you and c. In the same way you get 10/36 + 10/144 points for the paths between you and b, 10/6 + 10/24 points for the paths between you and a and 10/4 + 10/36 points for the paths between you and d. In total you therefore receive 775/144 points in this example.

A.3.3 Social tradeoff YES Value transferability NO

For example, in the above network [Figure 1] you have two direct neighbours: a and d. For neighbour a you get 10 points divided by 2 (since you have two direct neighbours) divided by 3 (since a has three direct neighbours). For neighbour d you get 10 points divided by 2 (since you have two direct neighbours) divided by 2 (since d has two direct neighbours). In total you therefore receive 10/6 + 10/4 = 25/6 points in this example.

[continued] In the example above, node c has one direct neighbour: b. Therefore, she receives 10 points divided by 1 (since c has one direct neighbour) divided by 2 (since b has two direct neighbours), which implies 5 points. In the same way, node b gets 10/2 + 10/6 = 20/3 points, node a gets 10/6 + 10/6 + 10/6 = 5 points, and node d gets 10/4 + 10/6 = 25/6 points. In total therefore 5 + 20/3 + 5 + 25/6 = 125/6 points will be divided equally among the other participants in the room in this example.

A.3.4 Social tradeoff YES Value transferability YES

For example, in the above network [Figure 1] there are two paths between you and c. For the path via a and b you get 10 points divided by 2 (since you have two direct neighbours in the network) divided by 3 * 3 (since a has three direct neighbours in the network) divided by 2 * 2 (since b has two direct neighbours in the network) divided by 1 (since c has one direct neighbour in the network). For the path via d, a, and b you get 10 points divided by 2 (since you have two direct neighbours in the network) divided by 2 * 2 (since d has two direct neighbours in the network) divided by 3 * 3 (since a has three direct neighbours in the network) divided by 2 * 2 (since b has two direct neighbours in the network) divided by 1 (since c has one direct neighbour in the network). In total you therefore receive 10/72 + 10/288 = 25/144 points for the paths between you and c. In the same way you get 10/36 + 10/144 points for the paths between you and b, 10/6 + 10/24 points for the paths between you and a and 10/4 + 10/36 points for the paths between you and d. In total you therefore receive 775/144 points in this example.

[continued] In the example above, there is one path between nodes a and c. Therefore, c receives 10 points divided by 1 (since c has one direct neighbour) divided by 2 * 2 (since b has two direct neighbours) divided by 3 (since a has three direct neighbours) = 5/6 points for the paths between her and a. In the same way c gets 10/2 points for the path between her and b, 10/72 + 10/288 points for the paths between her and d, and 10/72 + 10/288 points for the paths between her and you. In total c therefore receives 445/72 points. In the same way node b gets 10/2 + 10/6 + 10/36 + 10/144 + 10/36 + 10/144 points, node a gets 10/12 + 10/6 + 10/6 + 10/24 + 10/6 + 10/24 points, and node d gets 10/72 + 10/288 + 10/36 + 10/144 + 10/6 + 10/24 + 10/4 + 10/36 points. In total therefore 445/72 + 265/6 + 20/3 + 775/144 = 2995/48 points will be divided equally among the other participants in the room in this example.

B Choice problems

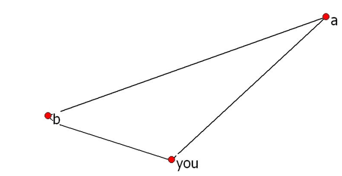
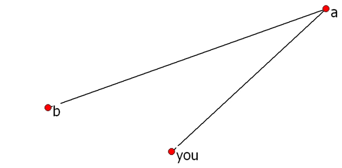
p1		What do you choose? ☐ I do nothing. ☐ I delete the link with a. ☐ I delete the link with b.
p2		What do you choose? ☐ I do nothing. ☐ I delete the link with a. ☐ I create a link with b.

