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The dynamics of coalition formation - a multilateral bargaining experiment with free timing of moves

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The dynamics of coalition formation - a multilateral bargaining experiment with free timing of moves

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Abstract

We experimentally study behavior in a finitely repeated coalition formation game played in real time. Subjects interact in groups of three, bargaining over the distribution of payments which occur at regular time intervals. During a given interval, payments occur if and only if a majority is in agreement about their allocation. Aside from these rules, we purposefully impose little structure on the bargaining process. We investigate the frequency and stability of different types of agreements, as well as transitions between them. The most frequent agreement is an equal split between two players, leaving the third with nothing. The most stable is the three-way equal split. Transitions between agreements are frequent and generally consistent with myopic payoff maximization. We find evidence that both fairness concerns and risk aversion may explain the prevalence of the three-way equal split, and that loyalty can play a role in cementing coalitions.

Keywords: Bargaining; group choice; experiments; coalition formation

JEL-Codes: C7, C9, D7

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1 Introduction

A large literature in economics and political science studies coalition formation as a bargaining game in which a majority of players must agree on a division of an exogenously available surplus. Most of this literature investigates situations in which the interaction ends once a coaltion is formed. In many real-world settings, coalition formation occurs in the context of repeated interaction over an extended period of time. Examples include the formation and maintanence of government coalitions, alliances between factions in international or civil conflict (Nolutshungu, 1996), and firms cooperating on supply chain management (Nagarajan and Sošić, 2008). In each of these examples, the members of a coalition reap benefits repeatedly or continuously for as long as agreement persists. Over time, coalitions may dissolve if agreement erodes and new coalitions may be formed. These dynamic aspects introduce new strategic considerations and raise additional questions concerning the stability of coalitions.

This paper reports on an experiment designed to study the formation and stability of coalitions in such a setting, more specifically, in a finitely repeated three-player majoritarian bargaining game. The immediate goal of our research is to observe what types of divisions arise most frequently and are most stable in this environment. The laboratory is well suited for this because we can exclude extraneous factors such as personality traits and control preferences through monetary rewards. The experiment ultimately serves as a search for stylized facts that can act as a guide for future theory development. The observed patterns in behavior may also help us to understand how behavior in more complex real world settings is driven by the underlying strategic context.

To the best of our knowledge, this paper is the first to study an unstructured and repeated multilateral bargaining game. One of our contributions is the development of a simple computer interface that implements such an environment. In our experiment, we impose no restrictions on the sequence of actions. All players may propose or agree to an allocation at any point in real time. Payments occur at regular time intervals if and only if a majority of subjects are in agreement as to their allocation. We investigate the frequency and stability of different types of agreements, as well as studying transitions between them. In the remainder of this section, we give an overview of the existing literature on multilateral bargaining and explain how our approach fits into that literature.

The literature on coalition formation comprises contributions from diverse fields, including sociology, social psychology, economics, and political science. The multitude of approaches within both the traditions of cooperative and noncooperative game theory, testifies to the complexity of the problem under investigation. Bargaining behavior and outcomes are likely to be affected by subtle institutional, environmental, and personal factors. This complexity makes experimental investigation of an unstructured environment particularly relevant, as it can help to test and inspire theory in the face of so many reasonable approaches.

Early theoretical contributions to the problem of coalition formation used the axiomatic approach of cooperative game theory. The relative strength of this approach is that it avoids the imposition of a particular structure on the bargaining process, a feature shared by unstructured bargaining experiments. A variety of solution concepts were developed, including the Shapley value (Shapley, 1952), kernel (Davis and Maschler, 1965), nucleolus

(Schmeidler, 1969), core (Aumann, 1961), and bargaining set (Aumann and Maschler, 1961). What these concepts imply in our bargaining environment will be detailed in section 3.1.

In keeping with the "institution-free" spirit of cooperative approaches, early experiments were typically unstructured. In Kalisch et al. (1996), subjects bargain face-to-face, and the only rule imposed is that they agree by majority vote. Fiorina and Plott (1978) follow a similar approach, arguing that this "allows (...) procedures to be essentially endogenous and as 'natural' as possible (...)." Thus, these authors felt that experiments on coalition formation should induce preferences and enforce majority rule, but otherwise leave subjects "free to do what they want" (ibid.). One of the conclusions from such face-to-face experiments was that personality plays an important role, with more talkative and aggressive subjects being more successful. There are numerous disadvantages associated with face-to-face experiments: bargaining partners can be identified, so factors such as gender and personal appearance need to be controlled for; face-to-face communication may be more likely to induce other-regarding concerns that interfere with monetarily induced preferences; completely free communication allows for the influence of personality as discussed above. These concerns suggest a role for computer-mediated experiments which exclude face-to-face interaction.

As far as we are aware, the earliest such experiments were performed using a set of programs called *Coalitions*, first described in Kahan and Helwig (1971). The program was designed to implement one-shot bargaining games in a characteristic function game framework. Communication was limited to a small vocabulary, and although players could send messages only in a predefined order, the options a player had during their turn, and the necessity of everybody first accepting then ratifying a coalition meant that little meaningful structure was imposed. A number of papers used this program to test and compare cooperative solution concepts with a variety of different games, for example Rapoport and Kahan (1976) which finds support for the individually rational bargaining set model and Horowitz (1977) for the core.[1]

In contrast to the axiomatic and institution-free approach of cooperative game theory, more recent theoretical contributions have followed a non-cooperative approach. The method is to explicitly specify a bargaining *procedure* as an extensive form game. The structure of a such a game imposes strict rules regarding, for example, who may make a proposal, when and in what order votes are taken, and so on. The most well-known theory in this category is the legislative bargaining model of Baron and Ferejohn (1989). Despite these *procedural* assumptions, the BF model admits multiple subgame perfect equilibria (Norman, 2002). Concrete predictions can therefore be derived only by imposing additional *behavioral* assumptions which restrict the kinds of strategies employed (e.g. symmetry and stationarity).[2] The general point is that all non-cooperative models impose rigid procedural rules on the timing of moves (offers, votes) as well as strong behavioral restrictions regarding the strategies players employ. Together, such restrictions yield results concerning equilibrium play, the properties of which are interpreted as predictions concerning actual behavior in real-world situations to which the theories are meant to

[1] Anbarci and Feltovich (2013) implements computer-mediated unstructured bargaining, but in the much simpler bilateral case.

[2] Since its publication, a number of extensions and alternatives to the BF model have been developed. A detailed review of this literature is beyond the scope of the current paper.

apply.