Table 5: Practice rounds

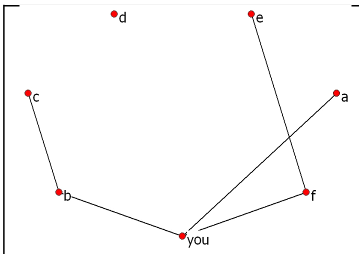
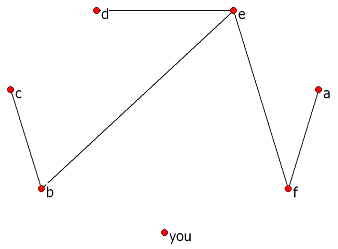
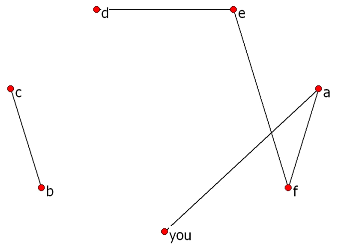
1		What do you choose? ☐ I do nothing. ☐ I delete the link with a. ☐ I delete the link with b. ☐ I create a link with c. ☐ I create a link with d. ☐ I create a link with e. ☐ I delete the link with f.
2		What do you choose? ☐ I do nothing. ☐ I create a link with a. ☐ I create a link with b. ☐ I create a link with c. ☐ I create a link with d. ☐ I create a link with e. ☐ I create a link with f.
3		What do you choose? ☐ I do nothing. ☐ I delete the link with a. ☐ I create a link with b. ☐ I create a link with c. ☐ I create a link with d. ☐ I create a link with e. ☐ I create a link with f.

Table 6: Choice problems 1 - 3

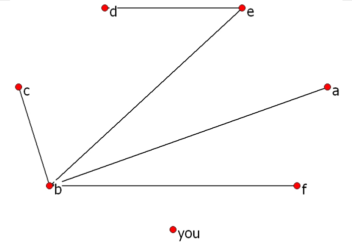
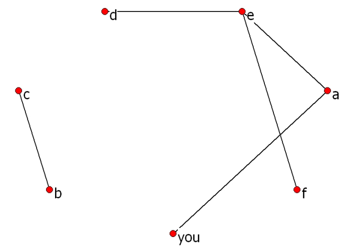
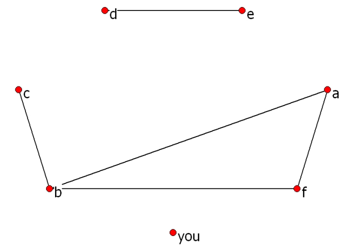
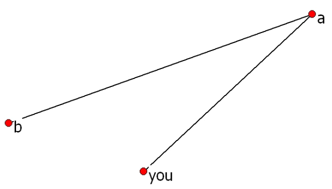
4		What do you choose? ☐ I do nothing. ☐ I create a link with a. ☐ I create a link with b. ☐ I create a link with c. ☐ I create a link with d. ☐ I create a link with e. ☐ I create a link with f.
5		What do you choose? ☐ I do nothing. ☐ I delete the link with a. ☐ I create a link with b. ☐ I create a link with c. ☐ I create a link with d. ☐ I create a link with e. ☐ I create a link with f.
6		What do you choose? ☐ I do nothing. ☐ I create a link with a. ☐ I create a link with b. ☐ I create a link with c. ☐ I create a link with d. ☐ I create a link with e. ☐ I create a link with f.

Table 7: Choice problems 4 - 6



What do you choose?

☐ I do nothing. This means that I earn 5 points and 15 points will be divided equally among the other participants in this room.
☐ I delete the link with a. This means that I earn 0 points and 20 points will be divided equally among the other participants in this room.
☐ I create a link with b. This means that I earn 5 points and 10 points will be divided equally among the other participants in this room.