Most of the recent experimental research on majoritarian bargaining is motivated as a test of theoretical predictions of non-cooperative models. The dominant approach is to faithfully implement all procedural aspects of these models. For example, a number of authors have tested the predictions of the BF model by implementing, within a laboratory environment, the precise procedural rules (extensive form game) assumed in that model (see McKelvey, 1991; Frechette et al., 2005, Miller and Vanberg, 2013, and many others). Within this approach, the study most closely related to our own is Battaglini and Palfrey (2012), who implement a repeated version of the BF game, first analyzed in Kalandrakis (2004). In all such experiments, the interaction is computer mediated in order to maintain anonymity and to make sure that subjects cannot take actions that are not part of the structure of the model, for example by negotiating verbal agreements.

When viewed as a test of theory, an advantage of rigidly structured experiments is that the failure of a model's predictions may be attributed to the failure of *behavioral* rather than procedural assumptions. Another is that structured experiments are well controlled in the sense that the range of possible behaviors is limited to a small set of easily quantifiable action choices and the interaction is simple. A disadvantage is that the conclusions drawn from such experiments may lack external validity, especially when the real world settings of ultimate interest are varied and lack the rigid structure imposed by non-cooperative models.

Not all structured bargaining experiments are intended as a test of non-cooperative theories. Thus, Nash et al. (2012) implement a multilateral bargaining game which allows players to cede bargaining rights to another player. Despite the clearly defined structure of the bargaining process, they also derive hypotheses from cooperative game theory, arguing that in their repeated game any division can be supported as an equilibrium so non-cooperative game theory can provide no predictions.

An intermediate approach combines the imposition of certain procedural rules with a wide scope for individual behavior. For example, Diermeier et al. (2008) conduct relatively free-form bargaining experiments involving communication. In contrast to the earlier unstructured experiments, these authors impose a set of procedural rules, allowing subjects to form 'protocoalitions' and negotiate freely in subgroups. This 'in between' method nicely combines the openness and realism of unstructured experiments with experimental control over substantive causal factors such as communication and some formal rules.

Consistent with this approach, we explore a setting in which we implement majority rule but otherwise impose minimal restrictions on the sequence and timing of the making and accepting of proposals. We maintain experimental control by imposing anonymity and not allowing verbal communication. As discussed above, cooperative game theory is the natural theoretical counterpart to such an unstructured environment, and it is from there that we draw solution concepts to guide our hypotheses.

Our research contributes to the literature on group bargaining in at least two ways. First, we can test whether findings from more structured experiments generalize to less structured environments. Second, our results exhibit regularities which in turn may inform future modeling efforts, as suggested by Roth (1995), who argues that one goal of experimental economics should be to 'search for facts' that can inspire the development of theories.

2 Experimental Design

Our experiment implements a finitely repeated multilateral bargaining game played in continuous time. Subjects bargain in groups of three over payments that occur once per second when agreements are in place, i.e. payments flow almost continuously. All subjects can propose allocations and agree to existing proposals at any time. Payments occur each second, if and only if at least two players agree on an allocation at that time. The game ends when a predetermined surplus is exhausted or after a total of five minutes has passed. This feature excludes efficiency costs of delay, reflecting our interest in the frequency and stability of coalitions rather than efficiency.

The design of an unstructured experiment mediated by computers presents two important challenges. First, the program interface must be simple enough to be easily operated, yet versatile enough to allow for a natural and procedurally unrestricted exchange of offers, counteroffers, and votes. Kahan and Rapoport (1974) report that the *Coalitions* program interface required several hours of training, a fact that is probably due to some extent to the technology of that time. A second challenge is that the recording and transmission of subjects' decisions must not take up too much time. This is especially important if one wishes to study bargaining over multiple rounds or an extended period of time, and also to allow for many repetitions of each game in case learning effects play a significant role (which is likely in a strategic environment as complex as multilateral bargaining).

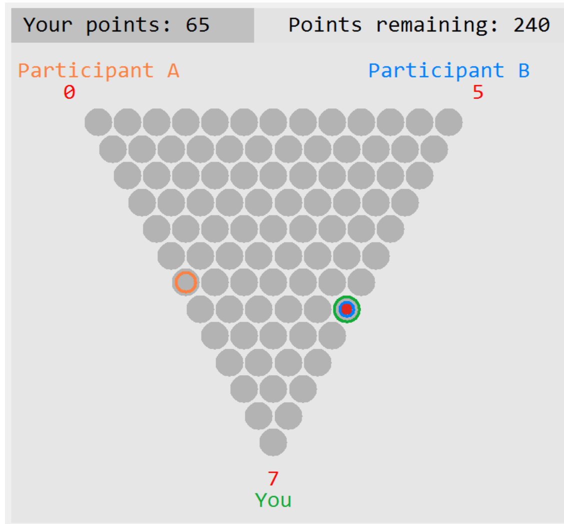

Figure 1: Screen Shot

In order to address both of these challenges, we designed a simple mouse-operated graphical interface. The bargaining set was represented in the form of a two-dimensional simplex consisting of a finite number of circles. Each circle represents a feasible allocation of the available (per-second) surplus. The allocation associated with a given circle was displayed if a subject hovered over that circle with the mouse. At any time, subjects could individually select a circle by clicking on it. This was made visible on all subjects' screens by highlighting the chosen circle with a color associated with that player. Once selected, a circle remained so unless and until the subject clicked elsewhere (either selecting another circle, or outside of the simplex, in which case no circle would be selected by that subject). Payments occurred if and only if at least two subjects were selecting the same circle at the end of a one second time interval. In what follows, we refer to the first click on a circle as a "proposal" and the second click on an already occupied circle as an "acceptance" of that proposal.

The game ended when a predefined aggregate number of points had been allocated or after a total of five minutes had passed. In our experiment, the surplus was always exhausted well within five minutes, so this deadline was never binding.

If no allocation was supported by a majority at the end of the one second time interval, no payment occurred. Since the aggregate payment was fixed, this rule is equivalent to 'pausing' the game whenever there is no agreement, until a new allocation (or the previous status quo) is agreed upon. Thus, there is no exogenously imposed pressure on subjects to quickly arrive at an agreement. This reflects our interest in a setting where the process of coalition formation is quick as compared to the time scale at which benefits accrue. The total number of points available was such that the game ended after 30 seconds of 'agreement time'.[3]

The experiments were conducted in the Vienna Center for Experimental Economics. 72 subjects took part, divided into 8 matching groups of 9 subjects each. Prior to the paid games, subjects completed a tutorial, including control questions, which lasted approximately 15 minutes. During the tutorial, subjects first familiarised themselves with the interface, learning how each circle defined the points earned by each player. The then interacted with simulated computer players which were programmed to select random circles to help understand how agreements could be formed. Onscreen and printed instructions can be found in Appendix A.

The game was repeated 20 times with stranger matching. (We will refer to these repetitions

[3] To better understand the rules of the game, the reader may wish to view a replay of one of the actual games which can be found at http://homepage.univie.ac.at/James.Tremewan/Research/simplex.wmv.

as rounds). One randomly chosen round was paid, and subjects received a 3 EUR show-up fee. The total surplus being divided was worth 36 Euros (360 'points'). Not including the show-up fee, subjects earned between 0 EUR and 24,50 EUR, with a standard deviation of 4 EUR. By definition, average earnings were 12 EUR. Games lasted for 30-60 seconds and sessions lasted approximately one hour.

The experiment was programmed and conducted with the software z-Tree (Fischbacher, 2007). Subjects were recruited using ORSEE (Greiner, 2004).

3 Frequency and Stability

Our analysis will be structured around sets of divisions of the per-second surplus that are suggested by concepts from cooperative game theory.[4] Each of these divisions can be motivated in a number of different ways, however we are not interested in distinguishing between theories but rather in identifying divisions of interest which will be useful for testing the hypotheses outlined later in this section. The three sets of divisions we consider are:

Two-way splits: These divisions are "coalitionally rational"[5], i.e. no subcoalition of an existing coalition can enforce a division that improves its collective payoff.[6]

Even two-way splits: The three even two-way splits comprise the bargaining set. Roughly

[4] Nash et al. (2012) follow a similar approach.

[5] Aumann and Maschler (1961)

[6] Note that this requirement is less stringent than for the core, which allows for deviations by *any* coalition. The core here is empty.

speaking, this is the set of divisions where any profitable deviation by a subset of a coalition can be followed by another profitable deviation where the original deviators are worse off and those they abandoned are no worse off. It is also the kernel and nucleolus, and focal in that it is an equal division among members of a minimum winning coalition.

The three-way even split: This is the Shapley value: each player earns the average of what they could contribute to all possible coalitions. It is also focal as an equal division among all players.

3.1 Hypotheses

We study two properties of divisions: their frequency and their stability. Frequency is defined as the proportion of time spent in a particular type of division. This is of interest because it tells us what type of division we are likely to see if we inspect a game at any given point in time. Stability is simply the average length of a type of division in seconds. We test the following hypotheses:

Hypothesis 1 *Focal divisions (Even two and three-way splits) are (a) more common, and (b) more stable than non-focal divisions.*

Hypothesis 2 *Two-way splits are (a) more common, and (b) more stable than 3-way splits.*

Hypothesis 3 *Even splits are (a) more common, and (b) more stable than uneven splits.*

	Proportion of time		Average Length	
Division Type	Rounds 1-10	Rounds 11-20	Rounds 1-10	Rounds 11-20
4 - 4 - 4	0.21	0.20	3.74	6.34
6 - 6 - 0	0.21	0.31	1.98	2.01
Uneven Two-Way	0.25	0.35	1.63	1.55
Uneven Three-Way	0.33	0.14	1.61	1.40
Two-Way	0.46	0.66	1.77	1.73
Three-Way	0.54	0.34	2.07	2.56

Table 1: Frequency and stability of divisions

3.2 Results

Table 1 summarizes the proportion of time spent in different types of divisions, as well as their average duration. These statistics constitute simple measures of the frequency and stability of agreements, respectively. The data are split into early (1-10) and late (11-20) rounds of the experiment. Figure 2 shows the distribution of coalition durations for each category of agreement.

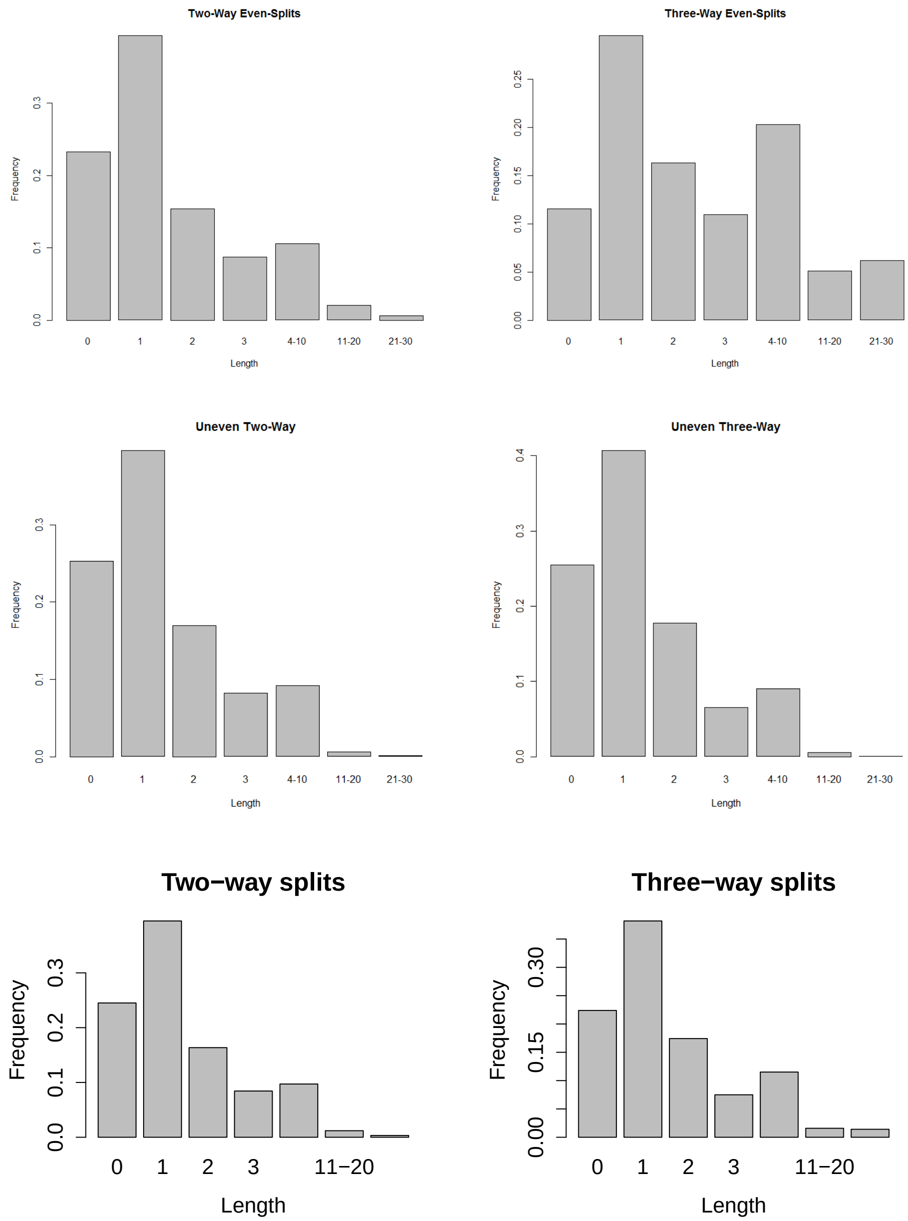

Figure 2: Distribution of coalition durations (seconds)

As Table 1 reveals, both the frequency and stability of different divisions change over time. In particular, we see that three-way splits become more rare and two-way splits more common. This pattern is driven especially by a decline in *uneven* three-way splits.