Figure 2: Illustration payoff information

	indirect payoffs: NO			indirect payoffs: YES		
1		you	others		you	others
	nothing	6.67	26.67	nothing	8.33	32.92
	a	5	25	a	7.5	30.31
	b	7.5	37.5	b	8.75	42.5
	c	6.25	21.25	c	7.5	26.48
	d	7.5	27.5	d	8.75	34.45
	e	6.25	21.25	e	7.5	26.48
	f	7.5	37.5	f	8.75	42.5
2		you	others		you	others
	nothing	0	33.33	nothing	0	41.25
	a	5	33.33	a	6.58	41.51
	b	3.33	32.22	b	5.03	39.72
	c	5	33.33	c	6.58	41.51
	d	5	35	d	6.25	42.5
	e	2.5	32.5	e	4.06	39.14
	f	3.33	32.22	f	5.03	39.72
3		you	others		you	others
	nothing	5	45	nothing	6.72	51.09
	a	0	45	a	0	51.25
	b	5	35	b	7.11	44
	c	5	35	c	7.11	44
	d	5	40	d	6.64	46.56
	e	4.17	39.17	e	5.83	44.58
	f	4.17	40.83	f	5.38	45.59
4		you	others		you	others
	nothing	0	27.5	nothing	0	35.31
	a	5	30	a	6.05	37.15
	b	2	26	b	3.5	32.7
	c	5	30	c	6.05	37.15
	d	5	27.5	d	6.52	35.74
	e	3.33	26.67	e	4.93	34.24
	f	5	30	f	6.05	37.15
5		you	others		you	others
	nothing	5	41.67	nothing	6.39	47.5
	a	0	40	a	0	46.67
	b	5	31.67	b	6.94	40.45
	c	5	31.67	c	6.94	40.45
	d	5	38.33	d	6.25	44.17
	e	3.75	36.25	e	5	40.94
	f	5	38.33	f	6.25	44.17
6		you	others		you	others
	nothing	0	38.33	nothing	0	43.33
	a	3.33	38.89	a	4.57	43.58
	b	2.5	37.5	b	3.91	42.03
	c	5	40	c	6.18	44.79
	d	5	33.33	d	7.5	40.83
	e	5	33.33	e	7.5	40.83
	f	3.33	38.89	f	4.57	43.58

Table 8: Payoffs choice problems

C Descriptive results

1. Duration: average 40,2 min., stand. dev. 14,8 min.
2. Almost all participants tried to earn as much as possible, whereas 17 subjects indicated other goals: best choices (6), fun / interest (2), optimal own payoffs and not too bad payoffs for the others (4), optimal own payoffs and minimal payoffs for the others (1), structural goals (4).
3. In the first choice problem (practice round), participants chose as follows: at random: 1, by calculation: 60, by intuition: 34, using a rule: 13, namely connect to the one with the least neighbors / shortest paths (13), otherwise: 6, namely mix of intuition and calculation (5), mistake in understanding instructions at first (1).
4. Thereafter, did participants change their strategies? No: 67, for the strategy was good or convenient and the problems were similar, yes: 47, switch (more) to calculation (12), intuition / experience (22), or rule mentioned in descriptive 3 (11), or consider other participants more (2).
5. In conditions *social* and *both*, did participants take into account the points created for other participants? 36 did not, since they didn't think about it (4), didn't care about it (16), didn't know how (5) or didn't like the effort (11), 20 did, where they (conditionally) maximized (≥ 8) or minimized (≥ 3) the points for the others, 2 participants seem not to understand that dividing among other participants does not include yourself.
6. Strategies in the second part (with numerical payoff information) of conditions *social* and *both*: (conditionally) maximizing payoffs for the others (25), choosing not too badly for the others (7), (conditionally) minimizing payoffs for the others (6), trying to repeat part 1 (8), unclear (10).
7. Strategic considerations in conditions *social* and *both*? No: 18, since they didn't think about it (7), thought that the other participants wouldn't care (5), the other participants are outside control (4), or it would be too difficult (2), yes, but did not influence choices: 9, yes, hoping for a favourable group: 5, or expecting an unfavourable group: 2, yes, unclear how: 22 (≥ 5 of these seem not to understand that this question is about the others creating points for you and not about you creating points for the others).
8. Difficulties were mentioned in the following fields: calculation: 33, choice complexity: 34, instructions: 27, equivalent options: 5, none: 16.
9. Further remarks: interesting / nice: 12, want to know more about the experiment: 10, confirming what was said before: 5, suggestions: 10.
10. Age: average 22,5 yrs., stand. dev.: 3,4 yrs.
11. Male: 48, female: 66.
12. Dutch: 40, German: 43, Chinese: 9, other: 22.
13. Faculty of Economics & Business Administration: 90, other: 24.
14. 90 participants did not participate in a similar experiment before; 24 did.
15. 112 participants would like to participate in future experiments, 2 would not.
16. In conditions *social* and *both*: 40 participants did not know any of their fellow session participants, 12 knew one and 4 knew more.

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