It is worth emphasizing that the majority of the points in the simplex are uneven three-way splits (see Figure 1). In the final rounds of the experiment, the vast majority of agreements occur either at the very center of the simplex ($4-4-4$) or on one of the borders (two-way splits). This suggests that subjects are learning either to split equally in a 'grand' coalition, or to form minimum winning coalitions and completely exclude one player. Another observable pattern is that the *stability* of three-way even splits (as measured by the length of time that they last) increases substantially in later rounds.

Given these visible learning effects, our empirical analysis will focus on the last ten rounds of the experiment. We will indicate in footnotes if results differ substantially when the earlier rounds are taken into account. As we are looking at multiple and sometimes overlapping categories of divisions, all comparisons are either between two of the sets of divisions we have identified as being of interest, or between one of these sets and its complement (i.e. *all other* types of divisions). For example, we may compare the length of time spent in three-way even splits either to that spent in two-way even splits, or to the time spent in *any* division that it not a three-way even split.

All frequency comparisons are adjusted for the number of circles in the simplex that belong to each set under consideration. For example, there are three even two-way splits ($6-6-0$, $6-0-6$, and $0-6-6$). If three times as much time is spent in even two-way splits as in the single even three-way split, both types of divisions are considered *equally* frequent. Statistical significance is based on two-tailed binomial tests using the eight independent matching groups as units of observation. This means that a relationship holding in seven out of eight groups implies significance at $p = 0.07$, and in all eight groups at $p < 0.01$.

Coming back to Table 1, we see that one fifth of the time is spent in three-way even splits, which are the most stable types of divisions, lasting 6.34 seconds on average. They are significantly more frequent ($p = 0.07$) and stable ($p = 0.07$) than the average over all other types of divisions. Even two-way splits account for 31% of the time and are the second most stable type of division, lasting 2.01 seconds on average. These divisions are also significantly more frequent ($p < 0.01$) but not more stable ($p = 0.29$) than the average over all other types of divisions.[7] *A fortiori*, the set of focal divisions, which includes both three- and two-way equal splits, is both more frequent and more stable than the set of all non-focal divisions ($p < 0.01$).

Result 1 *Consistent with hypothesis 1, focal divisions (Even two and three-way splits) are (a) more common, and (b) more stable than non-focal divisions.*

Two-thirds of the time is spent in two-way splits, which is significantly more than three-way splits ($p < 0.01$)[8], but there is no difference in average length. Focusing on even splits, while there is no difference in frequency, even three-way splits are more stable than even two-way splits ($p = 0.07$).

Result 2 *Consistent with hypothesis 2, (a) Two-way splits in general are more common than three-way splits, but this does not hold when focusing on even splits. (b) Even three-way splits are more stable than even two-way splits.*

[7] Looking at all 20 periods, even two-way splits are more stable than the average over all other types of divisions ($p = 0.07$).

[8] There is no difference in the aggregate data.

With regards to Hypothesis 3, we have already made comparisons between, even three-way splits and other types of divisions. Confining attention to two-way splits we see that such divisions are both more frequent ($p < 0.01$) and more stable ($p = 0.07$)[9] when the division is equal.

Result 3 *Consistent with hypothesis 3, even splits are (a) more common, and (b) more stable than uneven splits. This also holds when considering only two-way splits.*

In summary, we see that most of the time (86%) is spent at one of the divisions identified by a cooperative solution concept. Overall, 2/3 of the time is spent in two-way splits, i.e. at circles somewhere along the edges of the simplex. [10] Interestingly, the set of uneven two-way splits (edges minus two-way even splits) accounts for the largest amount of time of any category. Conditional on being on an edge, more time is spent at uneven than at even splits. Despite the complete symmetry of our experimental setup, we thus see a substantial amount of (temporary) agreement on uneven divisions within minimum winning coalitions. This pattern hints at the transition dynamics that occurred in the experiment, an issue to which we turn in the next subsection.

[9] $p < 0.01$ in the aggregate data.

[10] This is significantly larger than the time spent at two-way splits in the first 10 rounds (46%), which suggests that subjects learned over time to build 'minimum winning coalitions' ($p < 0.01$).

4 Transition Dynamics and Individual Behaviour

Having established patterns in the frequency and stability of different types of divisions, we now delve deeper into the underlying causes of these results by investigating individual behaviour and the transitions between divisions that are generated. We begin by stating hypotheses regarding the rationality and motivations governing subject behaviour. We then provide an overview of the observed dynamics then formally test the hypotheses.

4.1 Hypotheses

First we examine to what degree individual behaviour is consistent with myopic[11] payoff-maximisation, testing the following hypothesis:

Hypothesis 4 *Transitions are such that two players receive at least as much as in the previous division.*

We then consider other factors that are may be associated with certain offers being suggested or accepted. The even three-way split is frequent but not coalitionally rational, so should not be chosen by myopic payoff-maximisers. We consider two types of players who may be attracted to this division: altruistic subjects who value its fairness, and risk averse subjects who recognise its stability.

Hypothesis 5 *Altruistic subjects are more likely to be attracted to an even three-way*

[11]We also informally consider far-sighted payoff maximisation, but provide no statistical evidence on this.

split.

Hypothesis 6 *Risk averse subjects are more likely to be attracted to an even three-way split.*

Finally we look at whether 'loyalty' plays a role in cementing existing coalitions. This could be motivated either by positive reciprocity, or as a rational response to the higher expected value of a coalition with a loyal partner.

Hypothesis 7 *The probability of a subject accepting an offer is decreasing in the number of offers an existing coalition member has not accepted.*

4.2 Results

We begin this section with a general description of the frequency of transitions between different types, then investigate what motivations might underlie the observed transitions.

All of the figures reported in this subsection use only data from the last ten rounds.

4.2.1 Description of Transitions

To give an overview of the dynamics without introducing an unworkable level of detail, we will consider transitions between 11 different sets of circles: the three-way equal split, the three 2-way equal splits, the six segments of the edge of the simplex corresponding to uneven two-way splits, and all uneven interior circles. The main detail we lose is in

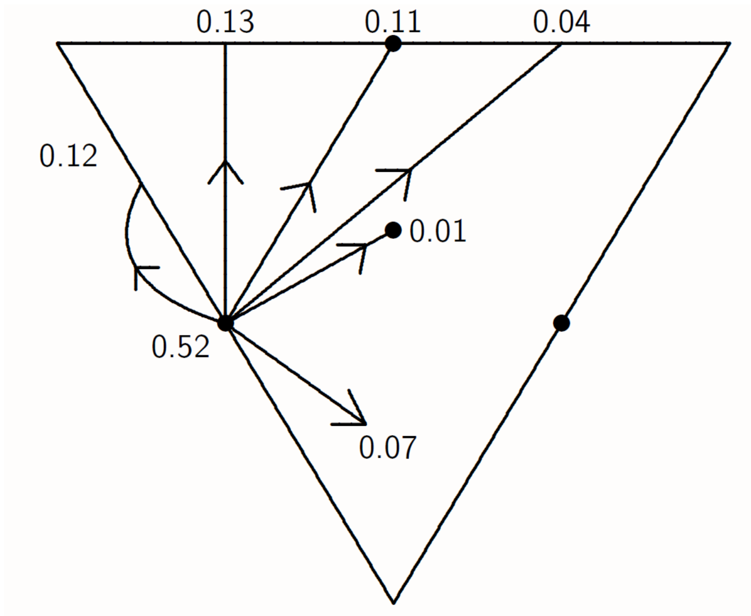

Figure 3: Transitions from 2-way equal splits

transitions involving different types of non-focal interior circles and movements among uneven 2-way splits on the same edge. However these account for a relatively small number of movements overall. Since we are interested in the frequency of different *types* of transitions, we group 'symmetric' transitions in the obvious way. For example, when considering transitions from the three-way even-split to two-way even-splits, we group all such transitions rather than distinguishing between the three possible destinations.

Figure 3 illustrates the relative frequency of transitions from a two-way even-split to the other sets. In this and the following figures, each second that subjects remain in an agreement is treated as a transition to itself. The 52% probability of remaining at the equal split indicates the stability of such divisions. Conditional on moving, the majority of transitions ($\approx 58\%$) are to a circle on another edge of the simplex, i.e. a two-way split between the previously excluded player and one of the previously included players. Of these transitions, roughly half are to uneven splits which favor the previously included player.

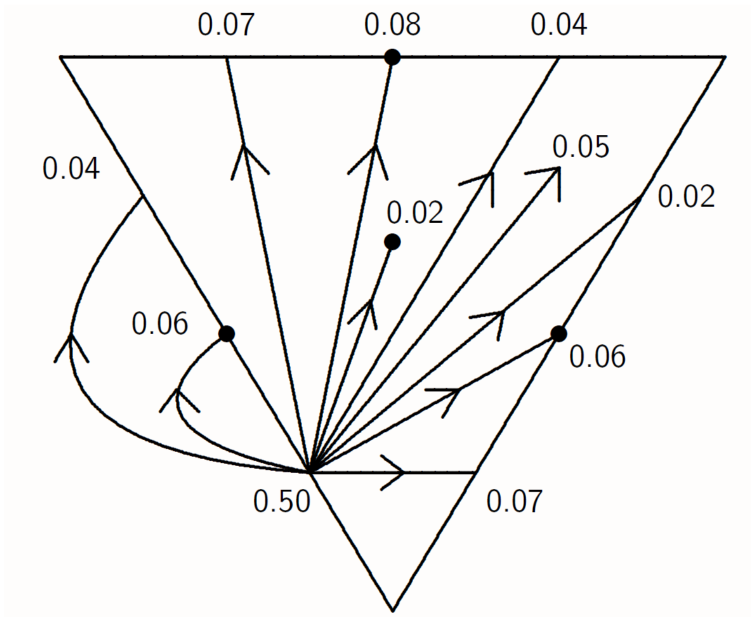

Figure 4: Transitions from uneven 2-way splits

This indicates that such transitions are likely initiated by the previous outsider offering a 'better deal' to one of the insiders. However, roughly 1/4 of transitions originating at a two-way equal split are redistributions within the active coalition, implying a loss for one of the included players. This is much more common than a transition to a two-way split with the previously excluded player where the subject who is in both the old and new coalition loses out (8%).

Figure 4 summarizes transitions from uneven 2-way splits. Again, the 50% probability of transitioning back to the same set of circles in the next second indicates the stability of these divisions. Conditional on moving, the most likely destination is to a 2-way split between the excluded player and the disadvantaged included player (38% of transitions to other sets). This is consistent with the hypothesis that these transitions are initiated by the excluded player offering a 'better deal' to the 'cheaper' included player. However

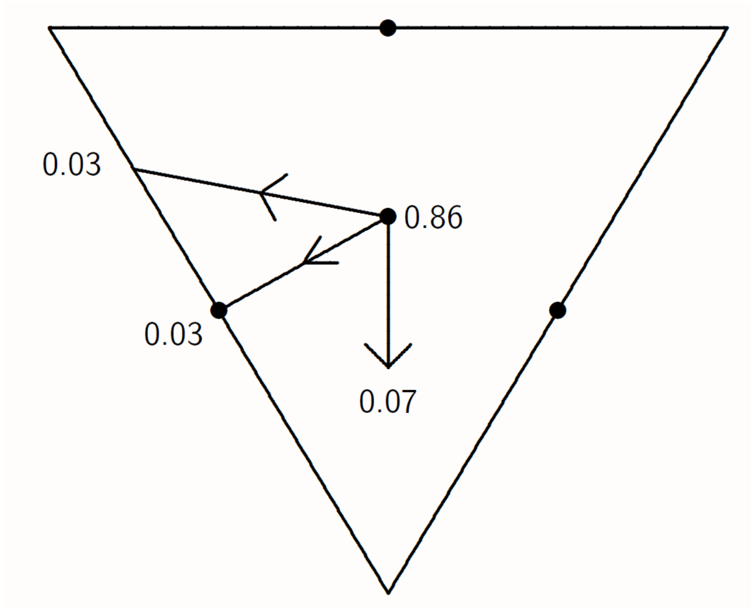

Figure 5: Transitions from the 3-way equal split

we also see a substantial amount of movement to other circles, including redistributions among the included players, mostly towards the center of the edge in question.

Finally, Figure 5 shows movements originating at the 3-way equal split. The 86% probability of remaining at this circle for another second indicates that this is the most stable division. Conditional on moving, roughly half of the transitions are to uneven internal circles, and half to either even or uneven 2-way splits.

4.2.2 Individual Behaviour

The majority of actions taken by subjects are consistent with myopic payoff-maximization, that is where subjects click on a division that would give them a per-second payoff no less than the previous agreement: 85% of offers and 75% of acceptances in the first ten rounds, rising to 87% and 78% respectively in the final ten rounds. The smallest figure for any of the eight matching groups is 72% (in both early and late rounds), so the proportion is greater than 50% at the 1% level.

Result 4 *Consistent with hypothesis 4, The majority of actions taken by subjects are consistent with myopic payoff-maximization.*

An interesting question is whether subjects can improve their long-term prospects by taking a short-term loss. For example a subject receiving seven points while their coalition partner receives five may wish to redistribute one of their points to their partner because they recognise the two-way split as being more stable. In order to approach this question in a tractable way we make the assumption that the transitions between outcomes are a Markov process: the probability of moving to a particular division is assumed to depend only the current division.[12]

We estimate the Markov process using the empirical frequency of transitions, making the further assumption that symmetric transitions occur with the same probability (e.g. the probability of moving from any one of the two-way even-splits to either of the others is estimated using the average number of all such transitions). Using the estimated probability matrix we can calculate the expected payoff after any number of seconds given the current division.

Figure 6 shows the difference between the cumulative expected payoffs starting in all types of two-way splits and receiving the average of four points per second. Short term pain for long term gain would be seen if the lines cross. This happens marginally for the second

[12]We will test the Markov assumption later in this section.

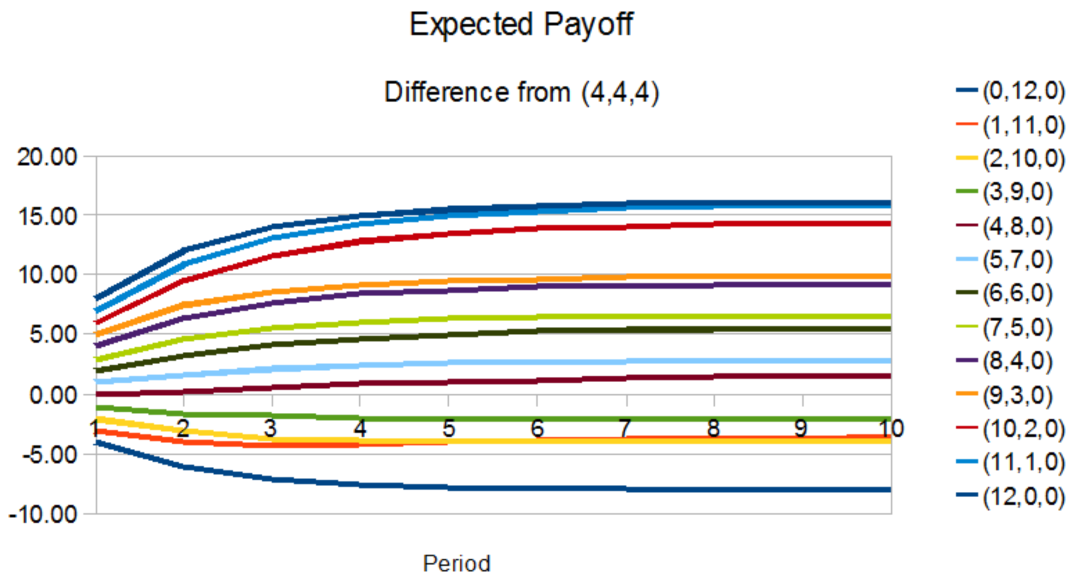

Figure 6: Expected long-term payoffs associated with divisions

and third lines from the bottom, meaning taking 10 rather than 11 is rational in the long term. In all other cases behaving myopically also maximises long run payoffs.

The question arises as to why subjects may take actions contrary to their immediate self-interest. Fairness concerns can underlie two types of common transitions which must make one of the agreeing parties worse off: transitions to the three-way equal split, and transitions from an unequal two-way split to a more equal two-way division. An alternative explanation for these transitions is risk-aversion which may make the even splits more attractive if they are (correctly) perceived as more stable.

We can try to disentangle these two explanations by looking at the personal characteristics of subjects who are instrumental in implementing three-way even splits: are they risk-averse or fair-minded people? The first column of Table 2 display OLS regressions of the number of times a subject clicks on the central circle of the simplex regressed on age, gender, score on the cognitive reflection test (Frederick, 2005), a self-reported measure of preference for risk[13], and measures of the "Big Five" personality traits.[14] Being male, a high score on the cognitive reflection test, and extraversion are all negatively associated with fair clicks, whereas the opposite relationship holds for agreeableness.

One thing these regressions do not account for is the fact that some people are more active than others so may make more fair clicks, but also more unfair clicks. The third column of Table 2 accounts for this by using the ration of fair clicks to total clicks as a regressand. Cognitive reflection no longer appears to be relevant for this measure, indicating that the significant coefficients in the previous regressions resulted because subjects with a high score on the test were less active in general ($r = -0.23$, $p = 0.05$). The effect of extraversion disappears, but is replaced by a significant relationship with risk preferences. Gender and agreeableness remain influential.[15]

Overall it appears that both fairness concerns and risk preferences play a role in making the three-way equal split attractive to subjects. Increased social concern as measured by "agreeableness" is associated with an increase in the number and proportion of clicks on the fair division. People who view themselves as unwilling to take risks make a higher proportion of fair clicks, while people identified as less extroverted make more fair clicks

[13]Our measure of risk aversion comes from the following question: How do you see yourself: Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks? Answers were on an 11 point scale from 0 ("Unwilling to take risks") to 10 ("Fully prepared to take risk"). This measure has been shown to be highly correlated with incentivised risk elicitation procedures (Dohmen et al., 2011).

[14]The questions for the Big Five were taken from Rammstedt and John (2007).

[15]The second and fourth column of Table 2 come from a "general-to-specific" approach, dropping variables with the lowest t-statistics until all remaining variables are significant. The conclusions in the main text are unaffected.

Table 2: Clicks on the even three-way split

VARIABLES	Number of clicks		Proportion of clicks	
Age	-0.309		0.00152	
	(0.427)		(0.00403)	
Male	-7.925*	-9.527**	-0.0849**	-0.0689*
	(4.153)	(3.837)	(0.0392)	(0.0354)
CRT	-3.650**	-3.677**	0.00131	
	(1.688)	(1.566)	(0.0159)	
Risk	0.657		-0.0227*	-0.0242**
	(1.207)		(0.0114)	(0.00960)
BF-Extra	-2.200*	-2.020*	-0.0157	
	(1.315)	(1.141)	(0.0124)	
BF-Agree	4.654***	4.557***	0.0295*	0.0257*
	(1.704)	(1.657)	(0.0161)	(0.0153)
BF-Consc	-0.667		0.00890	
	(1.157)		(0.0109)	
BF-Neuro	1.323		-0.00971	
	(1.018)		(0.00961)	
BF-Open	0.202		0.0113	
	(1.172)		(0.0111)	
Constant	10.72	11.32	0.0695	0.124
	(19.58)	(12.18)	(0.185)	(0.112)
Observations	72	72	72	72
R^2	0.253	0.225	0.200	0.142

Notes: CRT = score on cognitive reflection test. Risk = self reported tendency to take risks. BF = Big Five personality dimensions. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

in total (as has been previously found (Becker et al., 2012) our measure of extroversion is highly correlated with the risk question ($r = 0.36$, $p < 0.01$).

Result 5 *Consistent with hypothesis 5, altruistic subjects are more likely to be attracted to an even three-way split.*

Result 6 *Consistent with hypothesis 6, risk averse subjects are more likely to be attracted to an even three-way split.*

Does loyalty play a role? We approach this question by looking at the relationship between the probability an attractive offer by one player is accepted, and the number of times the third player has not accepted earlier beneficial offers (the variable "*prevoffs*").[16] Because in our setup offers are not made to a specific individual, we include only an offer where a player would get more than their current per-second payoff and consider this to be an offer to that player.[17] As shown in the first of the linear probability model regressions reported in Table 3, each additional beneficial offer not accepted by a subject's coalition partner is associated with a 7% reduction in the probability an offer is accepted.

In the second column we control for the number of points offered, the type of division that was previously in place (the absence of which may have resulted in ommitted variable bias), as well as the type of division that is suggested. The coefficient is marginally diminished,

[16] An alternative measure would be length of the current agreement, but this is clearly endogenous.

[17] It may be the case that both of the two other players would be made better off, in which case it is included twice, in relationship to the number of offers rejected by each of the players.

Table 3: Probability of accepting an offer (Linear Probability Models)

prevoffs	-0.0677***	-0.0538***	-0.0931***	-0.0199**	-0.0188**	-0.0631***
	(0.0146)	(0.0119)	(0.0205)	(0.00583)	(0.00760)	(0.0111)
prevoffs x last10			0.0476*			0.0544***
			(0.0243)			(0.0151)
pointsoffered		0.0442***	0.0445***		0.0389***	0.0392***
		(0.00622)	(0.00615)		(0.00511)	(0.00499)
rational		0.0543**	0.0536**		0.0143	0.0130
		(0.0214)	(0.0206)		(0.0233)	(0.0235)
even2way		0.0872**	0.0868**		0.0547**	0.0546**
		(0.0311)	(0.0312)		(0.0224)	(0.0223)
even3way		0.0141	0.0138		-0.0691	-0.0707
		(0.0615)	(0.0629)		(0.0598)	(0.0604)
prevrational		-0.00885	-0.0100		-0.0140	-0.0152
		(0.0301)	(0.0300)		(0.0213)	(0.0211)
preveven2way		0.0265	0.0257		0.0203	0.0197
		(0.0421)	(0.0417)		(0.0360)	(0.0358)
preveven3way		-0.152***	-0.153***		-0.123**	-0.122**
		(0.0406)	(0.0395)		(0.0511)	(0.0504)
Constant	0.482***	0.175***	0.176***	0.473***	0.235***	0.235***
	(0.0431)	(0.0287)	(0.0292)	(0.00110)	(0.0432)	(0.0435)
Observations	3,931	3,931	3,931	3,931	3,931	3,931
R-squared	0.011	0.075	0.076	0.001	0.040	0.041
Subject FE	NO	NO	NO	YES	YES	YES

Notes: prevoffs = number of earlier offers *not* accepted by partner in the current coalition. last10 = 1 for offers in last 10 seconds, otherwise 0. pointsoffered, rational, even2way, even3way describe the current offer. prevrational, preveven2way, preveven3way describe the current division. Standard errors (clustered by session) in parentheses. *** p<0.01, ** p<0.05, * p<0.1

but still large (5%) and highly significant.[18]

The regression in the third column interacts *prevoffs* with a dummy for the final ten rounds to see if the effect survives learning. The estimates imply a strong effect in the early rounds (10%) which is later much diminished (to 5%).

The final three columns include subject fixed effects to account for the possiblity that individual effects may be correlated with *prevoffs*. This could arise because subjects who have a tendency not to accept offers would be more likely to be in long-lasting coalitions, thus their coalition partners would be more likely to receive more offers, increasing the number that may not be accepted. The inclusion of individual fixed effects reduces the implied effect of *prevoffs*, however the last regression shows a significant impact in the early rounds (6%) which disappears in the later rounds. The substantial changes in coefficients suggests that the OLS regression was suffering from ommitted variable bias, so we base our conclusions on the fixed effect model.

Result 7 *Partially consistent with hypothesis 7, the probability of a subject accepting an offer is decreasing in the number of offers an existing coalition member has not accepted for inexperienced, but not experienced, subjects.*

[18]The regression also shows further evidence of the attractiveness of two-way splits and the stability of even three-way splits.

5 Conclusion

Our experimental design is motivated by the desire to strike a balance between experimental control and freedom from artificial constraints on the sequence of moves in a bargaining process. We argue that such an environment is appropriate for testing the predictions of non-cooperative bargaining models which impose a specific sequence of moves. The reason is that move structures are imposed for technical reasons, to make a model tractable and to permit the identification of specific equilibria. When we move to the laboratory, the substantive assumptions of such theories should be maintained, but technical restrictions should be relaxed.

Following this methodological strategy, we conducted a multilateral bargaining experiment involving payoffs that occur repeatedly. Players were free to make proposals and agree to existing proposals at any time. In order to facilitate quick and intuitive decision making, and allow for a reasonably long time horizon within each game while keeping playing time short enough for many games to be played and learning to occur, we designed a simple graphical interface involving a clickable simplex representation of the bargaining set.

One of the primary purposes of this exercise was to provide stylized facts to inform theoretical work. Our results have established a set of patterns which theories of repeated coalition formation should predict:

1. Fair, or focal, outcomes predominate in terms of frequency and stability.

2. When all players receive a non-zero payoff, the division is likely to be equal.

3. When play centers around majoritarian outcomes, asymmetric divisions within the coalition are common.

4. The making and accepting of proposals tends to be consistent with myopic payoff-maximization.

5. Subjects often forgo short-term gain in favor of remaining in a stable division.

Our analysis is also suggestive of the kinds of assumptions that might generate these patterns. First, the frequency of even three-way splits, and loyalty in the rejection of some tempting offers suggest that fairness concerns and reciprocity motives are important. Second, increasing loyalty over the duration of a given coalition suggest that a Markov assumption on transitions, as is commonly used in theoretical work (e.g. Konishi and Ray, 2003), may be inappropriate. Third, the importance of fair and focal outcomes may be further explained by risk aversion and self-fulfilling beliefs about the stability of these divisions.

One of the contributions of this paper was to develop a simple interface for computer-mediated multilateral bargaining experiments. An important feature of our program is that it is time-efficient, requiring only a brief tutorial for subjects to understand its use, and allowing for a rapid exchange of offers and acceptances. The numerous learning effects we identify highlight the importance of designing experiments that allow for a reasonable number of repetitions to enable subjects to come to grips with a complex strategic environment. In this paper we have used the program to investigate a repeated environment with symmetric players, but it can easily be adjusted to look at other questions. In another experiment we have modified the program to implement a one-off division in an infinite horizon framework to test the robustness of experimental findings obtained using the Baron-Ferejohn framework. Future work will consider situations involving heterogeneous preferences and asymmetric information.

A Instructions

Subjects received both printed and onscreen instructions. Onscreen instructions involved a tutorial in which subjects could try out the software used in the experiment.

Onscreen Instructions (1)

The first screen contained the following text.

In this experiment, participants will interact in groups of three. The interaction will be repeated a number of times. In what follows, we will call each repetition of the interaction a “round”.

During each round, the three members of a group will distribute 3600 points between themselves.

The points you receive will determine how much money you earn at the end of the experiment.

In addition to the money you earn during the interactions, you will also receive 3 Euros for filling in a questionnaire.

In order to help you understand exactly how the interactions work, we will now demonstrate the functioning of the program on your screen.

There will be a short tutorial followed by two practice rounds.

In the tutorial you will be shown the screen that will be used during the real rounds. How to understand this screen and use it to interact with the other participants in your group is explained to you in the printed instructions you have been given.

During this tutorial and the two practice rounds which follow no money will be awarded. The purpose of this tutorial is only to help you understand how the program works. You will be informed before the real interactions begin.

Please follow the printed instructions carefully. It is important to understand how the program works!

PLEASE CLICK "CONTINUE" IF YOU ARE READY TO BEGIN THE TUTORIAL

Printed Instructions

The following instructions were provided in hardcopy. The tutorial exercises were conducted onscreen while reading the instructions. See Figure 1 for a screen shot.

Tutorial: DO NOT CLICK CONTINUE UNTIL YOU HAVE COMPLETED AND UNDERSTOOD THE EXERCISES BELOW.

IF YOU HAVE ANY QUESTIONS, PLEASE RAISE YOUR HAND AND SOMEONE WILL COME TO ASSIST YOU AS SOON AS POSSIBLE.

- The participants in your group must decide how many points each will receive at any moment in time. A total of 12 points can be allocated every second.
- On your screen, you will see small circles arranged in the form of a large triangle. Each circle represents a different way of allocating the 12 points among you and the other two participants you are interacting with in a given round.
- The corners of the triangle are labeled "You", "Participant A", and "Participant B".
- The points in the corners correspond to allocations in which the indicated participant receives all 12 points, while the others receive no points.
- The closer a point is to a given corner, the more the corresponding allocation assigns to that participant.
- If you move your mouse over a circle, the corresponding points to be allocated to each subject are displayed in the appropriate corners of the triangle.

- Exercise:
  - Move your mouse around the triangle until you understand how the circles are arranged.
  - Click on a point to select it. Notice that the selected point is circled in green (for now, do not click on the circles that are already marked).
  - Click on a point outside the triangle. The green circle should disappear.
  - During the real interactions, when you click on a circle this will be shown on the screens of the two other participants you are interacting with, and it will disappear from their screens if you click outside the triangle. If two participants have their circles showing on the same circle, points will start to be distributed according to this division. This is explained in more detail below.
- During the real interactions, any of the three participants (including you) may click on any circle at any time.
- When you click on a circle, the other two participants in your group will see this circle marked on their screen.
- When another participant in your group clicks on a circle on their screen, it will be marked on your screen in the color corresponding to that participant: orange for"Participant A" blue for "Participant B". You can see how this looks now on your screen.
- Clicking on an unmarked circle is like suggesting that division.
- Clicking on a circle marked by another participant is like (temporarily) accepting the division they have suggested.
- When another participant clicks on a circle you have marked, they have (temporarily) accepted your suggestion.
- Points are distributed for as long as at least two members of a group select the same circle in the triangle.
- These agreements are not permanent and can be changed, as any participant can click on another circle at any time.
- If at least two participants are simultaneously choosing the same circle, the corresponding point allocation is implemented: each second, each participant receives the number of points assigned to

them. All subjects will temporarily stop receiving points if subjects click on different circles such that all members of the group are now selecting different circles.

- The points a participant receives do not depend on whether she herself has selected the circle being implemented. In particular, it is possible that a subject who has clicked on the circle receives no points, and that a subject who has not clicked on the circle receives points. The allocation of points depends only on the location of the point in the triangle, not on the subjects that are selecting it (as long as there are at least two).
- In this tutorial there is no limit to the number of the points you can distribute. This is so you have time to understand how the program works. In the real interactions the round will end when 360 points have been distributed among you and the other two participants in your group.
- Exercise:
  - On your screen, the computer has randomly selected two circles on behalf of your hypothetical group partners.
  - Experiment by clicking on each of these circles, as well as other circles.
  - Watch how your points accumulate when you select the same circle as another group member, and how points stop accumulating when you subsequently click on a circle different from those selected by either of your partners. (Naturally, points are also allocated whenever the other two members of your group select the same circle. In that case, the points you receive will not depend on which circle you are selecting.)
  - Notice that an agreed / active circle is highlighted in red, and that the shares of points that correspond to the agreed circle appear in large red font at the appropriate corners when your mouse is outside the triangle.

WHEN YOU HAVE READ AND UNDERSTOOD THE INSTRUCTIONS AND COMPLETED THE EXERCISES, PLEASE CLICK CONTINUE.

THIS TUTORIAL WILL BE FOLLOWED BY TWO PRACTICE ROUNDS, AND YOU WILL HAVE THE OPPORTUNITY TO ASK FURTHER QUESTIONS BEFORE THE REAL ROUNDS BEGIN.

Onscreen Instructions (2)

After completing the turorial using the printed instructions, the following screen was displayed.

There will now be two practice rounds.

During these practice rounds you will be interacting with the computer. The divisions the computer chooses will be random. Everything else will be the same as in the real rounds which will follow.

There will be three differences between the previous screen and the practice (and real) rounds:

- The divisions chosen by "Participant A" and "Participant B" will move as they click on different circles. Sometimes you will not see their circles on the triangle: this is when they have not yet clicked on a circle, or have clicked off the triangle.
- There are only 360 points to be awarded. When these points have run out the round will end. The number of points remaining to be distributed will be shown next to the number of points you have currently received (check this on the picture on the last page of printed instructions).
- If not all points have been distributed after 300 seconds, the round will end automatically and any remaining points will be lost. The number of seconds remaining before the round ends automatically will be shown below the triangle (check this on the picture on the last page of printed instructions).

You will have an opportunity to ask questions after each of the two practice rounds.

During these practice rounds, no money will be awarded. The purpose of the practice rounds is only to help you understand how the program works. You will be informed before the real interactions begin.

It is more important during the practice rounds to learn to understand how the program works than to get the division of points that you want.

You may now ask questions about the way the program works, however please do not ask questions about strategies and divisions you or the computer may use. These types of questions will not be answered.

If you have a question, please raise your hand and ask it quietly when an experimenter comes.

If you have no questions, please click "Continue" and wait for the first practice round to begin.

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